ISBN 978-86-80439-20-4

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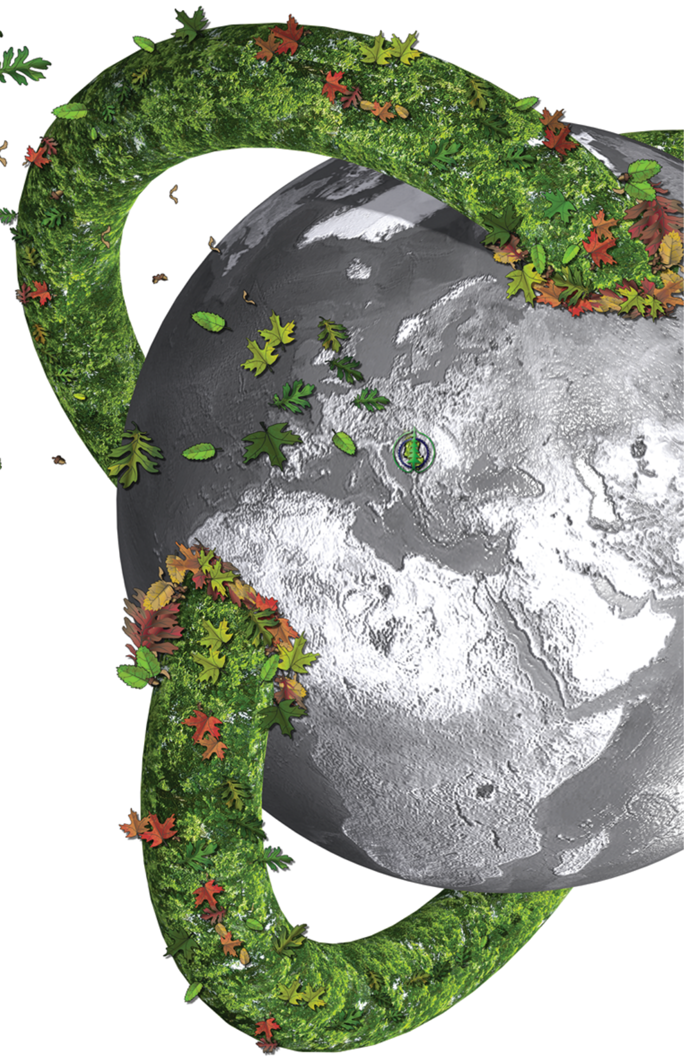

Forest ecosystems and climate changes

March 9-10th, 2010
Belgrade, Serbia

PLENARY LECTURES

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FOREST ECOSYSTEMS AND CLIMATE CHANGES

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MINISTRY OF SCIENCE AND TECHNOLOGICAL DEVELOPMENT, REPUBLIC OF SERBIA

MINISTRY OF AGRICULTURE, FORESTRY AND WATER MANAGEMENT – DIRECTORATE OF FORESTRY, REPUBLIC OF SERBIA

MINISTRY OF ENVIRONMENT AND SPATIAL PLANNING, REPUBLIC OF SERBIA

PE „SRBIJAŠUME“

SOCIETY OF FORESTRY ENGINEERS AND TECHNICIANS OF SERBIA

Belgrade
March 9-10th, 2010.

Citation
International Scientific Conference
Forest ecosystems and climate changes

Publisher
Institute of Forestry, Belgrade,
Serbia

Chief Editor
Ph.D. Ljubinko Rakonjac

Technical Editor and layout
M.Sc. Tatjana Ćirković-Mitrović

Cover design
Nevena Čule, B.Sc.
Suzana Mitrović, B.Sc.

Printed in
200 copies

Printing
KLIK PRINT, Belgrade

Belgrade
March, 2010

Address of the Organizer
Institute of Forestry
Kneza Višeslava 3
Belgrade, Serbia
www.inforserb.org

CIP- Каталогизација у публикацији Србије
Народна библиотека Србије
630*42 (082)
551.583 (082)
504.7
INTERNATIONAL Scientific Conference Forest Ecosystems and Climate Changes (2010; Beograd)
Plenary Lectures/ International Scientific Conference Forest Ecosystem and Climate Changes, Belgrade, March 9-10th, 2010. ; organized by Institute of Forestry, Belgrade…[et.al.] ; [chief editor Ljubinko Rakonjac], - Belgrade : Institute of Forestry , 2010 (Belgrade : Klik print). – 260 str. : ilustr. 24 cm

Tiraž 200. – Napomene i bibliografske reference uz tekst. – Bibliografija uz svaki rad.

ISBN 978-86-80439-20-4
1. Institut za šumarstvo (Beograd)
a) Šume – Klimatski uticaji – Zbornici
b) Klimatske promene –Zbornici
COBISS.SR-ID 174544140

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FOREST SCIENCE, POLITICS AND CLIMATE CHANGE – AN IUFRO PERSPECTIVE

Peter MAYER[1]

Summary: *IUFRO is „the" global network for forest science cooperation. It unites more than 15,000 scientists in almost 700 Member Organizations in over 110 countries. Scientists cooperate in IUFRO on a voluntary basis in more than 270 research units that deal with virtually all aspects related to forests and trees.*

IUFRO's mission is to promote global cooperation in forest-related research and to enhance the understanding of the ecological, economic and social aspects of forests and trees; as well as to disseminate scientific knowledge to stakeholders and decision-makers and to contribute to forest policy and on-the-ground forest management.

In pursuing its mission, IUFRO integrates emerging issues in forest science and policy into its work. The new IUFRO Strategy for the period 2010-2014 identifies six emerging issues that will guide the scientific collaboration within the IUFRO network: "Forests for People; Forest Bioenergy; Forest Biodiversity; Forests and Water; Resources for the Future; and, Forests and Climate Change". When addressing "forests and climate change" particular emphasis will be placed on climate change impacts on forest ecosystems and forest dependent people, forest ecosystem responses, and evidence-based options and technologies for forest adaptation.

IUFRO also promotes the use of scientific knowledge in the formulation of forest-related policies. Therefore, IUFRO is actively working at the science-policy interface. Being aware of the complex relationship of science and policy, the science-policy initiatives led by IUFRO have been designed to enable long-term interactions between scientists, policy makers and stakeholders.

One promising example of continuous interaction between science and policy is the IUFRO-led initiative "Global Forest Expert Panels" (GFEP) in the framework of the Collaborative Partnership on Forests. The first scientific assessment carried out by GFEP addressed "Adaptation of Forests and People to Climate Change". The report launched in 2009 constitutes the first global assessment of its kind and revealed, inter alia, that the carbon sink regulating services of forests are at risk of being lost entirely unless current carbon emissions are reduced substantially.

[1] Dr Peter Mayer, Executive Director, IUFRO

BUILDING FOREST POLICIES AS A CHALLENGE WITHIN A CLIMATE CHANGE FRAMEWORK

Margaret SHANNON[1]

Climate change is very critical topic now days. Two main simple ideas are put in political, economical and social context of climate change, which all people who studies forests ecosystems share. Those are conceptual ideas of time and of space. One of the challenges of policy is conceptual work as we all know "political time". Political time is the time which pass due elections, during changing governance and laws. It's very short time to address subject of climate change. In economy is similar, it has its own "political time".

Subject could be observed from very different levels. What level of society has been defining the climate changes as a problem? At local level people have to adopt changing conditions and this is localized kind of response. But changing of climate has no boundaries. Climate change is become a political entities. Who makes decisions – who makes the policies? Who defines questions, what climate changes are indeed as a problem. On politicians now is to define where conditions are changing boundaries. Something must be done. In context of space there are many local ways of thinking about addressing climate change, but the local level ways, no matter how many they are, cannot possible address a problem of a nature climate change. One argue from a policy side, is that best we can do is slow down the momentum of change. Conventions are one way thinking about that. This conference is very interesting way of exploring biological and physical aspects of climate change. But everybody should be emerged, keep on mind social, political and economic aspects of people adopting.

This conference and another similar can make a large contribution, so the society can be organized. Our lives are leading to change in a face of climate change. National level policies are critical and important but only if there is existing context of scale that could be addressed to. In terms of time, one other element is used, an introduction to discussion and that is what policies are generally, obtain to provide stability and continuous expectations of people. Climate change are not stabile, and its surprise us over time more and more. Certainly, it is not in ways that we do not know and cannot understand, but it's a problem of further expectations, since that is a huge challenge for us to learn the ways that forests ecosystems react on climate change. On that base, science and people have to organize together and to create further policies. We must make policy arrangements that are based on unsurprised and not stability. This is critical challenge for all of us. This kind of conference is bringing together different scientists and experts from forestry expertise. We together could easier provide suggestions for forestry and ecological measures which could be further steps in climate change control.

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[1] Prof. Margaret Shannon, Ph.D., FOPER II coordinator, European Forest Institute

BIODIVERSITY OF FOREST ECOSYSTEMS AND CLIMATE CHANGES

PLENARY LECTURES

THE POTENTIAL VEGETATION AND ECOLOGICAL CLASSIFICATION OF FORESTS IN SERBIA AS THE BASE FOR THE AFFORESTATION IN THE ALTERED CLIMATE CONDITIONS

Zagorka TOMIĆ[1], Ljubinko RAKONJAC[2],
Milorad VESELINOVIĆ[2], Mihailo RATKNIĆ[2]

1. INTRODUCTION

The proper selection of the species and successful afforestation are impossible without the knowledge of the natural forest vegetation of certain area or sample plot. Many unsuccessful afforestations in the past, and previos or subsequent deterioration of the plantations are the result of the introduction of domestic and foreign species on the unsuitable sites. Therefore, before the afforestation planning it is necessary to define the natural potential vegetation, or to be on the safe side, the complete forest ecosystems, based on which the proper selection of taxa and afforestation technology is made.

2. POTENTIAL FOREST VEGETATION

The potential forest vegetation is defined based on the general laws of the vegetation zonation in the different plant-geographical regions of the central Serbia (Tomic, Z., 2004). Based on the new scientific views, the vegetation is divided into: zonal (climatozonal – climatogenic and climate-regional), influenced by the regional macroclimate on placor sites located at the lower altitudes, or climate-regional zones at the highest altitudes; extrazonal, which refers to somewhat altered form of the climate-zonal forest from the surrounding floral-geographical region; azonal, which is influenced by some other (mainly extreme) site factors, different from regional macroclimate, and is distributed along several zones; intrazonal, which is also influenced by some extreme site factors, but it is of the limited distribution – within only one zone.

Climatozonal–climatogenic forests are at first glance uniform for the whole of Serbia and presented by the association Hungarian oak-Turkey oak - *Quercetum frainetto-cerridis* Rudski 1949 (alliance *Quercion frairnetto* Ht 1954). However, the association of Hungarian oak and Turkey oak have several geographical variances in its wide altitudinal zone, out of which two are located in Serbia proper and are regarded as the individual regional zonal vegetation:

- In Sumadija, some parts of East and central Serbia the typical association of Hungarian oak and Turkey oak is climatogenic - *Quercetum frainetto-cerridis* Rudski 1949

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20052 „Changes in forest ecosystems affected by global warming“

- In Timocka krajina, some parts of Eastern and Southeastern Serbia the more thermophilic form of associations of Hungarian oak and Turkey oak with oriental hornbeam – *Quercetum frainetto-cerridis* Rudski 1949 var. geograf. *Carpinus orientalis* (Knapp 1944) B. Jovanovic 1956, is climatozonal.

- The monodominant Hungarian oak forests – *Quercetum frainetto* B. Jovanovic 1982, located at the farthest southeast of Serbia, in Negotinska krajina, is regarded as the zonal forest.

- At the northwest, in Macvansko-pocerski region, which is the transitory Illyric Illyric-Moesian province, and in some parts of Mt. Fruska gora, the mesophilic association of sessile oak and horbeam oak, located on the placor sites, is very similar to the Illyric zonal forest *Querco-Carpinetum illyricum* Ht et al.1974.

In the Pannonian forest-steppe zone there are no climatogenic forests which occupy great areas, whereas the "groves" – small stands of xerothermic associations of oaks different from associations *Quercion pubescentis-petraeae* Br.-Bl.1931 and *Aceri tatarici-Quercion* Zol. et Jak.1956, are dominant.

Climatoregional zone of beech and beech-fir forests – association *Fagion moesiacae* Blecic et Lakusic 1976 – particularly in the mountain region, is well-expressed and rather homogenous in the whole of Serbia. It is divided into four sub-zones (sub-association) in regard to the different altitudes: *Helleboro odori-Fagenion moesiacae* Soó et Borhidi 1960 (syn: *Fagenion moesiacae submontanum* Jov.1976); *Asperulo-Fagenion moesiacae* Knapp 1942 (syn: *Fagenion moesiacae montanum* Jov.1976); *Abieti-Fagenion moesiacae* B. Jovanovic 1976 and *Aceri heldreichii-Fagenion moesiacae* B. Jovanovic 1957 (syn: *Fagenion moesiacae subalpinum* Jov.1976).

Subalpine zone of conifer forests is influenced by cold and humid, boreal climate conditions, at the altitudes ranging from 1,300 to 1,400 m, and from 1,800 to 1,900 m, and the spruce forests are dominant – association *Vaccinio - Piceion* Br.-Bl. 1939. This zone is divided into two sub-associations – subzone – lower and higher: *Abieti-Piceenion* Br.-Bl. 1939. and *Vaccinio-Piceenion* Oberdorfer 1957.

In Metohija, with the significant floral-geographical differences (Scadric-Pindic Province), Bosnian pine forests – association *Pinion heldreichii* Ht 1946 are located on limestones and serpentinites, at the altitudes ranging from 1,400 to 1,800 m. In other regions, the fragments of Bosnian pine forests are found in Negbina and in Mt. Ozren, in the vicinity of Sjenica.

The second relict high-mountain pine, Macedonian pine, also occurs only in Metohija, on the silicate rocks of Prokletije, Sar-planina and Mokra gora, within the association *Pinion peuces* Ht 1950, and perhaps in some places in Southeastern Serbia.

High-mountain bush vegetation is presented at the altitudinal limit of trees, above 1,800 meters. It is represented by the bush associations of conifer and some broadleaf species, and two associations and two orders were defined: *Pinion mugo* Pawlowski 1928.; *Juniperion sibiricae* Br.-Bl-1939.; *Vaccinietalia* Laksusic 1979 and *Adenostiletalia* G. Br.-Bl. et J. Br.-Bl. 1931.

Extrazonal xerothermic broadleaf forests of Submediterranean type occur at warm expositions and high slopes in hilly-mountain region. In most parts of Serbia – from central (border at Ibar river) to Eastern and Southeastern extrazonal xerothermic oriental hornbeam forests are the representatives of association *Syringo-Carpinion orientalis* Jakuch 1959, and mostly refer to the different associations of oriental hornbeam (*Carpinus orientalis*).

Extrazonal mesophilic forests of Mideuropean type, the representatives of association *Carpinion betuli* Ht (1950) 1963, differ from the zonal sessile oak-horbeam forests of the Illyric province by the higher presentage of the steppe and moesian xerothermic elements. These forests occur in the shaded valleys and at the cold expositions in the lowland, or at wide, flattened cliffs at the border of hilly and mountainous zone, in the form of mesophilic associations of sessile oak and hornbeam - *Querco petraeae-Carpinetum betuli* Rudski 1949 (syn: *Querco-Carpinetum moesiacum* Rudski 1945).

Hygrophilic-alluvial forests, as the azonal vegetation influenced by the additional moisture, are mainly spread in the downstream of the rivers, and occupy the greater areas in the northen – lower parts of Serbia.

Willow and poplar forests (association *Salicion albae* Soó 1940), as well as the pioneering associations of willow bushes (association *Salicion triandrae* Müller- Görs 1958) are to a lesser or greater extent similar in the riparian zones of all big and small rivers. However, the bush pioneering associations of grey willows (association *Salicion elaeagni* Aichinger 1933) are limited to southern hilly-mountain area, from the seprentinites of central Serbia to the mountains of Metohija.

Some regional differences are also visible in the marshy hygrophylic forests of grey sallow and black alder (*Salicion cinereae* Müller-Görs 1958. i *Alnion glutinosae* Malcuit 1929): in most parts of Serbia black alder occurs in the form of "rows of trees", by water flows, and in Posavina, the small black alder forests occupy the smaller areas of marshy-gley soils. The mosaic, small grey alder stands (association *Alnion incanae* Pawlowski 1978) and some hilly forms of black alder are located at the higher altitudes, in the upstream parts of the river courses.

In the central part of the riparian zone, which is less exposed to the influence of the flood water, mainly pedunculate oak forests, "hard-wood fluvial forests" (association *Alno-Quercion roboris* Ht 1938.), which are also characterized by the regional differences: in flat Srem, Macvansko-pocerski and Posavo-tamnavski regions the peduncultate oak and narrow-leaved ash, monodominant pedunculate oak forests, as well as pedunculate oak-narrow-leaved ash – hornbeam forests occur; in the alluvial plains of Velika, Juzna and Zapadna Morava, Jasenica, Mlava, and other rivers in central Serbia, the mixed forests of hornbeam and ash are mainly directly sequenced to the pedunculate oak-hornbeam forests, which are without reach of the flood water; in Negotinska krjaina, which has the most diverse climate in Serbia, the peculiar associations of pedunculate oak-Pallis ash (*Fraxinus pallisae*) and steppe pedunculate oak (*Quercus pedunculiflora*) occur.

Azonal forest vegetation of hilly and mountain area, is influenced by the orographic, edaphic, or orographic-edaphic conditions, characterized by numerous permanent phases, and very diverse:

In the whole of Serbia, at the warm expositions in the hilly region the xeromesophilic sessile oak and Turkey oak forests occur – association *Quercion petraeae-cerridis* Lakusic et B. Jovanovic 1980. These forests alternate with the hilly beech and are located at the south expositions at the altitudes ranging from 400-800m. Within this association the monodominant Turkey oak forests, mixed sessile oak-Turkey oak forests, and monodominant sessile oak forests are formed.

However, in Southern (particularly Southeastern and Southwestern) Serbia the border of altitudinal zone of these forests is located at even 1,400 meters above the sea level, so the increasing number of authors regard the monodominant sessile oak forests as the climatoregional zone in these parts of Serbia.

- In the transitory Illyric–Moesian province (with the limit of altitudinal zone in Rudnik and Kopaonik mountains), as well as in Scandric-Pindric province (Metohija), on the limestones of hilly-mountain region, at the altitudes ranging from 600 to 1,000 meters, the basiphilious hop-hornbeam – association *Fraxino orni-Ostryon carpinifoliae* Tomazic 1940, which are at some places (in refugiums) of the relict character, occur.

- Basiphilious pine forests on limestones, dolomites and serpentinites in the mountain region – ranging from (400) 600 to 1,450 m, are also the association of the azonal character. If these forests are of the primary character, in refugiums, they are also relict. In Serbia they are represented by two associations: *Orno-Ericion* Ht 1958 (*Pinus nigra var.gocensis* and *Pinus sylvestris* on serpentinite) and the association *Pinion nigrae* R. Lakusic 1976 (Austrian pine forests on the limestone).

- Acidophilic sessile oak and sweet chestnut forests – association *Quercion roboris-petraeae* Br.-Bl. 1932 are the azonal vegetation influenced by extremely acid soils, which occupies small altitudinal range in Metohija and Southern Serbia, and rarely occurs in Western Serbia.

- In lowland and hilly regions the bush associations - shrubs are present, and they occur as the rim vegetation of the forest areas.

Azonal vegetation in beech forest zone is represented by several associations and subassociations:

- Forests of mountain maple and white ash – association *Fraxino excelsioris-Acerion* Fukarek 1968 are in some places dispersed in mosaic pattern in beech and beech-fir altitudinal range, most frequently at about 1,000 meters above the sea level.

- Beech and hop-hornbeam forests – sub-association *Ostryo-Fagenion moesiacae* B. Jovanovic 1976 are xeromesophilic (mesothermic) associations present almost exclusively on the limestones of Western and Southwestern Serbia and Metohija.

- Beech and Turkey hazel forests – subassociation *Fago - Corylenion colurnae* Borhidi 1963 are also xeromesophilic associations on the limestones, but they occur in Eastern and Southeastern Serbia.

- Acidophilic beech forests – sub-association *Luzulo-Fagenion moesiacae* B. Jovanovic are influenced by edaphic conditions. These forests occurs over a wide altitudinal range – in hilly, montain and subalpine zones – on very acid, extremely acid and podsolic acid brown soils.

Two groups of associations, which both mainly refer to the herbaceous plants and typical for Pannonian plane and the rim of it, occur as the intrazonal vegetation in Serbia: sand vegetation and saline soils.

The "relict" associations, present in numerous refugiums , mainly in gorges and canyons on the limestone, are particularly rare.

The presence of these associations is not the result of the modern conditions, but of the historical development of the vegetation from the Tertiary, via glacial periods, to the present. The term "relict associations" should be understood conditionally, since none of these species has remained the same from the Tertiary to the present – with the same floral composition, physiognomy and structure. The most well-known associations of the relict species in the refugiums of Serbia are the following forests: Serbian spruce (in Mt. Tara, in the Drina and Milesevka canyons); Austrian pine (Jerme gorge, Polom in the vicinity of Zlot, Goles in Suva Mt, Kozje stene in Tara Mt.); walnut and common hackberry (Djerdap); polydominant associations with the Turkey hazel in Eastern Serbia; associations of hop hornbeam on the limestones cliffs in the gorges of Western Serbia, and many other.

Using the zonation of the forest vegetation of Serbia as a frame, the potential vegetation in Pesterska plateau was study in a great detail, and the map with the ratio 1: 300,000 was created (Rakonjac, Lj, 2002).

If Pester Plateau is regarded as an entity, certain reguliarities of zonation of the potential vegetation in the altitudinal ranges are observed, but also the different directions and intensity of degradation in some complexes.

Hygrophilic vegetation (*Salicetum purpureae, Salicetum incanae, Alnetum glutinosae, Alnetum incanae i Alnetum glutinosae-incanae*) are located at the lowest altitudes and occupy the great areas of valleys and the areas along the watercourses, on alluvial deposits, gley soils and pseudogleys. It refers to the azonal type of vegetation, which is suspectible to the degradation to the form of marshy meadows, but it able to renew, by the progradation when the antrophogenic factors are no longer present.

The next altitudinal zone refers to the potential zonal forests *Querco-Carpinetum,* located up to 1,100 m above the sea level, on brown soils and pseudogleys. These forests are damaged by the irreversible processes and transformed into the agricultural land. The relicts of sessile oak and hornbeam are preserved in the forms of oriental horbeam shrubs, which occupy small areas, on the limestones which are unfavourable for agriculture. The azonal vegetation of limestone cliffs *Ostryo-Pinetum nigrae* also belong ot this zone.

Oak forests, alternating with beech forests, are located at higher altitudes, which range from 1,000 to 1,200 m.

All expositions on ultramaphite complex belong to the zonal forests of Balkan oak (*Asplenio cuneifoliae-Quercetum dalechampii*) and azonal *Pinus nigra var. gocensis* (*Potentillo heptaphyllae-Pinetum gočensis*). The latter is located in Dubocice canyon of the primary character, whereas in the zone of sessile oak and partly beech-fir forests it is of the secondary character (as one of the transitory degradation stages). For both associations, the pastures of type *Poetum molinieri* and *Danhonietum calycinae*, etc, are the last stage of degradation.

Sessile oak forests, alternating with Turkey oak (*Quercetum petraeae-cerridis*), are located on the complexes of acid silicate rocks at southern expositions, whereas montane beech forests (*Asperulo odoratae-Fagetum moesiacae silicicolum*) are located at northern expositions. The sessile oak and Turkey oak forests were degraded to common hazel shrubs, whereas there is a following pattern of the degradation of the beech forests: pioneering associations of aspen-birch and aspen-birch-common hazel, and common hazel shrubs and pastures *Nardetum strictae and Festuco-Chrysopogonetum grylli*.

As the possible former presence of the oak forests cannot be determined on the limestone complex, which is degraded by the irreversible processes, the whole process was defined as the potential montane beech forests on the limestone (*Cephalanthero-Fagetum moesiacae calcicolum*). There is the following pattern of the degradation in this potential association: common hazelnut shrubs and stage of juniper tree, pastures of types *Festucetum, Danthonietum calycinae, Cariceto-Brometum erecti*, etc, and the final stage refers to the almost completely bare stone fields.

Beech – fir forests (*Abieti-Fagetum moesiacae*) are mosaically arranged, located at the altitudes 1,100-1,300 m, and it can not be safely assumed that they belong to the oroclimatogenic zone. The pattern of their degradation within the ultramaphite complex is following: pioneering associations of Austrian and Scots pine, the stage of hawthorne bushes, and the pastures of type *Agrostidetum (vulgaris) capilaris*.

On the acid silicate bedrock the pattern of the degradation of beech-fir forests is following: poplar-birch or frequent birch forests, common hazel, and the pastures of type *Festucetum fallacis* and *Festuco-Chrysopogonetum grylli*.

On the devasted limestones no traces of beech-fir forests have been found, but only the relicts of the coppice beech forests, which are located at the suitable altitudes, and the pattern of degradation of these forests was the same as the pattern of degradation of montane beech forest.

The oroclimatogenic zone, located at the altitudes ranging from 1,200 to 1,500 m, occupy the greatest areas in Pester Plateau and partly in Western Serbia. This zone refers to the potential beech-fir-spruce forests (*Piceo-Fago-Abietetum*). The most frequent pattern of degradation of this association is following: secondary forests of Scots pine, which were researched at many sites.

The pattern of degradation of beech-fir-spruces forests on the ultramaphite complex is following**:** *Pinus nigra var. gocensis* at warm expositions, Scots pine and Bosnian pine at cold expositions, and the final stage refers to the pastures of the type *Poeto molinieri-Plantaginetum carinatae, Halacsia sendtneri-Potentilletum mollis, etc.*

The first stage of the regressive succession on the acid silicate complexes refers to the presence of Scots pine and birch, in some places to the presence of Scots pine and aspen tree, whereas the final stage refers to the association of blueberry and pastures of the types *Nardetum strictae, Festucetum falacis*, etc.

On the limestone massifs, except for some solitary spruce and coppice, stunted beech forests, located at the altitudes ranging from 1,200 to 1,500 meters, there are not many traces, by which the regressive succession of the potential beech-fir-spruce forests would be determined. Based on the individual traces, the pattern of the regressive succession is the following: Scots pine and aspen, juniper tree, and the final stage refers to the pastures of the type *Festucetum, Danthonietum calycinae, Cynosuretum cristati, etc.*

The oroclimatogenic zone of Bosnian pine (*Pinetum heldreichi* and s.l.).is the potential vegetation on the bedrock in the few areas located at the altitudes above 1,500 m The traces of Bosnian pines were found on the ultramaphite complex, whereas they are belived to have been present on the limestone.

Based on the ecological-degradation sequence and on the ecological-vegetation zonation of the natural vegetation, the Map of potential vegetation, which is the precondition for the proper selection of the species during reforestation and reclamation, was created.

3. ECOLOGICAL CLASSIFICIATION OF THE AREAS INTENDED FOR AFFORESTATION

The ecological classification and the selection of species for afforestation were made only for the areas intended for afforestation, since it is considered that these areas have priority, in order to mitigate the erosion process. It is indisputable fact that the even the areas which are not favourable for afforestation, and particularly barren land, also needs a special attention and recultivation. However, the afforestation of these areas has not been economically justified so far.

Based on the analysis of the general condition of the ecological factors of bare lands, which were made by Jovic, N., et al. (1998) in 14 (out of 17) forest areas of central Serbia, managed by State Enterprise "Srbijasume: Jablanicki, Nisavski, Moravski, Toplicki, Timocki, Severnokucajski, Juznokucajskom, Gornjeibarski, Sumadijski, Golijski, Tarsko-zlatiborski, Limski, Podrinjsko-kolubarski and Posavsko-podunavski (Juznomoravski, Rasinski and Donjeibarski forest areas were excluded), it was concluded that the bare areas are characterized by a large scale of ecological site condtions, based on which the appropriate ecological classification is made.

The percentage of the complexes (zones) are characterized by the following relations:

- Bare forest areas of central Serbia cover an area of all seven zones:
    1. complex (zone) of alluvial-hygrophilic forests
    2. complex (zone) of the xerothermophilic Hungarian oak-Turkey oak and other xerothermophilic forests
    3. complex (zone) of xeromesophilic sessile oak, Turkey oak and hornbeam forests
    4. complex (zone) of mesophilic beech and beech-conifer forests
    5. complex of thermophilic pine forests
    6. complex (zone) of frigophilic conifer forests
    7. complex (zone) of Subalpine bushy conifers and broadleaves.
- Owning to the peculiar sites of Ramsko-golubacka sands (Severnokucajsko forest area), the eighth complex – complex of grass formations was also singled out.
- Bare forest areas which refer to the forests of the zone of mesophilic beech and beech-conifer types of forests (Tomić, Z. And Jovic, N., 1990) (these forests should have been formed on them) occupy from 19.52% of the studied area (Tarsko-zlatiborski region) to 84. 71% of the total area (Jablanicki region). In regard the percentage of the bare forests area per forest areas, the forests of the second zone of the xerothermophilic Hungarian oak-Turkey oak and other xerothermophilic types of forests (Jovic, N. Et al,1991, 1996), which account for 15.41% (occur in all forest areas except for Tarsko-zlatiborski region), are second-largest and followed by the zone of the xeromesophilic sessile oak, Turkey oak and hornbeam types (complex 3), accounting for 12.99% of forests in 12 forest areas (it is not present in Tarsko-zlatiborski and Posavsko-podunavski forest area) (Jovic, N.et al. 1991, 1996).The fourth-largest is the complex of alluvial-hygrophylic forests (complex 4), which is present in 10 forest areas (Jovic, D. et al, 1989/90, Jovic, N. et al, 1981), and followed by the complex of thermophilic pine and oak types of forests – complex 5 (present in 8 forest areas) (Tomic, Z., Jovic, N., 1985). The other complexes (zones) are determined in less forest areas.

4. CONCLUSION

The selection of species for afforestation has been the weakest link in the previous afforestation strategy. The striking contrast to the great natural wealth – biodiversity at the levels of species and phytocoenosis – is very small number of taxa of domestic and foreign species in reforestation practice. The following conifers were mainly used: *Pinus nigra* (rarely *Pinus sylvestris*), *Picea abies, Pseudotsuga mensiesii, Larix europaea, Pinus strobus,* only in some cases *Abies alba, Abies nordmanniana, Abies grandis*, etc. The selection of broadleaves was even more limited and mainly refers to *Populus euramericana* on alluvial and *Robinia pseudoacacia* on all other terrains. The attempts to use American ashes (*Fraxinus lanceolata* and *Fraxinus pensylvanica*), black walnut (*Juglans nigra*), and some other exotic species were rare and mainly unsucessful. As a result, the effectiveness of the established plantations is not uniform, and the great percentage of the plantations in which the selection of species is not in accord with the site conditions. In addition, many effective plantations do not fully use the site potential, or they use it only over a short period.

The following theories for the selection of species, which were scientifically verified, were elaborated recently:

a) the use of the potential local heat, based on the altitudes, expositions and degreee of terrain warming for the afforestation of barren soils;

b) genetically-selective theory, which instists on the use of not only species, but also of of lower and intraspecific taxa of known orientiations;

c) during the selection of species based on the natural potential vegetation it is instisted on the renewal of the edificator species of the autochthonous species on the preserved terrains, as well as on the pioneers from the degradational stages of vegetation on the degraded terrains;

d) ecological-vegetation differentiation of the forest esosystems, i.e. the ecological units (main type of forests) in which three coordinates are summarized: edificator species, vegetation and soil, are the most comprehensible base for the selection of species.

The recommended selection of species by using this methodology anticipates three categories: a) main species – edificators of autochthonous phytocoenosis of the potential vegetation, which can be used in the initial phases of degradation, when the processes are reversible;

b) accessory species – mainly refers to the pioneering species on certain site, when the degradation processes are more expressed;

c) bushes, which occur in the natural degradation stages, as ameliorators, i.e. the primary vegetation of bare terrains on which the degradation processes are irreversible. Owning to the accountability of the data, only the autochthonous species of natural potential vegetation were taken into account, and it was recommended that the foreign species should be introduced only to the appropriate sites.

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ECOLOGICAL – ECONOMICAL IMPORTANCE OF FOREST DEGREE INCREASING IN CENTRAL SERBIA

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Abstract: *The strategic objectives of increasing, organising and utilizing forest eco systems, defined in Serbia Spatial Plan and confirmed at the conference " Afforestation with the aim of spatial plan realisation and agriculture, forestry and waterpower engineering development of The Republic of Serbia" held in Novi Sad in 2006., with a significant number of scientific-expert papers published in "Collection of papers" under the slogan " Help Serbia breathe", an expert, general public and the relevant social organs' opinion was shared that the basic prerequisite for 'ecological healing' of our part of the earth, and economic-social and demographic equality of hilly-mountain regions and urban-industrial centres, is increased level of woodiness of hilly-mountain regions with simultaneous increase of infrastructural, transport and other investments, which would contribute to improvement of life and work of rural areas throughout our country.*

The paper analysed different factors which affected forests, depending on the level of human civilisation development, human activities, historic events and the level of woodiness on the territory of The Republic of Serbia, and harmful effects of forest destructions which led to destructive effects of erosion and flood processes.

Key terms: forests, eroded barren land, afforestation, economic and ecologic function of forests, environment protection

1. INTRODUCTION

People of primitive societies – tribes, obtained food and means for addressing their existential needs by collecting goods from the existing natural environment – mostly within the area of forest ecosystems. At that time there was no need for wood felling and destruction of forests.

However, with civilisation evolution and demographic expansion, the existing spontaneous production of goods from natural forest and other ecosystems was not sufficient.

Therefore, man had to substitute the system of collecting food and other products with the system of producing goods.

Instead of collecting food from natural environment, man had to produce it in order to survive biologically. That was the very beginning of crop farming agricultural activities, and in order to pursue these activities, he needed open land areas, which he provided by wood felling and destroying forests.

Cattle breeding was another agricultural sector which has developed intensively since ancient times. As cattle breeding developed extensively by means of nomadic way of life, it was necessary to create vast pasture – meadow areas, which were also created by wood felling and burning of vast forest areas.

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20052 „Changes in forest ecosystems affected by global warming"

Eroded skeletal barren lands were formed by degradation of pasture areas of Pester plateau, Zlatibor, the Kopaonik mountain massif, the Ibar gorge, mountain complexes around the Vlasninsko lake and other large area of barren land and they were interconnected by sheep introduction in Europe from Asia Minor at the turn of the Christian era.

One of the causes of the forest destruction of local importance, in the area of present Central Serbia, is the mining activities. In certain regions mining activity dates from the time of the Roman Empire, but it flourished in the time of the house of Nemanjic medieval state during 13th century.

Forests were felled in order to provide mining wood for supporting walls in mine halls, for smelteries, and forest areas were cleared in order to build mining towns and create agricultural areas which could satisfy the needs for agricultural products of the population.

Since the cleared forest areas were exposed to uncontrolled grazing – especially goat breeding, as a consequence, large areas were transformed into barren land exposed to destructive erosive processes. In order to ensure the natural renewal of felled forests, Dusan's Law Codex, in the regulations on wood felling and afforestation, inter alia, in the Article 123, states *"Whatever Saxons felled, before this Council, let them be their land… From now on, what is felled, it is not to be tilled or settled, but it ought to be let as it is, only trees ought to grow, only as much as it is needed, can be felled."*

Authentic written documents are not available concerning the structure and condition of natural forest ecosystems, but J. Jekic's assumption, exposed in his work "Contributions to the history of forestry in Serbia" in which he states that "*Serbs, when settling into these area, found immense forests and large mountains"* concluding "*only within forests, such a fertile land, rich pastures and other favourable conditions for settling could be found",* can be considered realistic. It is confirmed by a Frenchmen Adam Gijem who, travelling through the kingdom of Raska before the battle of Kosovo, states that: *"the kingdom of Raska is full of riches, abundant in grain, wine, oil, meat; a land through which spring waters pleasantly flow and rivers are embellished by thick forests, pastures, groves and mountains, full of game of every kind".*

The Italian chronicler Matia Viloni, describing the war of the Hungarian King Ludwig I against the Emperor Uros (1359) remarks... *" Large Raska mountains near Rudnik, forest fortresses, he could not fight against Serbs without heavy losses".*

After the defeat of the Serbian troops at Kosovo, conquest of the Serbian territory and Turkish occupying invasion caused a massive migration of people from plains and hilly terrains. The migration had two directions: long term abandonment of Serbian state territories and migration to neighbouring states (known in history as migrations under Arsenije Carnojevic) and local migrations of part of population from plains into inaccessible mountain, mostly forest covered areas, within the territory of Serbian state.

Since the large areas became unpopulated as a result of a large migration of people from Sumadija plains and hills, the result was spontaneous reforestation of barren lands in plains of Pomoravlje, Stig, Macva and hills of Sumadija, Pocerina and other lower regions.

As a result of the above stated facts, during five century long slavery under the Turks, the degree of Serbian territories woodiness increased and immediately before the First Serbian uprising the woods covered more than 75% of the land, while the population density was only 3-4 inhabitants per 1km^2.

The degree of woodiness in Serbia of that time, particularly in hilly areas and river valleys, was illustrated by a number of contemporary travellers:

Stepan Gerlok, a protestant priest in 1573, describing the road from Batocina to Jagodina, says: "*Having travelled from Batocina along an uncomfortable and unpleasant road, through woods and groves, after two miles we arrived in Jagodina…".*

From the travel account of Edward Brown, the physician of the English King Charles II (from 1669), it can be seen that the river Morava was navigable, since it was used for transporting goods by Danube to Hungary and Austria, while salt and other goods were imported for the upper parts of Morava.

Oto Dubislav Pirh (1829.), having travelled across nearly the whole Serbia, frequently mentions abundance of forests in this area in his travel accounts. While describing the road Grocka – Pozarevac he says: *"... Cultivated and wild fruit grows, particularly walnuts stood one next to the other. There, I have realised for the first time, the vast richness of this country, in the forest which was felled and unused…"*

The road from Porec via Majdanpek and Homolje to the source of Mlava he describes by the following words: *"…We had been riding through wilderness for four hours. Nothing is more noticeable as the nearly unused abundance of timber… one generation of trees suppresses and pushes out the other… the whole Serbia is so rich in forests that wood is of no value".*About Rudnik mountains he says: *"Rudnik mountains lie nearly in the centre of Sumadija and they are the true heart of the country and its natural fortress…. Its highest peak Sturac… is the only part of the mountain without woods, it stands out as an observing tower of that natural and large fortress…Only to the foot of the mountain did the Turks come, but never further, for tens of years the Turkish foot have not stepped into the mountain interior…"* While describing the road Kragujevac-Beograd, he writes: *"We have been riding for three days through oak woods".*

And Lamartin had an impression in 1833. that he was *"in the middle of North American forests"*

Archpriest Mateja Nenadovic writes in his "Memoars" (1893) that during the First and Second Serbian uprising Morava valley and Macva plain were covered with thick wood.

From the above mentioned illustrations, it can be concluded that even in the mid and towards the end of 19th century, Serbia was one of the most wooded countries in Europe. Oto Pirch (1829), describing the abundance of forests, among other things, says: *"... forests can be cleared for generations here, before this area becomes barren land…"?* Unfortunately, he was profoundly mistaken when writing about indestructibility of our forests since, only 75 years later, M.Vasic writes in 1904. in his booklet "Our forests" the following words: *" Our forests are in critical condition, and chances are that they will be completely destroyed…"*

Although this pessimistic forecast has not entirely come true, the fact is that today we have vast areas of barren land in hilly-mountain regions, which were exposed to the destructive effects of erosion. Furthermore, more than a half of present forests are devastated to the higher of lower degree, with considerably reduced production of quality wood mass and significantly reduced other generally beneficial functions, since more than 50% of the total forest reserve is of sprout origin and planted after the felling of high trees, while in place of felled conifer forest eroded barren land remained, due to the fact that conifer forests cannot be renewed vegetatively.

Some of the causes of disappearance of forests in Serbia after the liberation from Turkish slavery

Beside mining, the development of cattle breeding - sheep breeding in particular, intensive population and economic development, as well as migration movements as a result of wars, also caused forest destruction. Forests were cleared in order to build new settlements. With the increase of population, areas for agricultural production, that is, development of cattle breeding, crop farming, fruit and vine growing, had to be enlarged and, since the agriculture was of extensive character, the growing needs were met by further forest clearing with the aim of increasing agricultural land.

Sudden increase of population in 19th century was not only the result of natural growth of population but it was also due to migratory movements and settling of people , particularly from east Herzegovina and partly from Montenegro, which resulted in foundation of new settlements in plains and near rivers.

The extent of population growth can be seen from the fact that in 1801. Serbia there were 3-4 inhabitants per 1 km^2, while in 1910. the number increased to 60 inhabitants per 1 km^2.

Since the population was mainly involved in agriculture, a rapid plain forest clearing took place together with transformation of forest land into agricultural. As a result, presently, forests in Macva and Pomoravlje can be found only in flood prone riverside areas, in which the agricultural production is impossible or risky, and in smaller oak grove areas in depressions.

Furthermore, The World War One and Two substantially contributed to destruction of vast forest areas. All the above mentioned factors resulted in the fact that the degree of woodiness immediately after The World War Two amounted to less than 20%. The after war afforestation and some spontaneous renewal in central Serbia increased the degree of woodiness, which today accounts to 32.8%.

Since the ecological effects of low level woodiness are becoming more and more drastic, one of the main tasks for the state is to provide preconditions for more intensive afforestation of eroded barren land in order to establish the approximate ecological balance in nature.

Instances of forest destruction testimonials and renewal efforts

The previous illustration pointed to causes and consequences of forest destruction immediately after the liberation of Serbia. It is interesting to remind of the documents which illustrate activities of experts and citizens of the Dukedom of Serbia local self-governments in order to remove the harmful effects of forest destruction.

Participating in the creation of monography 'Half a century of forestry 1876-1926', Ćurković, M. (1926) in his work 'Forestry and forest conditions in Serbia' writes: *When Milos' state gained its independence (1830) and when the country conditions improved, foreign buyers appeared for our oak wood. Poor people, who until then couldn't earn much because of constant wars and the fight for liberation, were happy to see them and sold wood extremelly cheaply and felled it mercilessly. They felled a lot, without any order or plan, with a deep conviction that the trees will grow again, while merchants took with them only what they needed, while massive remains of wood, without being sold, were simply burnt. Afterwards, herds of cattle were sent to the cleared areas, what completely destroyed remaining sprouts and prevented new sprouts to grow. In that way poor pastures emerged which later became barren lands."*

Having learnt about Velika Morava catastrophic floods during his journey accross Sumadija and Stig, Grand Duke Mihailo, at the opening of the first session of Dukedom of Serbia National Assembly in Kragujevac 1864, gave the following speech:

Our forests, which are capital of ours, a source of country's wealth, have been destroyed mercilessly. I am happy to be in the midst of people of this beautiful country, but I am forever saddened by devastation done to our forests... Don't tell me that devastated forests are not the great cause for having so many people suffering from floods this year... Posterity will curse us unless we have taken care of our forests, our wealth."

J. Pancic (Archive materials of Serbia – Serbian news, 1864) had constantly pointed to the consequences of forest destruction – in 1856. he called the attention to the expansion of barren land and severe biological balance upset on 'barren steep slopes', stating examples on west side of Raska, *'from Kopaonik to Avala, particularly in the area of serpentine soil.'* He states the characteristic examples of deforestation above the village of Beli Potok in the foothill of the Avala mountain, part of Ralja, Kubrusnica tributary, Jasenice, Despotovice and others. He made some interesting observations, saying that: *'None of us has come up with the idea to make a distinction between hill and plain forests, between forests on sunny and shady side, between forests on good and rocky soil... Many places have become rocky grounds... Law makers, skilled foresters and good will of the people ought to act there.'*

And the first Serbian expert forester Aleksa Stojkovic reports on the first journey accross Sumadija and part of western Serbia, ordered by Grand Duke Mihailo that: *'... forests near villages in Belgrade district are mainly felled. Only remote forests remained. In Kljestevica forest (ca 150ha), oak is being felled a lot, particlularly for fences and other things, it is disappearing and the young trees are rarely planted. Vencac did not require long observation. It was sufficient to see its streams with lot of stone and sand. Vencac is a very steep hill anyway. Its soil is rocky and it is bound to face the same fate as two peaks of neighbouring Kljestevice, Orlovo brdo i Sutice...'*

He noted about Rudnik that: *'the neighbouring villages streched high into this mountain, which si detrimental for this mining mountain in need of wood. The harmful effects in this thinned out part of forest have already been felt in the village of Jermenovac. Additionally, in the high areas of this mountain, there is no wood whatsoever, not because of water activities, but due to the ancient mining works, cruel and cold winters, frosts, strong winds,etc and as a result, wood could not be renewed by itself...'* For the narrow valley of the small river Despotovica, named Klisura, he says that: *' its sides are very rocky and a rare stump can be seen here and there as a sad witness... instead of nice and green hills in this area he could not see.. neither pig nor goat nor cow to wander in this gorge.'* He proposed the measures for prevention of *'further devastation of this gorge.'*

J. Pancic visited for the first time in 1852. Ram-Golubac sand area and after a long research, published in 1863. a notable study 'Quicksand in Serbia and the vegetation growing on it,' in which he, inter alia, states: *'from Ram to the confluence of Timok and Danube there are larger and smaller areas covered with white quartz sand which is constantly moved by wind, and for that reason it is called quicksand by people.'* Noticing the negative effects of unreasonable wood felling, he states: *'...in the east hillside of Ram there was a thick wood in 1852. and sand was consolidated by firm shrubs.'* In 1862., *' he finds this wood greatly thinned out with remains of English oak shrub in places, stuck into sand to boughs,'* while, *'on moving sand surface he could not see a single plant.'* He criticised the municipal authorities for not having determined the places in which wood can be cleared or cut for thinning, *'and prohibit the cattle movement and grazing,'* because '*each wood, bush or shrub, well rooted, serves as the strongest wind protection.'*

A. Stojkovic, in his report to the Ministry of Finance, submitted on 27th July 1872., well describes the conditions of the forests and the problems of their preservation in the area of Ram-Golubac sand area and the wider area of this part of Podunavlje, and after accomplishing the surveying task, he says..' *and those places in which wood felling has been conducted since 1863. on behalf of the Minister of War'* and *'those places in which mostly private individuals fell wood and export to Vlaska..'* After accomplishing the first task he states that felling *'was conducted in a very improper manner,' ...'wood was felled in places exactly where it was not supposed to be felled.' .. new seeds were not planted,'... ' in some places very young trees were cut,'..'after cattle (goats in particular) being allowed into the cleared areas, new trees could not grow,'..'there are many goats, woods are much thinned out and damaged and only in inaccessible and remote places good and large woods can be found.'* He states further in his report concerning his second task: *'From the Golubac subdistrict I entered the Kljuc subdistrict of the Krajina district in which most fire wood is exported to Turky and Romania.. Cut trees are transported to Ada Kale, below Tekija, then to Sip in Kladusnica, near Velesnica and beyond Brza Palanka within the area of the Grabovica municipality, and only in this last place at least 100 ships a year are exported.'*

'And in this district goat breeders are real pestilence for forest, since they fell hundreds of trees a day to provide pasture for goats and it is the best trees, such as elm bark trees. Here also entrance ought to be banned to goat breeders'...'and in this district all places near the Danube do not have old wood, but every tree is bent, as a result of cattle who constantly bite young trees and goat breeders who fell wood for pasture both in summer and winter'.. 'there are a lot of places with no wood at all, barren places. These are old fields and meadows, abandond for not being fertile. There are many such places around Petrovo selo in particular.'

From the above illustration of causes of forest disappearance can be seen that the forests paid the toll for economic-demographic development, mining development, war devastations and after war renewal of the country.

It can be understood that such devastating treatment of forests caused ecological disbalance with diverse harmful effects, among which erosive clearing of deforested areas in hilly-mountain regions are most striking, which led to creation of vast areas of skeletal barren land, occurence of devastating floods and other negative ecological effects.

The above mentioned negative effects were noticed very early, so we have interesting findings about simultaneous process of uncontrolled forest destruction and efforts by state organs to ensure conditions for their renewal.

Efforts to limit forest clearing by state regulations

We stated the Article 123 of Dusan's Law Codex, which strictly prescribes that forest cleared areas are not to be settled or used for other purposes, but *' to remain abandoned, to let trees grow,'* so that it can be considered the first written official document which addresses the issue of forest renewal.

After the five centuries long slavery, a few years after liberation from Turks and gained independence, obligation of forest renewal and planting new forests in the Dukedom of Serbia is regulated by the law acts.

Noticing the dangerous effect of uncontrolled wood felling, the first Forest decree from 1839., regulation number 5, prescribes *that 'in places were the wood has existed and it can be easily destroyed, it is necessary to make an effort to plant young trees, which must not be harmed, in order to obtain new woods in time and to compensate for the old wood which is felled.'*

Another decree from 1857. and its amendment from 1858., act 3 and the amendment to the Article 3 of the base Decree, state: *'...linden and Europan ash treed in thinned woods must not be further felled, taking care to plant new seeds and to protect that space by fence in order to prevent kattle from entering, in order to ensure that the young trees grow in a most efficient way.'*

It is clear from the cited decrees that it was cared for the natural renewal of woods, and the Article 26 of the 1872. Decree priscribes the obligation of afforestation *'where municipal authorities find necessary to plant wood.'*

The first Forest Law from 1891., inter alia, states: *'All barren, severly thinned and places incompletely covered by wood, and crags, rocky slopes and hillsides of state forests in particular, will be prevented from entering immediately and afforested as soon as possible.'* Similar regulations were priscribed for municipal, village and monastery forests. It is interesting to mention, that even that law, as a form of stimulous for private individuals to plant wood, had a regulation which prescribed that newly afforested area are exempted from land tax for 20 years.

During the reign of the Grand Duke Mihailo Obrenovic first expert foresters were engaged to resolve the issue of preservation of existing woods and afforestation of barren land, since in all parts of Serbia of that time harmful effects of forest destruction could be noticed.

First attempt to create a barren land cadastre in Serbia was made in 1872. On suggestion of A. Stojkovic, the Ministry of Finance, its Economic Department, sent to all section offices a circular number 854 of 28th January 1872., *'to make a list of all barren places – hills, which ought to be fenced and entrance prohibited, in order to plant woods in both natural and artificial manner.'*

There is no data whether all districts responded to this order, since only the report from Valjevo district, including the list of barren places in subdistricts: Valjevo, Podgora and Kolubara, was found in the archive materials.

Unfortunately, not even today, 138 years later, we do not have a complete barren land cadastre in Serbia providing informantion on land which ought to be afforested.

Local authorities and towns engagement in resolving the afforestation of barren land issues

It is interesting to mention how the above mentioned forest regulations from 1839. -1872. had an encouraging effect on contemporary local authorities to deal with the afforestation of barren land issues.

There are numerous instances of municipalities and individuals asking for help or only approval to plant wood by their own effort and means. (Source: Archive materials of Serbia).

In that sense, the Administrative Office of the Knjazevac District on 5t^{h} March 1873. at the proposal made by village of Kopajkosare, imposed entrance prohibition for the purpose of planting new wood in Glavcine, Mali Zabel and Nadsusvek, in the area of village Grabovacko

The Crnogorski District Administrative Office in Kosjeric, at the proposal of village Brajkovic, ordered planting of a new wood on Glogovac hill.

The Head of the Niski District Adiministrative Office ordered planting oaks on the barren land above villages Kamenica, Matejevca and Knez. That crop, as Vule Nikolic said, *‚took well and it is growing nicely'* (M.Milicevic., 'Dukedom of Serbia' 1876).

The municipality of Selac (1883) asked for an approval from the Ministry of National Economy to plant a new wood.

The Kosmaj District Head of Administrative Office ordered afforestation of barren places around Kosmaj. Earlier, it was demanded by a village of Babe (7th October 1869).

The municipality of Brusnik, the Rudnik District asked for certain area to be afforested.

The municipality of Bacevo (1875) in the Belgrade District asked for an approval, reffering to a certain area of 100 days of plough, in place called Strana, to plant oak wood, which was granted.

The Administrative Office of Cacak Subdistrict adopted the proposal made by the Head of the Administrative Office of Karanovacki Subdistrict and a forester Petar C.Markovic, referring to an area called Ravni Gaj in the municipality of Mrsac, to plant oak wood in the same year (1875), since, *'it was ruined by improper felling'.*

Seeds and seedlings were asked for by the Administrative Office of Jacenicki District (1875) for seeding and planting on acid water in their area.

Even earlier (1851), the village of Vlacna demanded wood planting on the 'Svetinja' hill.

These few extracts from the documentation from the archive materials indicate that towns and villages in that time were the initiators of demands for afforestations of barren land, understanding the harmful effects of forest destruction.

Unfortunately, today, when the effects of forest destruction are incomparably more drastic, such initiatives from local and higher authorities are very few, and the voice of forest professionals is not sufficiently strong nor persistant.

2. THE HISTORY OF AFFORESTATION IN SERBIA

Afforestation in Dukedom and Kingdom of Serbia

We have pointed to the fact that the fatal effects of forest destruction were strongly felt even in the time of reign of Milos Obrenovic.

Already cited J.Pancic, apart from pointing to the disasterous effects of forest distruction, provided practical advice on what ought to be done for their renewal.

It is suggested that in Sumadija the greater attention is paid to English oak, then to Sessile Oak (*Quercus petraea*), cerris and others. It is further stressed that: *'...on barren land and closer to settled areas, trees which can be used in industry or fast growing trees, such as black locust, mulberry tree and ailanthus ought to be planted. Black locust is benefitial in many ways and it can* *grow on any type of soil. Its wood is good for all uses. It is successfully used for creating hedges, which should be applied. It will stop the previous method of fencing property by expensive and worthy oak tree. There are numerous examples of black locust use in the outskirts of Belgrade, Pozarevac, Kragujevac and other places,'* which was presented in his lecture on 'Some facts about our forests,' given within the framework of agricultural fair 'First display of earth products' in Kragujevac, 4^{th} October 1870.

Although there are no ordered and systematised data on first organised afforestations in Serbia, according to the archive documentation and official gazettes, such as 'Labourer', 'Serbian word', expert publications and articles, and other sources of that time, first (or among first) afforestations were conducted by seeding acorn in Topcider and Kosutnjak 1853 (Serbian newspaper from 14^{th} September 1859). Students of Agricultural School in Topcider (1853-1859), as a part of a subject 'Forestry' practical training, worked on seeding acorn and beech nut on the cleared areas of Topcider and Kosutnjak. The Kosmaj District Head of Administrative Office sent 50 oke (old measure of weight) of acorn and 50 oke of beech nuts.

Next recorded afforestation in this area took place in 1867. A forester and hunter of the Topcider estate Maksimilijan Mouks proposed to plant young beech in the empty areas of Topcider. 9,000 young seedlings were obtained from the peasants of Rusanj village, at the cost of 20 para (1 dinar=100para) each. The first set of 6,000 trees was planted near 'Bela Cesma' in Topcider, and the remaining 3,000 in Kosutnjak.

First afforestations of larger extent at Rudnik were conducted in 1866. by seeding 19,000 oke oak acorn. Aleksa Stojkovic, during the first forester training course at Rudnik in monastery Blagovestenje, organised with the attendees and Stragar powder plant staff seeding of the above mentioned quantity of acorn on the barren areas of Rudnik.

After Rudnik, acorn seeding took place in Vujin where, *'there are many sad barren lands which, with their severe sterility, simply frighten the observer.'*

In this period, first afforestations in Serbia were conducted in Ramsko-Golubacka sand area. J. Pancic, in the above mentioned study 'Quicksand and the vegetation growing on it,' 1863. recommends *'...to plant white and black poplar tree, aspen, and further black locust and bush on the Danube banks towards slopes.' 'Planting should be done in late autumn and early spring while the sand surface is wet and farmer has enough time for this type of work.'* Although recommending different types of trees and bushes, as well as the way in which afforestation should be conducted, he states, nevertheless: *'...Practical foresters will make a better judgement, and whether I suggested good means – that I do not know, but what I could propose on the basis of the theoretical knowledge I possess, should be sufficient to make quicksand in the Danube Basin dissapear.*

His interest in quicksand can be seen from a bag of grass he sent to the Head at the Interior Ministry with the following letter: *'I got these seeds of certain Elymus avenarius grass, from an acquintance in Banat, which grows well in sand and it binds sand well and therefore it is planted in Banat sand areas bringing much benefit.'*

'Would you kindly order to sow these seeds later somewhere in sand, divided into smaller piles. Possibly the best place for the first attempt is Ramsko Brdo.' The Interior Ministry Head Spasic and the Secretary Aleksa Stojkovic sent that bag of grass to the Head of Pozarevac District, *'..to sow the sent bag of wild sand oat (Elymus avenarius),which can be successfully grown in sand areas of Banat, and inform the Ministry in one year time whether the seed sprouted and whether it grows well.*

Certainly at a recommendation given by Pancic, in January 1869. a vacancy for a forester in the Golubac forest arose and, after an open competition also published in foreign press, Prokopije Simic, who previously worked as a forester in the Srem county, was appointed. According to expert instructions given by J.Pancic and Stojkovic, he treated a large part of this sand area with 10 oke of black locust and some 'ajlantus', with the help of villagers of Radosevac, Uskrs, Vince, Vikovce and Kusic. In seedling nurseries near villages Usje and Vince, he produced seedlings of Canadian poplar and black locust. In a village Bikotnice he planted 500 seedlings with local farmers. From the seedling nursery in Kosic he received and planted 300 black locust seedlings on *' sand areas and slopes'* near the Danube. From the seedling nursery in Pozezen he received 800 black locust seedlings and planted them near the bank of Danube.*'Seeding was improving and, by erecting solid fences, an access of cattle was prevented.'* The municipality of Golubac fenced the area in which 400 pieces of Canadian poplar was planted.

P. Simic continued his work, about which the following data can testify:

From the seedling nursery in Ram he took 3,140 black locust seedlings and planted them at Ram hill. From the seedling nursery of the municipality of Zatonje, he took and planted in *'sandy slopes'* 875 seedlings of black locusts. He also took 500 poplar seedlings from this seedling nursery and planted them near hill, *'all the way to the stream.'* Around the stream spring he planted willows and poplar trees.

It can be learnt from the data recorded in the archive materials of the Ministry of Finance Economic Department for 1866. and 1867. that even in 1865. black locust seeds were sent from Topcider, since the Head of Ram subdistrict reported that: *'..there are no black locust seeds there, nor willow seedlings, that is, people do not want to give them from their willow groves without being paid...'*

In spring 1867., an expert gardener from Topcider Ivan Protic was sent to Pesak in order to help establishing *'seedling nurseries and planting poplar and willow seedlings.'* I. Protic was staying at Pesak in spring of 1867. where he *'...conducted some protection work, sowed black locust seeds and ajlantus.'* Many seedling nurseries were established in this area: 1866. on the locations of Bukotnice, Vince, Pozezen, Kusici and Usije, and in 1872. in Golubac, all in the Ram subdistrict.

However, afforestation results were not satisfactory, since I. Protic, who was sent to conduct expert examination of seedling nurseries and supervises sowing and planting on the site, in his report for the period between 1868. and 1874., inter alia, says: *'The steps taken in this direction* (referring to afforestation, M.D.), *would give better results if the municipalities, which are most concerned, implemented given recommendations with better will, and to their negligence could be attributed the fact that oak wood at Ram hill, planted in1868, and already sprouted, is destroyed by cattle to large extent.'*

Speaking about the emerging and spreading of sand, Stojkovic emphasises: *'Everybody agrees that only by planting forests in some parts, it is possible to prevent its expansion. Even villagers realised that and began to plant black locust trees around their houses even ten years ago. But that could not the remedy the whole problem, mesures had to be taken to plant black locust, poplar and willow trees in some places, and when this is once accomplished properly, and wood grows, then it is certain that the spreading of sand will be prevented.'*

'...Out of all planted areas, those near seedlings the Danube took best, a Canadian poplar in particular, since, apart from some trees being destroyed by ice in some places, all others grew nicely and progress well.'

'...The prevention of flying sand spreading can be achieved only by planting in those places which are elevated above riversides, areas on the hill planted with black locust trees, in which grass began to grow and sand began to consolidate to some extent.. From my point of view, planting in sand areas should have the intensity which will reduce the effect of strong winds...planting ought to be done as soon as possible since there are many seedlings that we received for that purpose.'

Assessing the quality of existing seedlings, A. Stojkovic states that:*' as far as seedlings are concerned, they progress well, but only they should be better ordered..'* Concerning the sand spreading he says: *'...Apart from Vinac, Pozezina and the whole area from Golubac to Pek, sand areas are most frequent in Zatonja, in the area accross the town Gorica and Ram hill. From the fields to the area bellow Gorica hill, sand prevails and continues even to Ram. This area can be consolidated only if the sand area around village Zatonja is consolidated.. apart from sand areas,* *there are many other deforested areas in the subdistrict of Ram, and such areas ought to be afforested without fail... Such places are located particlularly above the villages of Kuman and Topolovik, there are many barren and steep areas and it is easy to plant wood there.. A fact that soil in some places began to erode and create many ravines, which threatens villagers, might present a difficulty'*

According to the stated report by A. Stojkovic, it can be concluded that the villagers, for the purpose of protecting houses and farms against sand, began to erect protection areas, on their own accord, in the middle of the 19th century.

However, out of the total afforested area of Ram-Golubac sand area, only fragments of woods remained in small valleys and protected areas and some shrub formations in the northern slopes.

Another importan location in which forests are destroyed and afforestation started in the last century is Avala in the proximity of Belgrade.

J. Pancic informed the Ministry of Education in 1856. that, *'... extensive and uncontrolled wood felling for the purpose of satisfying the needs for fire wood and timber in the near proximity of Belgrade, and Belgrade itself, tilling of suitable land, cattle grazing, cutting and prunning for feeding cattle, unauthorised appropriation and other difficulties, enabled the transformation of slopes above Beli Potok, with brittle serpentine soil of former wood, into barren land in which organic life became extinct.*

The condition has further deteriorated, and Kanic wrote in 1895. that Avala became *'almost bare hill.'*

How sad and sombre impression that Avala created affected even the Grand Duke Milos, can be seen from the information that he (in 1859.), simoultaneously with introducing new and re-adopting some of important regulations from the time of his first reign, also adopted *'The Decision to build fence around Avala and, by that means, save not only forest, but the whole vegetation blanket.'*

A strong need for wood emerged in 1880's, in particular oak tree for the purpose of production of railroad ties and burrel components, for export abroad. Apart from that, on the larger area of Avala, many contractors obtained an oak wood concession, concerning oak for the planned railroad Beograd – Nis, mercury mines and other purposes. That caused further devastation – *'wiping out'* of forests in larger areas, as well as an unauthorised appropriation of state and municipal forests by private individuals.

Faced with constant state of deterioration of forests in Serbia, the Ministry of National Economy of that period, via its Department of Forestry and by persistant efforts of the Head of Foresters, Jevrem Novakovic and his follower Krsta Djordjevic, for whom Avala, being closest, was of a particular interest, provided 60,000 dinars from the annual budget for 1887. for works on forest improvement in Serbia, out of which significant funds were invested in Avala.

Establishing a seedling nursery at Avala is linked to Milan D. Obradovic – Licanin, a Serb from Gospic, graduated forestry engineer, a professor at Vienna Bodenkultur, who, after short period in Vienna, found himself in Serbia in 1891, and immediately faced Belgrade dust, which, carried by strong -south east and south west –winds, made the living conditions difficult. Noticing the bare slopes of Avala, only in following 1892., via daily newspaper, Obradovic appealed to the public with proposals how to alleviate negative factors of life in Belgrade. Firstly, he insisted on afforestation for the purpose of creating pleasant vacation areas in the surroundings of Belgrade-Karaburma, Topcider, Kijevo, Avala and other places. He emphasised that, among all stated locations, Avala had the best preconditions to become what all large world cities had had for a long time.

As a regional forester, he asked for tools and equipment for establishing a forest seedling nursery at Avala. He managed to obtain the approval in form of the decision of the Ministry of

Forests no.261 of 5th March 1897. concerning seedling nursery establishing at the chosen location on west side foothill of Avala.

The original area of the seedling nursery was 0.48ha, which soon, at the request of Practical School of Forestry Principal, increased to 0.99ha, and whose students took part in work in the increased area.

Wide spectrum of seeding materials was produced in the forest seedling nursery at Avala, forest species of conifer and deciduous tree seedlings, park trees and bushes, not only for the purpose of afforestation of Avala, but for the afforestation needs of other complexes in Serbia.

During the same spring the first sowing in the seedling nursery was conducted by M.D. Obradovic, with the seeds obtained from Belgrade seed and seedling vendor Todor Mraovic. Among other plants, he sowed 6kg of osage orange (maclura pomifera) 2kg of larch and 3kg of fir, spruce, black and white pine tree each. Horse chestnut seed was obtained from the Topcider estate. There are no data concerning the successfulness of this sowing.

Franjo Fogl, Czech, who came to Serbia in 1896. and took Serbian citizenship and converted into Orthodoxy, changing his name into Milos Josifovic, was appointed a district forester in 1898. He, apart from his engagement in seedling production, in 1898. conducted a survey of deforested land on Avala peak and afforested it with black fir and spruce seedlings which he got from Topcider from seed merchant T. Mraovic. Two hundred pieces of grown seedlings of black fir were planted in the proximity of forester house for a future park, while 10,000 pieces of spruce seedlings were planted on Avala peak. For these and other forest-cultural activities at Avala in 1898. 3,000 dinars from the state budget was approved.

From 8th to 10th April 1906. planting of 15,000 seedlings of black pine tree and 3,000 seedlings of fir was carried out in Mali Kosmaj. Seedlings were bought from "Berkon' company-Bohemia. At the insistence of the Minister Milorad Draskovic, and under supervision of subforester Milos Cirkovic from Avala, pine tree seedlings were planted in barren soil of Mali Kosmaj, while fir seedlings were planted in the proximity of stream and seedling nursery at Tresije. Seedlings were paid 103,50 Austrian crowns.

From the establishing of Avala seedling nursery to the spring of 1902., 218,954 seedlings from that nursery had been used for different type of forest-cultivation work at Avala. Out of that number, 157,800 seedlings had been used for the afforestation of barren areas, supplementing thinned out forest areas and supplementing insufficiently successful cultures, while remaining 61,154 seedlings were used for laying out a park area, tree line and hedge around paths and roads. A significant number of seedlings was distributed into other parts of country. M. Obradovic, a district forester, recorded that 7 million seedlings of different types of conifer and deciduous trees had been produced in the Avala seedling nursery from establishing in 1897. to 1904.

In the drier areas afforestation was conducted mainly by three year old pine tree seedling clumps. In the area of 'Crveno Brdo' in 1902. and in spring 1905., 4ha were afforested with three year old pine tree seedling clumps and in the area 'Zivanova krcevina' planting of five year old larch seedling clumps was carried out.

From the presented analysis of the afforestation activities in Serbia before the World War One, it can be seen that the extent of afforestation was most frequently recorded according to the quantity of seeds and seedlings used in sowing, without data regarding planted and sowed areas, so the total afforested areas remain unknown.

Afforestation between two world wars

After the World War One, the newly created country of Serbs, Croats and Slovenians, later called Yugoslavia, also faced severe ecological consequences of low level woodiness.

Despite the above mentioned fact, the ruling establishment did not care enough about preservation of existing forests, nor about encouraging eroded barren land afforestation.

Although the Forest Law from 1929. kept the regulation of 1891. Law to exempt from taxation owners of afforested land, it seemed that that regulation, due to the administrative – bureaucratic procedures which obstructed its practical application, did not have encouraging enough effect.

Beside the above stated facts, it was noted that one of the reasons for the afforestation stoppage was undefined and unidentified area of barren land for afforestation.

For that reason the cited Law prescribed that the identification and recording of barren land ought to be completed in 10 years. The on site part of the work was accomplished in the majority of subdistricts before the World War Two. The classification of on site collected data and creation of general base for afforestation were behind the schedule. Unfortunately, all collected on site data were destroyed during the war, which is highly regretful, since we do not possess a complete record of barren land for afforestation until today.

In the period from 1919-1938 (there are no data for 1939-1940), in the region of central Serbia, the afforested areas are the following:

- afforestation of Ram – Golubac sand area	322 ha
- afforestation of barren land in the other areas of Serbia	3.248 ha
The total afforested area according to the available documentation	3.580 ha

The structure of afforestation tree type in percentages:

- black locust	75%
- black pine tree	8%
- European ash	3%
- honey locus	3%
- other types	11%

As it can be seen, black locust was a dominant afforestation tree type.

The average success of afforestation was 60%.

Afforestation after the World War Two

During the four year of occupation of our country, from its own security reasons, the occupier destroyed forests by frequent felling in the proximity of towns and along transport communications, which unavoidably caused intensified effect of erosion processes and frequent occurrences of devastating torrents and floods.

For that reason, immediately after the war, organised mass afforestation activites of serpentine and limeston barren areas had began.

According to the data concerning afforestation in the period between 1955.-2008. and sources from other documents for the period between 1946.-1954., the following afforestations were conducted in the region of central Serbia:

Table 1. *Central Serbia afforestation survey for the period 1946-2008*

Afforestation period	Total afforestation	Deciduous trees							Conifers				
			Hard deciduous trees			Soft deciduous trees				According to tree groups			
		Total	sTotal	Black locusts	Other hard deciduous trees	T Total	Selected poplar trees	Other soft deciduous trees	Total	Black and white pine tree	Spruce and fir	Douglas-fir	Oother conifers
(16 god.) 1945-1960	63.836	38.205	No data						25631	No data			
Annual average	3.989	2.388							1.602				
(15 years) 1961-1975	94.414	56.093	37.676	35.704	1.972	18.417	16.760	1.657	38.321	29.867	6.741	471	1.2442
Annual average	6.294	3.740	2.512	2.380	131	1.228	1.117	110	2.555	1.991	450	31	83
(15 years) 1976-1990	180.604	36.987	23.828	22.356	1.472	13.159	11.780	1.379	143.617	83.290	55.098	1.455	3.774
Annual average	12.040	2.466	1.589	1.491	98	877	785	92	9.575	5.553	3.673	97	252
(18 years) 1991-2008	39.481	8.616	6.351	3.602	2.749	2.265	2.142	123	30.865	16.193	14.271	254	147
Annual average	2.193	479	353	200	153	124	119	7	1.715	900	793	14	8
Total 1945-2008 64 years	378.335	139.901							238.434				
On average	5.911	2.186							3.725				

Uneven afforestation dynamics is mainly the result of available forestry financial funds intended for the infrastructural investment. In the period by 1960's, there was a Fund for Improvement of Forestry (FIF), which financed afforestation. That fund was relatively modest, mainly created from the accumulation of forest economy, which was considered a low accumulation economic sector. In the 1960's, beside FIF, a General Investment Fund was established for afforestation crediting, mainly plantation setting up and intensive fast growing of Euroamerican poplar clones and, to a smaller extent, fast growing conifers, resulting in intensified activities on establishing of plantations and intensive cultures of fast growing poplar trees.

Golden age of forestry, viewed from the aspect of non-refundable infrastructural investments, began by establishing the republic and regional self-management interest communities for forestry, in the framework of which financial non-budget funds, from the contributions of all direct and indirect forest beneficiaries, were accumulated. Building of forest communications, melioration of degraded forests, care of young woods, and other activities were financed from these funds, while the largest financial funds were used for afforestation of eroded barren hilly-mountain areas, such as Pester plateau, barren land of Ibar gorge, mountain massif of Vlasina region and other barren land of hilly-mountain part of Central Serbia.

Because of demographic changes in rural areas, field of forestry faced the problem of lack of work force for the realization of ambitious afforestation plans. The Institute for Forestry in Belgrade mastered the technology of production of seedlings with protected root peat substrate in suitable containers and by pilot-experiments confirmed the opportunity for successful afforestation even in vegetation period during summer, and self-management interest communities assigned the task of conceiving numerous afforestation projects to the Institute.

Team work of different profile researches was applied on analysis and mapping of ecological conditions of environment and categorisation of soil relevant for the selection of tree type, application of optimal afforestation methods and technology taking into account engagement of unskilled labour – shool, student, working class youth in brigade workin system – self-management interest communities for forestry. Considering that afforestation took place in summer period, the method and the technology of planting seedlings with protected root by 'cells' (M.Drazic), whose basic characteristic was that the cell in space should be placed in 'chess'position in order to keep the surface atmospheric water in the 'cell' profile, which ensures supply of moisture in dry periods, were analysed in detail and developed into projects. Drying of the existing moisture from the soil is prevented by digging up the cells in such a way as not to throw out smaller parts of earth from the cell profile, but only the larger skeleton.

In 1978., in cooperation of Youth Nature Conservation Club, The Republic Self-management Interest Community for Forestry and The Institute for Forestry Belgrade, the first youth work action was organized for the purpose of afforestation in vegetative period of the Pester plateau barren land. In the following years 1979.-1980., voluntary youth work actions were organized for the purpose of afforestation of eroded skeletal barren land in Ibar gorge, the mountain massif around Vlasina lake, barren land in south Serbia and other places. These actions took place from 1978. to 1988.

Youth brigades were formed from school, student and working class youth from all republics of former Yugoslavia. They worked in one month shifts from June to September. Brigade members had accommodation, food and available sport-cultural facilities for free time activities. Many friendships among youths from different parts of Yugoslavia, some of which have lasted until present, were created there.

During 1979. to 1986., thanks to the youth brigades work on the most difficult terrain, it was afforested 18,000 to 20,000 ha of forest annually and, hence, that period in rightly called 'the golden age of Serbian forestry.'

The structure of afforested areas according to the different tree type share from1961 to 2008

Since The Statistical Office did not register afforestation according to different tree type share from 1945.-1960., it is not possible to present afforestation structure according to different tree type share for the whole 64 year period, so the analysis of the stated structure refers to the period between 1961-2008.

Out of the total afforested barren land area, the share of deciduous trees and conifers in total and according to the type groups is the following:

- Total afforested area for the period 1961-2008. is 314.499 ha
- Out of which:
- Conifer afforestation 212.806 ha (67,7%)
- Deciduous trees afforestation 101.693 ha (32,3%)

Table 2. *The share of different tree types in total afforestation*

Tree type	1961-1975		1976-1990		1991-2008		On average 1961-2008	
	ha	%	ha	%	ha	%	ha	%
Black locust	35.704	37,8	22.356	12,4	3.602	9,1	61.662	19,6
Other hard deciduous trees	1972	2,0	1.472	0,8	2.749	7,0	6.193	2,0
Selected poplar trees	16.760	17,8	11.780	6,5	2.142	5,4	30.682	9,7
Other soft deciduous trees	1.657	1,8	1.379	0,8	123	0,3	3.159	1,0
Black and white pine tree	29.867	31,6	83.290	46,1	16.193	41,0	129.350	41,2
Spruce and fir tree	6.741	7,1	55.098	30,5	14.271	36,2	76.110	24,2
Douglas-fir	471	0,5	1.455	0,8	254	0,6	2.180	0,7
Other conifers	1.242	1,4	3.774	2,1	147	0,4	5.163	1,6
Afforested in total in the period	**94.414**	**100**	**180.604**	**100**	**39.481**	**100**	**314.499**	**100**

Black locusts account for 37.8% of deciduous tree type afforestation in the period from 1961. to1975. , after which its share dropped to only 9.1% in the period from 1991. to 2008., which is a favourable trend, since black locust is an aggressive tree type with extremely strong roots, which is why it was frequently used for anti- erosive afforestation of eroded skeletal barren land on slopes.

3. LONG TERM AFFORESTATION PROJECTION BEFORE REACHING THE OPTIMUM LEVEL OF WOODINESS

According to the Serbia Spatial Plan (1996) the central Serbia optimum afforestation plan is presented in the following survey:

Table 3. *The strategic plan of central Serbia optimum woodiness*

Area	Total area ha	Condition (1993)		Ought to be afforested ha	Targeted optimum state	
		Forest area ha	Woodiness %		Woodiness %	Total forest area ha
Central Serbia	5.596.800	1.837.417	32.8	949.790	49.8	2.787.207

Source: The Collection of works from the conference, held under the slogan“ Help Serbia breathe”, Novi Sad 2006. - ”Afforestation with the aim of spatial plan realisation and agriculture, forestry and waterpower engineering development of The Republic of Serbia” (M.M.)

4. THE CRITERIA FOR SELECTION AND PROPOSAL OF DEFORESTED AREA INTENDED FOR AFFORESTATION

The selection of areas intended for afforestation, which are for the most part registred in the cadastre as agricultural areas of 6., 7. and 8. class, does not aim at reducing the total amount of agricultural production.

Eligible for afforestation are the areas of degraded land which cannot be transformed, by implementation of agro meliorative measures, into highly productive production potential, which would economically justify their retaining the status of agricultural land.

The selection of deforested areas intended for afforestation is based on three basic criteria, although there are other reasons why they ought to be afforested.

Those criteria are the following:

1. The terrain inclination and altitude zone criterion
2. The criterion of exposure to destructive effects of erosive processes and current state of degradation
3. The criterion of current state of production quality according to cadastre and exposure to further degradation by erosive processes

It is understandable that there is a number of parameters which can influence the way of using land potential, but we considered three above mentioned criteria decisive and that they, in a certain manner, possess a causal / resultive connection.

The terrain inclination criterion according to the altitude zones

Table 4. *The survey of Central Serbia areas according to the altitude zones, and within the zones, according to the terrain inclination* (The total area of Central Serbia: 55.968 km^2)

Inclination in degrees	**Altitude zones**														
	0-200 m			**201-500 m**			**501-1000 m**			**above 1000 m**			**total**		
	km^2	**% accord. the inc.**	**% accord. the a.z.**	**km^2**	**% accord. the inc.**	**% accord. the a.z.**	**km^2**	**% accord. the inc.**	**% accord. the a.z.**	**km^2**	**% accord. the inc.**	**% accord. the a.z.**	**km^2**	**% accord. the inc.**	**% accord. the a.z.**
0-10	7.272	61,4	61,8	3.840	19.2	32,6	611	3,6	5,2	48	0,7	0,4	11.771	21,0	100
10-15	2.138	18,0	17,5	5.510	27,5	45,0	2.712	16,0	22,2	1.877	26,4	15,3	12.237	21,9	100
Total 0-15	9.410	79,4	39,2	9.350	46,7	38,9	3.323	19,6	13,8	1.924	27,1	8,1	24.008	42.0	100
15-20	1.788	15,1	20,8	3.140	15,6	36,5	3.007	17,8	34,9	675	9,5	7,8	8.610	15,4	100
20-25	110	0,9	1,6	2.615	13,0	37,1	3.625	21,4	51,4	702	9,9	9,9	7.052	12,6	100
25-30	228	1,9	2,9	2.951	14,7	37,8	2.831	16,7	36,2	1.808	25,5	23,1	7.818	14,0	100
30-35	272	2,3	3,9	1.652	8,2	23,7	3.282	19,4	47,1	1.765	24,9	25,3	6.971	12,4	100
above 35	46	0,4	3,1	374	1,8	24,8	865	5,1	57,3	224	3,1	14,8	1.509	2,7	100
Total 15-40 above 35	2.444	20,6	7,6	10.732	53,3	33,6	13.610	80,4	42,6	5.174	72,9	16,2	31.960	57,1	100
Total	**11.854**	**100**	**21,2**	**20.082**	**100**	**35,9**	**16.933**	**100**	**30,2**	**7.099**	**100**	**12,7**	**55.968**	**100**	**100**

Assuming that all available areas of altitude zone inclination above 15 degrees in altitude zones are predetermined for forest eco-systems and areas of inclination up to 15 degrees for agriclulture, with the condition that the spatial layout of agricultural cultures adapt to ecological conditions of the environment, the optimum level of woodiness should be 50%, exempting the area of urban settlements, roads, aquatic ecosystems and sterile inert rocky grounds and slopes from the total area of Central Serbia. The approximate level of woodiness is determined by long term afforestation projection through adopted Serbia Spatial Plan, which defines optimum level of woodiness at approximately 49.4%.

The criterion of land exposure to devastating erosive processes

The erosive processes in Central Serbia have been very acute, in particular in the second half of the 19th century and throughout 20th century, which coincided with the drastic acts of forest destruction in large areas. Beside unfavourable natural factors, the share of frail rocks in erosive activities resulted in removing the most fertile soil from the deforested areas, thus the research established that the 90.18% of the total area of Central Serbia is affected by different categories of erosion.

Table 5. *The size of erosion in Central Serbia*

Area	Total area km^2	Affected by erosion	
		km^2	%
Central Serbia	55.968,00	50.477,91	90,18

Table 6. *The production and spreading of alluvium*

Area	Total area	Eroded area km^2	Production of alluvium		Amount of alluvium	
			m^3 in total annually	m^3 annually per 1 km^2	in total m^3 annually	per l km^2 m^3 annually
Central Serbia	55.968,00	50.477,91 90,2%	33.413.226,59	661,94	8.288.517,83	164,20

Alluviation causes great harm since it strews hydro electric water plants which drastically reduces their capacities and it has damaging effects on production of electricity, waterpower engineering, water supply- depending on the purpose of hydro electric water plant, and ultimately the entire economy, and irreparable damage on areas affected by erosion by removing the productive soil layer, which, unless the process is stopped, can be transformed into inert 'rocky deserts.'

The fact that the issue of preventing the devastating effects of erosion is a pressing task of community and state, was confirmed by the words of our renown and internationally recognized academic, Sinisa Stankovic, who, at the Academic Council way back in 1955., said: *'The problem of soil erosion is not only an agricultural problem, nor only problem of forestry, that is, the problem of social sector of our material life only, it is the problem of the whole our homeland. And, without doubt, the fight for consolidation of our native soil – even in a figurative form – is, in fact, the fight for preservation of our village, against the threat from the main enemy, from erosion, which is destroying it with increasing speed.'*

Although such and similar warnings have been repeated many times until now, it has not been put enough effort in prevention of erosion process and improvement of condition, which can be successfully achieved only by afforestation of erosion affected soil in hilly – mountain region.

S.Jovanović (1969) in his study 'Values of generally benefitial forest function related to economic benefit in our country' states that, according to Djordjevic, the Ovcar Banja power plant was strewn over 50% of its capacity, while in the Jablanica power plant 95% of mud carried by water current remains, and the Zvornik power plant is annually strewn with 1.28 million m^3 of alleviation, which permanently reduces the production of electric energy.

The criterion of share of agricultural land of 6-8 capability class according to the Cadastre

The destructive erosive processes are the basic cause of agricultural land degradation, which is manifested by removal of the most fertile part of the soil, frequently as far as to the skeletal base. The results are, inter alia, the decrease of production potentials of erosion affected areas, primarily in hilly-mountain regions.

According to the data from the Republic Cadastre, degraded agricultural areas classified into 6 – 8 capability class, which cannot be transformed into highly productive areas by any means of ameliorative, agro technical or agrochemical measures, have the following areas, presented in the following table:

Table 7. *The survey of agricultural areas of 6-8 class in Central Serbia*

Type of culture	**Capability class according to the Cadastre**											
	VI			**VII**			**VIII**			**Total**		
	ha	**%**	**%**	**ha**	**%**	**%**	**ha**	**%**	**%**	**ha**	**%**	**%**
Farms	318.011	54.9	49.0	228.520	51.2	35.2	101.885	46.1	15.8	648.416	52.0	100
Meadows	126.019	21.7	46.2	116.992	26.2	42.8	30.023	13.6	11.0	273.034	21.9	100
Pastures	135.641	23.4	41.7	100.402	22.6	30.9	89.011	40.3	27.4	325.054	26.1	100
Total	**579.671**	**100**	**46.5**	**445.914**	**100**	**35.8**	**220.919**	**100**	**17.7**	**1.246.504**	**100**	**100**

Source: 1972 Cadastre

It is easy to notice from the survey in the above table, that the largest areas of 6., 7., and 8. capability class represent farms, which is understandable since land cultivation facilitates the destructive effect of erosion.

Apart from 1,246, 504 hectares of agricultural areas, not a small area of land which is now classified as a capability class 5, and is under inclination higher than 10 degrees, particularly farm land, will be degraded into lower capability classes unless the further development of erosion is prevented by ameliorative biological measures and, therefore, such areas also should be planned for afforestation.

Taking into account that, since 1972., it has been afforested 260,000 ha of barren land (area not covered by wood) in Central Serbia, after the realisation of the long term afforestation projection, degraded agricultural areas of 6.-8. capability class according to the Cadastre, will be largely substituted by forest ecosystems.

5. THE DYNAMICS OF ERODED BARREN LAND AFFORESTATION WITH THE AIM OF REALISATION OF A LONG TERM STRATEGY 'SERBIA WITH NO BARREN LAND BY THE END OF 21st CENTURY'

In order to realise the optimum 49% woodiness by the end of this century, it is necessary to conduct barren land afforestation in the area of 949,790 ha. That impressive task is possible to accomplish only on condition that the area of 10,553ha on average is afforested per year.

According to the analyses of afforestation dynamics in the last period, the average annual extent of afforestation higher than 12,000 ha has been accomplished only in the period from 1976. to 1990., when the intended aim funds were provided from non- budget sources, by contribution of all direct and indirect beneficiaries of forest functions, when the large areas of state owned barren land were afforested by means of organisation of mass youth - nature conservation club members voluntary actions and by engagement of Institute for Forestry –Belgrade, republic and regional self-management interest communities and forestry experts.

In present altered social – politic and economic circumstances, it is necessary to find a modality how to permanently ensure non budget financial funds for the drawing up of the barren land for afforestation cadastre, with the approval of the owners, since presently remaining barren lands are largely owned by private persons, which is essential for realisation of valid practical projects and laying out of new organisation of afforestation project realisation.

6. POSITIVE ECONOMIC – ECOLOGICAL EFFECTS OF BARREN LAND AFFORESTATION

Although it is not possible to separate strictly economic and ecological functions of newly created ecosystems, since they are simultaneously directly manifested, economic-production functions are measurable, while generally – beneficial ecological functions cannot be easily qualitatively and valuably defined. However, we will state approximate economic importance of production of biomass, which can be represented qualitatively and valuably in an exact manner, as well as its most important ecological functions which have exceptional importance for environment, although these functions are difficult to measure financially.

The economic importance of establishing anthropogenic forest ecosystems of afforested eroded barren land in the area of 949,790 ha represents the anticipated annual average biomass production of 4.5 tonnes per hectar, that is, total for the above mentioned area 4,274,055 tonnes per year. Approximately, 30% of the total biomass produced can be used by mechanical and chemical procession industry, about 30% can be used for heating in individual homes, primarily in village households and about 30% is can be used use for electro energy purposes in thermo electrical power plants and for thermal energy in heating plants. In that manner, use of fossil fuels would be reduced, which is of tremendous importance for preservation of healthier environment, since biomass, being a renewable energy resource, among other ecological advantages, emits many times less carbon dioxide and other gases, causes of so called ‘greenhouse’ effect and of rapid warming of our planet with fatal consequences for living world.

The ecological importance of biomass production is manifested by the following facts: Taking into account that 1 tonne of produced biomass binds 1.82 tonnes CO_2 and releases 1.39 tonnes of oxygen, that means that newly created anthropogenic forests created by afforestation bind annually 7,778,780 tonnes of CO_2 and release 5,641,753 tonnes of oxygen and, in that manner, contribute to maintaining the balance of carbon and oxygen in the atmosphere. In case that balance of CO_2 and O_2 in the atmosphere is maintained, there is no occurrence of the ‘greenhouse’ phenomenon, and consequently no rapid warming of our planet.

Ecological functions of newly created forests as ecosystems

Regulatory role of forests in relation to water regime

Forests affect to a higher degree the intensity and distribution structure of precipitation in the areas where they are located.

We stated that, in present condition of high degree deforestation, apart from harmful effect of atmospheric water on erosive processes and permanent loss of the most fertile part of land, the damage caused by torrents and floods, deforestation creates direct damage caused by mudding and strewing of hydroelectric plants and, additionally, by overflow of unused waters over dams.

That means that in present condition waterpower engineering suffers harmful effects as a result of alluvium, consisting of hard particles, strewing of hydro accumulations and unused water overflowing dams in rainy periods, and in dry periods harmful effects are due to the water deficit. If the optimum afforestation level in river areas and hydro-accumulations were achieved, an erosion process would be stopped, hydro- accumulation strewing would be prevented, an even inflow of quality water into accumulations would be provided, together with a number of other positive effects.

There would be less uneconomical loss of overflowing water and less water deficit in the dry period because, instead of floods, the water which forests accumulated in soil throughout the year would use slower underground flows to join rivers and accumulations, not containing hard ingredients. That would prolong the life of hydro-accumulation beneficial functions of all purposes – energy, supply of towns and industry, agricultural areas amelioration, balanced production of electric energy throughout a year and have a number of other positive effects.

The research of dynamics of forest precipitation water movement shows that the part of rainfall remains on tree crowns, evaporating without reaching the soil (interception). That watering capacity most frequently amounts to 1-3mm horizontal projection of a tree crown (B. Kolic, 1978). The capacity for watering depends on a wood type, structure, age and the intensity of rain. Depending on tree crown thickness and the type of tree, the tree crowns themselves let through 60-90% of rain, but 10-20% of water more than compared to that in clear areas run down into the soil from the tree crown edges. The water arrived on the ground is thoroughly absorbed by dregs, after which it sinks, led by gravity, to the watertight layer and by side flows joins water current. Forest also receives surface waters which flow from the deforested areas above and, in that manner, protects from erosion agricultural areas below forest and also moisturises them by slow underground side inflow in the dry period, which contributes to the increase of crop. The loss of water by evaporation from tree crowns is compensated by its influence on precipitation increase in that area. The results of the research conducted by Schubert, in 1937. (according to Kolic), show that, in case area afforestation is increased by 1% the amount of rainfall is increased by 0.78mm, and the afforestation larger than 20-25% increases the rainfall by 40mm, and that trend continues until level of afforestation reaches 50%. With further afforestation increase, the amount of rainfall remains constant. According to the above mentioned facts, forests increase the annual amount of rainfall from 2 -10%, depending on the size of forest area, type and thickness of forest, as well as orographic conditions.

The influence of forest on air quality

Forest ecosystems, apart from absorbing carbon dioxide and oxygen release, neutralising and absorbing other long-term gas pollutant from the atmosphere, air sterilization from pathogenic microorganisms by phytoncide products, clean low layers of air by filtration of particles of numerous hard pollutant. Having in mind that forests in their tree crowns retain 30-80 tonnes of hard particles per year per 1 ha, that means that newly created forests with the area of 949,790 ha, annually retain in their tree crowns from 28,493,700 - to 75,983,200 tonnes of hard pollutant small particles from the low layers of air.

7. CONCLUSION

Scientists have issued an alarming warning that the biosphere is endangered, and at the same time, the environment.

International organisations, among which the United Nations, have made the attempts to reduce the use of natural resources, either renewable or non-renewable, to the level of 'sustainable development' (Agenda 21 – Rio), which means that the resources can be used only to the level which does not endanger the existence of posterity.

Having in mind that that forest ecosystems represent the most important ecological pillars of bio geo sphere, it is clear that its effect on biosphere significantly exceeds the effect level of other ecosystems, which confirms the invaluable importance of forest ecosystems existence.

Circulation of water, oxygen and carbon has the vital importance for the biosphere, and that very fact reflects the role of forest ecosystems as a factor of maintaining a favourable state of nature, taking into the account the forest ability to release oxygen and, at the same time, absorb carbon, and in that manner contributes to maintaining the balance of oxygen and CO^2 in atmospheric air. The amounts of released oxygen and absorbed carbon are exactly proportional to productivity of forest ecosystems phytomass and their longevity.

Only by planting new forests on eroded barren land can further erosion processes be stopped or alleviated the devastating effects of torrents and floods. That will contribute to decreasing the range of minimum and maximum flow in water currents – rivers and small rivers and balanced inflow of quality water to hydro-accumulations, which will extend their lifetime with stability of functions.

Considering the fact that the forest functions positively affect hydrology regime in the area of Central Serbia, it seems absurd that organisations in charge of managing forests have to pay water charges to waterpower engineering.

On the contrary, because of ecologic multi functions of forests, not only in preventing further destructive effects of erosion, torrents and floods and improving hydrology regime, but in the sphere of protection and preservation of quality environment, it is necessary that all social community and all direct and indirect beneficiaries of forests, including waterpower engineering, contribute certain funds which would enable long term afforestation projection of 949,790 ha of eroded barren land is conducted during first century of third millennium.

In order to start organisational realisation of this ambitious long term afforestation plan, it is necessary to meet the following prerequisites:

-To start work, without delay, on creation of cadastre of eroded barren land for afforestation, to except eroded barren land from agricultural area category and register them as a new cadastre category ‘barren land for afforestation’ with relevant data which define characteristics of these areas and their sistematisation.

- Define them spatially, map and register in a manner in which other existing cadastre items are classified: municipalities, cadastre municipalities, cadastre lot number and ownership. Needless to say, a law should be adopted in order to clearly define a manner of on site research, the structure of parametres which identify the characteristics of degraded barren land areas.

- The law should establish non budget sources and extent financial funds for realisation of this programme. It is our opinion that, provided that a quality programme is drawn up, it is realistic to expect that funds from international organisations can be obtained, since the international community is deeply interested in this issue and has at disposal financial means for ‘ecological healing’ of our planet.

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FOREST GENETICS, NURSERY PRODUCTION, PLANT BREEDING AND CLIMATE CHANGES

PLENARY LECTURES

SPECIFIC-PURPOSE PRODUCTION AND THE DEVELOPMENT OF TECHNOLOGICAL PROCESS OF TREE AND SHRUB PLANTING STOCK PRODUCTION

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Abstract: *The present level of forest seedling production technology should be enhanced in the sense of improved coordination of all factors necessary for the production of good-quality planting stock. The success of afforestation in the field, both from the aspect of survival dinaimičnog growth i development sadnica,and from the aspect of using the site potential, will be increasingly uncertain, because the climate and degradation changes will make the sites intended for afforestation in Serbia even more difficult and demanding from the aspect of site preparations. Maximal reduction in the unfavourable effects of these limiting factors, can be achieved only by specific-purpose production of the conditioned planting stock. The term »specific-purpose planting stock«, refers to seedling production, propagated primarily from seeds, which will be characterised by the properties favourable for the predetermined silvi-technical works in forestry. Specific-purpose production of planting stock also includes the developed seed science research, because, in addition to special production technology and the seedling conditioning during the nursery cultivation, the seed origin (provenance) is of prime importance, as well as the intraspecific taxonomy. This paper presents the biotechnical and organisation characteristics of specific-purpose production of forest seedlings intended for the afforestation of arid lands.*

Key words: specific-purpose production, forest seedlings, afforestation

1. INTRODUCTION

The success of seedlings in the field, both from the aspect of survival and from the aspect of using the site potential, will be increasingly uncertain, because the climate and degradation changes will make the sites intended for afforestation in Serbia even more difficult and demanding. These new challenges can be satisfied only by specific-purpose production of the conditioned planting stock. The term »specific-purpose planting stock«, refers to seedling production, propagated primarily from seeds, which will be characterised by the properties favourable for the predetermined silvi-technical works in forestry, Đorović M, et al. 2003.

In the conditions of planned – more or less programmed production, nurseries produce the stock for these objectives and therefore receive guaranteed revenues from regular contracted sales. They can also increase the trade and profit by selling the remaining supplies in the open market.

Specific-purpose production of planting stock also includes the developed seed science research, because, in addition to special production technology and seedling conditioning during the cultivation in the nursery, the seed origin (provenance) is also of prime importance, as well as the

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intraspecific taxonomy, Tucović et al. 1990,1994, Isajev et al. 2008. This is especially important in specific-purpose seedling production for the afforestation in extreme conditions, Isajev et al. 2000.

General environmental conditions, such as air temperature, absence or unfavourable distribution of rainfall, length of insolation, soil depth and skeletalness, decide the technological procedures in stock production for the afforestation of extremely unfavourable terrains, Herpka et al. 1987, Stilinović, 1991. In planting stock production and trade, advantage is given to seedlings produced from the seed provenances which are, based on site characteristics, similar to those which are planned for afforestation or establishment of specific-purpose plantations. When the management goal is to establish plantations for the production of timber for mechanical processing of wood, the seeds to be used in nurseries should originate from seed forests or provenances of the first site class. This concept must be harmonised with general bio-ecological characteristics of the species and must follow the realisation of all production segments - from seed to outplanting. The above concepts confirm the obligation of provenance tests for the species, intraspecific taxa, but also for the sites.

When the objective of planting stock production is defined, the activities in the nursery are facilitated, from those referring to seed selection and production technology, to outplanting method and time, tending, etc. This speeds up and makes easier the transition from uniform production of large quantities of planting stock of uniform quality to technologically more complex (sowing-planting, classical beds-duneman beds, container seedlings, etc.) specific-purpose stock production for concrete sites and known buyer. The more complex production process (in the same nursery, on the same area, seedlings of the same species often require different production technologies) is economically justified by different, usually higher prices. Simultaneously, this also implies the modified meaning of the term “quality seedling”, because obviously different objectives of planting stock also imply different parameters for the evaluation of its quality.

2. ECO-TECHNOLOGICAL BASES OF PLANTING STOCK QUALITY FOR THE AFFORESTATION OF DEGRADED SITES

The main criteria for the definition of good-quality planting stock, in addition to general standard properties, should be harmonised with its objective, especially taking into account that there are vital biotechnological differences in the afforestation of abandoned agricultural lands, degraded stands, degraded sites, bare lands, erosion risk areas, water-logged and marshy areas, etc. In modern nurseries, production of quality seedlings for the above objectives includes a dynamic and balanced proportion between:

- seed production and trade,
- seedling production and trade, and
- planned scope of silvicultural operations which require the appropriate specific-purpose stock.

In Serbia, forest nurseries production is usually oriented to: (a) production of seedlings for the afforestation and (or) reclamation programme, (b) for the open, domestic market, i.e. for the unknown buyer, and (c) for export.

The afforestation success on the sites under erosion hazard and (or) the sites with unfavourable general climate characteristics (low and unfavourable rainfall distribution), depends on the type of the applied planting stock and site conditions, Isajev et al. 1998.

The existing afforestation programmes for different site types are characterised by insufficient database which integrate the desirable seedling quality, their performances after planting and site data. As seedling quality can change essentially from the time of delivery to the time of outplanting, the analysis of seedling development should be extended after outplanting. Monitoring of seedling development and growth outside nursery and laboratory and making it an integral part of each afforestation programme is a complex and indispensable task. Integral analysis of seedling quality includes numerous components, such as: seedling quality in the nursery and on the planting site; assessment of plantation performances and their relation to site conditions; interpretation of the obtained results and feedback for nursery production. This method enhances the criteria for the best correlation between the seedling genetic-physiological condition and their morphological traits, which is simultaneously the base for the definition of critical values of seedling quality parameters. The value of critical thresholds of seedling quality parameters should be based on the results of directed and coordinated researches in laboratories, nurseries and in field tests. The significance and value of the test results are represented by seedling morphological and functional traits after planting on selected locations of known microsite conditions. The study of inter-relationship between seedling quality, their morphological traits and site conditions is one of the central issues of seed science, nursery production and afforestation of ecologically different sites.

According to South and Mexal 1984, the parameters for seedling quality assessment are changeable and depend on the objective. Seedling quality is a complex concept which includes their: *genetic, morphological* – (shape and structure) and *physiological* ch*aracteristics* – (growth and development dynamics, adaption) – which are inter-conditioned and interlinked. The "genetic-physiological condition" should be synchronised with the morphological characteristics which enable the survival in unfavourable site conditions after outplanting, such as: drought, pests, competing vegetation, etc. However, it should be taken into account that the seedlings should satisfy the specific morpho-physiological requirements for each target objective. Evidently, the morphological and physiological characteristics of seedlings for droughty sites are not necessarily desirable characteristics for wetter sites. Table 1 presents the effect of individual morphological characteristics on seedling growth and development after outplanting.

The parameters affecting the plant rehabilitation after outplanting shock and the adaptation to eroded areas are numerous. They can be classified into two groups – biological and technological factors.

One group includes genetic and physiological parameters which dominantly affect all the phases of plant production – from seed to seedling. The other group includes the technological procedures which, by successive implementation, direct the seed and seedling genetic potential to realise the target condition and performance.

Table 1. *Seedling characteristics and their potential advantages for survival and growth after outplanting (after Johnson and Cline,1991).*

Characteristic	Advantage
Well defined terminal bud	Dormant stock: greater shoot growth
Large root collar diameter	heat greater survival and volume growth; resistant to animal and heat damage
Height	Better competition with weeds and brush
Low height diameter ratio	Better resistance to wind desiccation; greater survival and growth on droughty sites
Numerous secondary needles	Greater regulation of water loss; better light interception and utilisation in photosynthesis
Fibrous root system	Greater exploitation of soil more root initiation points
High root-growth potential	More rapid proliferation of roots, greater survival
Cold hardiness	Better resistance to cold damage and other environmental stresses

Based on the so far achieved results in the production of planting stock for eroded lands, the following factors are distinguished as the most important for plant survival percentage, adaptation, and further development after outplanting, of which:

1) potential root regeneration capacity;

2) water in seedlings;
3) mineral nutrients in seedlings;
4) carbohydrates in seedlings;
5) plant growth regulators;
6) seedling frost hardiness;
7) temperature status, and
8) resistance to pathogens.

1) One of the most commonly applied and probably the most important tests for the assessment of seedling quality is the test of potential root regeneration capacity, Sutton 1983. Planting stock characteristics, such as species, provenance, seed source, selected mother tree and seedling type are key factors affecting the capacity of root regeneration. Other factors include physiological condition – seedling dormancy at the time of lifting and carbohydrate supply available for root growth. Shoot and leaf vigour is also an important factor affecting the intensity of root regeneration, since the leaves and needles synthesize the essential co-factors necessary for root growth. As the conditions in the eroded areas are unfavourable, it cannot be expected that the root regeneration capacity will be fully expressed after outplanting, but it is proved, Sutton 1983, that it affects field root growth after outplanting. Root regeneration is in strong correlation with the seedling performance after outplanting, i.e. it has a strong impact on survival and further growth. Root rejuvenation is a good indicator of seedling quality, because it reflects the outplant capacity to restore the root contact with the soil after planting, which facilitates the uptake of water and nutrients, i.e. seedling survival.

2) water relations in seedlings affect plant dormancy, frost hardiness, mineral nutrition, enzymatic activity, i.e. a series of parameters which directly or indirectly determine seedling quality, i.e. field performance. Water stress in plants is not readily identifiable, although classes of water stress can be applied in the sense of water potential, Table 2.

Table 2. *Relation of water stress and water potential in plants, after Kramer,1983*

Water stress in plants	Water potential (bar)
Mild	1- 3
Moderate	12 - 15
Severe	above 15

The system of nursery production must enable the maintenance of seedling water potential at a desired level. In this sense, seedlings should not be lifted if their water potential is below 10 bar. During sorting and packing operations, seedling water potential should not be below 5 bar. The state of water potential points to the seedling physiological condition at the given moment, possible application of some technological procedures, and the seedling readiness for lifting, storage, planting, and other operations.

3) Seedling quality defined by seedling performance after planting, is logically related to the content of mineral substances. Nitrogen and phosphorus are building materials for growth restoration, and further growth and development of outplants depends on the reserve of nutrients until plants start the synthesis of new ones. Although the content of mineral nutrients defines the seedling vitality, the problem is that it is difficult to quantify its effect on seedling survival and growth. The relation between seedling survival and growth on the one hand and the content of mineral matter on the other hand, is not always clear due to a series of factors such as storage, handling, and the differences in planting sites, which can affect the mineral concentration in plants. The state of mineral matter in seedlings is also influenced by plant density in nursery beds, watering, root pruning, fertilisation, and many nursery procedures during the seedling production processes.

Fertilisation is the simplest method of improving the mineral content in seedlings, but it should be observed that the absorption and utilisation of mineral substances is not independent and that the change in the concentration of one element is followed by the change in the concentration of other elements. Fertiliser application is indirectly related to the state of mineral substances in the seedlings, because fertiliser application does not guarantee that the seedling will absorb the applied mineral matter. Bell, 1968 showed that the positive effect of fertilisation on seedling survival was actually reflected two years after treatment.

Mineral content varies depending on tree species, ecotype, individuals, plant tissue, season, nursery or nursery part where the plants are produced. So it can be concluded that the mineral content is in much stronger correlation with seedling growth than with survival, because abundant fertilisation does not guarantee the seedling vigour, and can even have adverse effects, such as lower resistance to drought, early buds in the spring, and frost damage, unbalanced shoot and root development and mass. In seedling production, the proportion of individual elements should be controlled by permanent analyses, so as to identify the fertilisation needs, fertiliser types and rates, aiming at a seedling with balanced relations of individual mineral elements which will make it suitable for the afforestation of eroded sites.

4) From the moment of lifting till the moment when photosynthesis becomes sufficient for the continuation of normal growth, seedling depends directly on internal supplies of carbohydrates. Seedlings without carbohydrate reserves are hopeless which points out the significance of carbohydrates for the maintenance of the outplant vital functions seedling under stressful field conditions. The effects of carbohydrate supplies on growth and survival are evident when the seedlings are obliged to use up their reserves, Benzian and Smith (1973). Seedling mortality is most often related to water stress directly, but the primary effect of water stress is reflected in the decrease in photosynthesis. In such conditions, seedling is obliged to use up carbohydrate reserves as long as the stress effect lasts. Seedlings with sufficient quantities of starch can endure a longer period of drought. The cause of mortality can easily be determined by chemical analysis. If there are no traces of starch and sucrose, plant mortality was the consequence of "fasting", and not as a direct consequence of drought.

Seedlings with the highest contents of starch and sucrose should be planted on the poorest sites, where seedlings have the greatest difficulties to attain and keep the positive carbon balance. Based on carbon translocation, it is possible to estimate the quantity of carbohydrates necessary for the target level of seedling survival and growth. The indicators of carbon status are budset time, leaf area, seedling density in the nursery bed, watering scheme. Based on the above data in seedling production, we can predict whether the improvement of carbohydrates increases the seedling survival and growth and identify the critical moments in the process of seedling production which cause the changes in the status of carbohydrates.

5) Plant growth regulators or hormones are chemical substances which are produced by plants in small quantities, and which control growth and development. Although involved in many physiological processes, hormone function is more to control specific biochemical reactions than to act as the main growth promoters or inhibitors. Of all growth regulators, probably abscisic acid (ABA) can be the direst indicator of seedling vigour. Also, it is the major hormone that triggers the opening and closing of the stomata and it can be used in the identification of certain types of seedling damage.

6) Extreme temperatures both in summer and in winter months are, as a rule, characteristic of eroded areas, so the planting stock should be both highly adaptable to drought and frost hardy. Frost hardiness is defined as the ratio of minimal temperatures at which 50% of seedlings are killed. It is designated as lethal temperature 50 (LT_{50}). Frost hardiness enables plant survival over winter months in temperate and cold climates. The dormancy phase or true dormancy starts in October or November and continues through December. It is manifested as the seedling inability to resume growth under higher temperatures unless a previous adequate chilling has not occurred. In winter

months, seedlings pass through a period of low temperatures and enter the phase of dormancy, which usually lasts through early spring. Over this period, the low temperatures inhibit the shoot elongation. Cold hardiness develops when shoot growth stops and it is related to changes in intracellular structure and membrane permeability.

The nature of frost hardiness must be investigated because of its effect on the selection of seedling production and manipulation technologies. Cold storage of seedlings is sometimes advised before outplanting in the field, or container seedlings are left in the open over the winter period, if they were previously grown in the conditions of abundant fertilisation. Seedlings should not be lifted in autumn for cold storage before their shoot and root are sufficiently resistant. This is important for container seedlings which are left in the open over the winter period and whose roots, due to desiccation, are above ground and exposed to cold air currents. Vegetative growth should be stopped by the correct regimes of fertilisation, watering or other procedures before unfavourable thermal conditions prevail in seedbeds or transplanting-beds, so that the seedlings can survive winter conditions. Frost hardiness can be assessed using different biophysical test methods, such as browning, electrolyte leakage, coefficient of electrical resistance, etc.

7) Temperature of buds, root tips and seeds can be measured as it depends on the scope of their metabolic processes and activities. Stomata conductivity and metabolic activity are the diagnostic factors which affect seedling temperature and are related to seedling physiological condition. The research of several coniferous species shows that seedling temperature varies significantly depending on the time necessary for the transition from dormant phase to active phase. Dormancy is an important indicator of seedling condition associated with the planting performance. It is necessary to identify the beginning and intensity of dormancy to be able to control initial dormancy and to identify the correct time of lifting.

8) The intensification of plant production reduces the complexity of cultivated populations and increases the genetic uniformity of widely cultivated plants. The impoverishment of genetic structure of cultivated populations and the simplification of structure of many cultural ecosystems affects their functionality, stability and economy of their cultivation. The observed tendencies lead to ecological and genetic sensibility of cultivated coenoses as the genetic potential and adaptability of pathogenic species exceeds the genetic variability of cultivated plants. Some of the technological characteristics of cultivation, such as the lack of essential macroelements, high rates of nitrogenous fertilisers, planting density, etc. essentially lower the physiological vitality, i.e. plant resistance to abiotic and biotic impacts. The complexity of relations between cultivated plants and pathogens is evident, and Table 3 presents some of the major specificities.

Table 3. *Basic specificities of cultivated plant resistance to pathogens (modified after several authors)*

1. Types of resistance,
2. Systems and mechanisms of resistance,
3. System: »host, plant-pathogen - environment«
4. System: »host, plant – pathogen«
5. Host adaptation

In accordance with the ecological-genetic concept, epiphytotics and outbreaks are conditioned by new races of pathogens and pests, better adapted to cultivated plants and environmental conditions compared to the previously existing pathogens and pests. Practical importance is assigned to the study and directed regulation of adaptation processes of the members of »host-pathogen« through the good-quality planting stock. The genetic structure of the established coenoses and the enhancement of the cultivation method by can be regulated by the adequate selection of planting scheme, density, sizes, areas to be planted, additional fertilisation, etc.

3. DIRECTIONS OF ENHANCEMENT OF SPECIFIC-PURPOSE PLANTING STOCK PRODUCTION TECHNOLOGY

Directed production of seedlings for target site types should be based on the climate and edaphic factors which represent the major difficulties in afforestation, Popovski P. et al. 1990. After the identification of the above limiting factors it is necessary to analyse the price and the potential reclamation of site conditions, aiming at the most reliable selection of seedling type or class which will be best adapted to the given site. The identification of seedling characteristics for the afforestation of difficult sites is a long-term research process which includes: production of seedlings with desired morphological traits, types and schemes of planting in the field, as well as the stress factors at the sites of afforestation and plantation development. When the programmed seedling characteristics are identified, it is necessary to select the most economical production method. The divergence of seed sources should be researched and also the technological procedures for the production of programmed seedlings from the collected seeds.

The possible directions of the enhancement of production technology of specific-purpose planting stock conditioned for the unfavourable field conditions mostly resulting from global and local climate changes and erosion phenomena, are:

- Higher percentage of container planting stock production Isajev et al.1999, Šmit et al.1995.
- The increase in the area under greenhouses and the higher percentage of container technology in planting stock production, will reduce significantly the area for the production of the same number of seedlings compared to the classical method.
- Production in controlled conditions of soil, temperature, photoperiodism, substrate moisture and air humidity (in greenhouses and plastichouses) enables the production of planting stock with desirable characteristics, and even the shortening of the production cycle (according to foreign results, in some nurseries, two production cycles are realised during one vegetation period).
- The inoculation of some species of mycorrhize fungi improves the planting stock quality, by increasing the outplant survival percentage.
- Seedling fertilisation and protection is performed by improved methods of watering, by introducing the suitable systems in nurseries (drip irrigation, mist systems, etc.), as well as by previous chemical and physical water conditioning.
- Greater use of machines in nursery practice, different technological lines for seedling production, both containerised and in classical or Duneman beds.
- Introduction of information-coordination centres which fully coordinate the specific-purpose planting stock production.
- The establishment and development of seed and planting stock exchange will enhance the quality, trade, and legal protection of plant production in forestry.

In the analysis of site conditions, before the afforestation, we must identify the factors which can endanger the outplants in the field and slow down or even disable their development, not neglecting the generally known fact that the interaction of ecological factors act is complex and their actions should not be observed isolated. The lack of available moisture in the soil, high temperature, small depth of soil layer, presence of competing vegetation on the planting position or around it, are the most frequent limiting factors for afforestation success, and the establishment of forest plantations. In addition to their impact on planting success and the later plant and plantation development, the above factors are, together with seed origin and quality and the applied seedling production technology, the decisive factors which affect all aspects of afforestation.

4. CONCLUSIONS

Forest nurseries can be programmed to produce either the specific-purpose stock for the open market, or for the known buyers, either based on long-term afforestation programmes or based on contracts.

The term »specific-purpose planting stock«, refers to seedling production, propagated primarily from seeds, which will be characterised by the properties favourable for the predetermined silvi-technical works in forestry.

In the conditions of planned – more or less programmed production, nurseries produce the stock for the above objectives and therefore receive guaranteed revenues from regular contracted sales. They can also increase the trade and profit by selling the remaining supplies in the open market.

Specific-purpose production of planting stock also includes the developed seed science research, because, in addition to special production technology and seedling conditioning during the cultivation in the nursery, the seed origin (provenance) is of prime importance, as well as the intraspecific taxonomy. This is especially important in specific-purpose production of seedlings for extreme conditions.

Directed production of seedlings for target site types should be based on the climate and edaphic factors which represent the major difficulties in afforestation.

When the objective of planting stock production is defined, the activities in the nursery manager are facilitated, from those referring to seed selection and production technology, to outplanting method and time, tending, etc. This speeds up and makes easier the transition from uniform production of large quantities of planting stock of uniform quality to technologically more complex (sowing-planting, classical beds-duneman beds, container seedlings, etc.) specific-purpose stock production for concrete sites and known buyer. The more complex production process (in the same nursery, on the same area, seedlings of the same species often require different production technologies) is economically justified by different, usually higher prices. Simultaneously, this also implies the modified meaning of the term "quality seedling", because obviously different objectives of planting stock also imply different parameters for the evaluation of its quality.

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THE ROLE OF NEW POPLAR STRAINS IN THE ALLEVIATION OF THE EFFECTS OF CLIMATE CHANGE

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Abstract: *This paper presents the characteristics of the poplar genotypes, which are in the different phases of acknowledgement, in the aim of starting the production of them. The results of the research of the susceptibility to the foliar diseases, rate of growth in the field multifactoral experiments, as well as the study of physical, mechanical and chemical characteristics, heat capacity and genetic characterization, are presented. The researches were conducted on the samples from the field multi-clonal experiments, established by the plantation of the seedlings of the following clones: B-81, B-229, PE 19/66, 182/81 i 129/8), and one clonal strain ("Pannonia"), which was acknowledged earlier.*

The observed poplar clones belong to the following taxa: : B-81 (Populus deltoides), B-229 (Populus deltoides), PE 19/66 (Populus deltoides), 182/81 (Populus deltoides), 129/81 (Populus x euramericana), I-214 (Populus x euramericana) i "Pannonia" (Populus x euramericana). The researches were conducted by the establishment of three field experiments on the following sample plots: (I) "Banov Brod", (II) "Kupinske Grede" and (III) "Tomasevac", which were established over the period 2000-2004, in the areas managed by State Enterprise "Vojvodinasume", in the Forest Management Units "Sremska Mitrovica" and "Banat" Pancevo. The experimental measurement was conducted when the clones were six-year-old, and by the results of the diameter and heights, as well as the volume, the conclusion that in most cases the clone PE 19/66 had the highest rate of growth, can be made. The genetic characterization was conducted by the use of two types of microsatellite markers (PTR and WPMS).

Sixteen loci participated in the genetic characterization of the above clones. Sixty-two different alleles, or 3.9 alleles per locus, were detected, which points to the high degree of the polymorphysm of the observed loci. The statistical data procession and cluster analysis pointed to the fact that there are clear genetic differences between the clones, and showed that there are the greatest genetic similarites between the clones B-229 and182/81, whereas there are the greatest genetic differences between B-81 and PE19/66.The presented results of the genetic characterization are important in regard to the marker-assisted selection used in the breeding poplar programs, in the aim of the preservation and increase of the variability of the genetic material. In addition, they are the integral element in the copyright protections after the recognition of the new poplar strains.

Key words: poplars, strains, growth rate, genotyping

1. INTRODUCTION

Populus genus is widely spread in Europe, North America and Asia. The wide altitudinal zone and ability to perform spontaneous and controlled intra and inter species hybridization, enabled the formation of many sub-species, as well as a series of transitional forms, i.e. simple and complex hybrides. The result of it is the great natural variability, owning to which the poplars inhibit different sites, both in the riparian zones and in the zone of mountain forests. In addition to all these advantages, which are particularly important to the breeding programs, poplars are

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characterized by fast-paced growth, by the simple vegetation multiplication (Cain and Ormord, 1984).

In the economic sense, the poplars from *Aigeiros* section, which occupy small areas in Serbia, but are important in regard to the felling volume and financial effects, are particularly important to the economy. The Short Rotation Culture (SPIC) is a great stimulus to the development of poplar growing, since it implies the creation of new strains and improvement of the techniques of the nursery production and establishment of the plantations. This programme is actually wide-spread concept of the production of biomass for energy and chemical and mechanical procession (Anderson et al, 1983; Fege, 1987); The poplar, as fast-growing tree species has been popular lately, since it can be used in phytoremediation, because of the fact that the pioneer types of the newly-formed alluvial soils and flooded areas occupy the areas along the rivers, are characterized by the rapid growth and well-developed root, which absorbs the large quantities of water. As a result, these soils are ideal candidates for phytoremediation (Licht and Isebrands, 2005). The most frequent contaminants for the removal of which the phytoremediation by poplars is applied and which were studied are: (I) heavy metals (Pilipovic et al., 2005; Katanic et al., 2006; Nikolic et al., 2006), (II) organic compounds (Chappell, 1997, Xingmao and Burken, 2004; Pilipovic et al., 2008). It implies that by growing certain poplar strains not only the wood volume can be produced, but the contaminated soil will be cleaned, and the landscape will be embellished.

Having in mind that fact that it is anticipated that the world will be increasingly deficient in the cheap wood volume for the mechanical and chemical procession, as well as forthe energy, it is not accidental that there is a sudden growing interest for the growing of fast-growing forest species. As a result, the most poplar breeding programs are aimed at the better use of their genetic potential and adaptive values. In this regard the effort is made to create the strains (clones) which are characterized by great rate (speed) of growth and by the resistance to the pests and foliar, stem and bark diseases. The main problem with which every scientist who is involved in the process of improvement of plants is faced up with is how to recognize the genotypes with the desirable characteristics as early as possible. The shortening of the period for selection is time-saving and reduces the costs of the researches (Ceulemans et al., 1987, Orlovic et al., 1998). The creation of new poplar strains is complex since the rate of growth is studied by monitoring the elements of growth (tree diameter and height) and by monitoring of the produced biomass, which, along with most of other quantitive characteristics, are controlled by several genes. Thus, the numerous anatomic characteristics, as well as the physiological and biochemical processes in regard to the growth are studied, in order to estimate the potential of genotypes as early as possible.

In the Institute of Lowland Forestry and Environment numerous poplar strains (clones), which are characterized by the extreme rate of growth and series of desirable properties, the most important of which is the resistance to the foliar, stem and bark diseases, have been created so far by hybridization and multiple selection.

In order to create main preconditions for the acceleration of the process of creation of the fast-growing species, i.e. for the early selection, as well as for the creation of ideotypes, the programme of the long-term researches, which by the study of the anatomic characteristics and physiological processes, i.e. structurally-functional relations, enables the early detection of the potential for fast growth, was created in the Institute. According to Dickmann, et al. (1994) by the construction of ideotypes the total plant physiology is united. The use of ideotypes is also the possibility for the creation of the strains for plantations of short rotation.

Numerous results of the genotype testing – the poplars clones, are published in the scientific papers: Herpka, 1986; 1988; Markovic et al., 1986; Guzina et al., 1991. All the results clearly point to the fact that by the creation and production of the new high-yielding poplar strains it is possible to a great extent increase the wood production, as well as to significantly increase the genetic potential of new strains. In addition, the research of the susceptibility to the diseases pointed to the

permanent need for the creation and introduction of new poplar strains, in order to prevent the possible adverse effects of the growing of the monoclonal plantations which occupy great areas.
Since the technique of the genotype testing – candidates for the recognition, last several years, the efforts are made to recognize them as soon as possible, so that they will be produced as soon as possible. The results of the researches of the juvenile-adult relations Herpka 1979; 1987; 1988), showed that it is possible to recognize the poplar clones with a great accuracy in the juvenile phases as well.

After the poplar plantations are established on different types of soil, it is very important to set the multi-annual field experiments on as many different types of soil as possible, in order to study the adaptivity of strain, i.e. to find out on which type of soil it gives the best results in regard to the production of wood volume, i.e. on which types of soil it can grow and provides the satisfactory yield.

The plant breeding programs of the Institute of Lowland Forestry and Environment so far have been based on the conventional systems of the identification of clones, based on the morphological and phenological characterizations (Orlovic et al., 1997). Genotyping or genetic characterization has been introduced in the poplar breeding programs for the first time, and the DNA-based profiles have been introduced in the process of their registration.

Highly polymorphic, consistent and codominant marker system, such as SSR, proved to be the excellent tool in the identification and detection of the unique genetic profiles of the observed poplar clones, which is also proved by the data from the references Dayanandan et al.(1998); Rahman et al. (2000), Rajora and Rahman (2003); Van der Shoot et al.(2000), Galovic and Orlovic (2007), Orlovic et al. (2009), etc.

This paper presents the results of the research of diseases, rate of growth, physical, mechanical and chemical characteristics, of heating potential of wood, as well as of the genetic characterization of several poplar clones in the phase of testing, along with the standard acknowledged poplar clones, in order to obtain the approximate indicators of the advantages of the newly-formed poplar strains.

2. MATERIAL AND METHOD

Clonal material

The researches were conducted by the setting of three field multi-clonal experiments, established by the plantation of two-year seedlings of poplar clones which belong to the following taxa:

1. B-81 (*Populus deltoides*)
2. B-229 (*Populus deltoides*)
3. PE 19/66 (*Populus deltoides*)
4. 182/81 (*Populus deltoides*)
5. “Pannonia” (*Populus x euramericana*)

Field experiments

The experiments were set in the forests managed by State Enterprise “Vojvodinasume” on the following sample plots:

I) experiment “Banov brod”, State Enterprise “Vojvodinasume”, Forest Estate Sremska Mitrovica, Forest Administration Visnjicevo, Forest Management Unit “Banov Brod” 18a , type of soil: humic fluvisol, established in February 2000.

II) experiment “Kupinske grede”, State Enterprise “Vojvodinasume”, Forest Estate Sremska Mitrovica, Forest Administration Kupinovo, Forest Management Unit “Kupinske Grede” 43 d, type of soil: meadow chernozem on loess-alluvium in the spring 2001.

III) experiment “Tomasevac”, State Enterprise “Vojvodinasume”, Forest Estate “Banat” Pancevo, Forest Administration Zrenjanin, Forest Management Unit “Gornje Potamisje” 27 b, type of soil: humic-fluvisol, established in the spring 2004.

The elements of growth (diameters and heights)

In all three experiments the diameters and heights were measured every year, and the paper presents the data of the measurements of the 6-year-old plantations. In each experiment the diameters and heights were measured on 20 trees, and repeated three times. The data of measurement were collected in the digital form and statistically processed in the MstatC program.

The susceptibility of the poplar clones to the agents of the most important foliar diseases (Marssonina brunnea (Ell. et Ev.) P. Magn. i Melampsora spp.)

In the multi-annual experiments the susceptibility of the poplar clones to the agents of the most important foliar diseases (*Marssonina brunnea* (Ell. et Ev.) P. Magn. and s*Melampsora* spp.) was studied over the six-year period, from 2004 to 2009. The well-known methods, which have been applied in the Institute for similar researches for many years, were used for the estimation of the susceptibility of the clones (Vujic 1969, Avramovic *et al*. 1998, Pap *et al*., 2006). Three, randomly used trees of each clones from the plantation, were studied. During the first ten days of September, two shoots from the lower parts of crowns of each tree were studied (six shoots in total). The number of fruiting bodies was determined on all leaves of the shoots by the ocular estimate method and by the determination of the degree of presence, i.e. the intensity of attacks of these fungi, by using five categories, ranging from "0" do "4".

The intensity of attack of *M. brunnea*:

„0“ – no fruiting bodies

„1“ – 1 spot (acervulus) on 1cm² of leaf area (averagely 1 spot)

„2“ – 2spots (acervuli) on 1 cm² of leaf areas (averagely 2 spots)

„3“ – 3 spots (acervuli) on 1 cm² of leaf area (averagely 3 spots)

„4“ – 4 spots (acervuli) on 1cm² of leaf area (averagely 4 spots)

The intensity of attack of *Melampsora* spp.:

„0“ – no fruiting bodies

„1“ – up to 2 uredinia per 1cm² of leaf area (averagely 2 uredinia)

„2“ – up to 2-5 uredinia per 1 cm² of leaf area (averagely 3.5 uredinia)

„3“ – more than 5 uredinia per 1cm² of leaf area (averagely more than 9 uredinia)

„4“ – more than 5 uredinia per 1cm² of leaf area and the presence of rot necrosis (averagely 9 uredinia)

The arithemic mean of the average number of fruting bodies per 1 cm² of leaf area was determined for each clone.

The determination of physical, structural and chemical characteristics of trees

Based on phenotype assessment of several important characteristics : tree diameter and height, stem and crown forms, stem straightness, degree of branching, susceptibility to diseases and damages, etc, the dentrometric measurements were conducted and three sample trees of each clone were selected. After the selection and felling of the model trees, the volume was analyzed and the wood discs with the diameter of about 3 cm at breast height were sampled.

The determination of the fiber length. The fibers were macerated by using the modified Franklin's methods (Franklin, 1945), and the average numerical and mass lenght of fibers for for each clone was calculated by the method which was suggested by Clark (1983).

Basic volume density (absolutely dry matter per unit of wood volume with a highest content of moisture) was determined by JUS standard D.A1.044.
Moisture content was determined in a classic way, by drying the samples the absolute dry condition at 104^0C to constant mass.

The determination of the chemical composition. Out of the wood samples, which were taken by the above methodology, the samples for the determination of the chemical composition were prepared by grinding and mixing in certain proportions. The chemical composition was determined by main components – groups of chemical compounds, by the standard technology: ash by TAPPI standards T 211 m-58; content of the extractive substances by TAPPI standards T 204 os-76; content of Clason lignin by TAPPI standards T 13 m-54; content of pentosan by bromide-bromate method (Pravilova, 1984); cellulose content by Kurschner-Hoffer' method (Pravilova, 1984).

Determination of gross calorific value– higher heating value for the wood samples of the studied clones was conducted by the standard methodology in the bomb calorimeter. The tablets – samples were prepared from the chopped wood after air drying of the samples at room temperature, which lasted one month. The tablets were made in the special device, and the mass ranged from 0.60 to 0,85g. The samples were burnt in the calorimeter C 200 IKA Werke by the standard (DIN 51708). The higher heating values of the studied clones were determined three times.

DNA characterization of poplar clones

Thirteen poplar genotypes, different genetic bases, were sampled from the plantations of the Institute of Lowland Forestry and Environment in the aim of their genetic characterization. A special attention was paid to four clones (B-229, 182/81, B-81 and PE19/66), which are important to the selection program of the Institute.

SSR protocol

DNA was extracted from the frozen leaf tissue, by using DNeasy Mini Kit system (Qiagen, GmbH, www.qiagen.com), according to the prescription of the producer. Twelve SSR markers (PTR1, PTR2, PTR3, PTR4, PTR5, PTR6, PTR7, PTR8, PTR11, PTR12, PTR14, PTR15), originally designed for species *Populus tremuloides* (Dayanandan et al., 1998; Rahman et al., 2000); 4 WPMS SSR markers (WPMS3, WPMS5, WPMS7 and WPMS12), originally developed for *P. nigra* (Van der Schoot et al., 2000), were used for the determination of the genetic identities and mutual relations of the observed genotypes.

For the SSR analysis the following PCR-protocols were used: for WPMS the type of marker in accord with Van der Schoot et al. (2000), whereas for PTR type of marker the protocol by Dayanandan et al. (1998). Only the constant "signals", ranging from 100 to 400 base pairs, were taken into account during the data procession. The DNA fragments were electrophoretically separated on polyacrilamide (PAA) 6% gel under denaturising conditions by using the constant current 75 w, for 2-3 hours. The gel was painted by silver, and the PCR products was visualized by DIAS system (SERVA Electrophoresis, GmbH, www.serva.de).

Data procession

The statistical data procession was performed in the sofware package NTSYS-PC, version 2.1(Rohlf, 2000). The genetic similarity (GS) between the clones was assessed by the number of the mutually amplified fragments by using Dice's coefficient (Dice, 1945). The coordination of Dice's similarity matrices was tested by using Mantel's test (Mantel, 1967).

The random samples were formed by using NTSYS-pc, version 2.1 (Rohlf, 2000) software package, including 10^4 level of the random permutations. The method of grouping pairs with the arithmetic means (UPGMA) was based on the similarity matrix by using PHYLIP software, version .63 (Felsenstein, University of Washington, Seattle, WA, USA). The additional bootstrap analysis on 1,000 bootstrap samples was conducted in order to test the reliability of the groups (Felsenstein, 1985). The UPGMA dendrograms were constructed by using the program TreeView (Page, 1996). The power of discrimination (PD) for each individial locus was calculted by (Klosterman et al., 1993).

3. RESULTS AND DISCUSSION

The susceptibility of poplar clones to Marssonina brunnea (Ell. et Ev.) P. Magn. And Melampsora spp.)

The clones B-229, PE 19/66 and B-81 were not susceptible to the fungi from *Melampsora spp*. Genus, since the presence of uredinia on the leaves was not registered in any year (Table 1). Nevertheless, the clones were susceptible to *Marssonina brunnea*, since on each of the observed clones over the research period the presence of the fruiting bodies (acervuli) was determined (Table 2). By the detailed analysis of the data, the differences in the susceptibility of clones, i.e. in the intensity of the attack of the above pathogens, is observed. It mainly refers to the presence of *Marssonina brunnea* fungus, since the occurrence of it is more related to the environmental conditions, and to a lesser extent it is genetically conditioned. The average number of the fruiting bodies of *M. brunnea* was greater during the first three years of the assessment of clones (period 2004-2006) in comparison with the subsequent years. It can be explained by the weather conditions which were more favourable for development and spread of the fungus, particularly by the increased quantity of precipitation in the growing season over the above period. The presented results of the assessment show that the group of the clones which are "practically" resistant to the rot agents (clones B-229, PE 19/66 and B-81) also had low susceptibility to *M. brunnea* fungus. The presented results are in the harmony with the previous multi-annual assessments of the susceptibility of clones, which are kept in the genetic collections of the Intistute (Pap et al, 2006). The fact that the above clones, along with the low susceptibility to the foliar diseases, have other desirable characteristics (growth rate, adaptation to the available sites, quality of wood, etc), is particularly encouraging. As a result, these clones have numerous advantages, since the methods of chemical protection are not needed for their growth in the plantations. Two remaing clones, which were also the subject of assessment, had the different degrees of susceptibility to above foliar diseases. For instance, the clone "Pannonia" had low susceptibility to *Melampsora spp*, but it had high susceptibility to *Marssonina brunnea*, whereas the clone 182/81 had low susceptibility to *M. brunnea*, and had the average susceptibility to the rot agents.

The susceptibility of clone Pannonia to *M. brunnea* was in recent years studied by the Serbian scientists (Avramovic et al., 1998, Pap et al, 2006). These authors in their researches point to the increased susceptibility of this clone to *M. brunnea*. In spite of the fact that this clone is highly susceptible to *M. brunnea*, the other desirable characteristics of this clone in the combination with the intensive development of plants can to a great extent eliminate, or at least significanly, alleviate the damages caused by the activity of above fungus.

The clone 182/81 had low susceptibility to the agent of brown spot diseases, which is in accord with the results of the previous researches (Pap et al, 2006). However, in regard to the agents of leaf rot of this clone, averagely 0.53 uredinia/1cm² of leaf area were determined, which is significantly lower in comparison with the results of these authors, based on which the clone is classified into the group of very susceptible clones (more than 1.00 uredinia by 1 cm² of leaf area). This fact is the result of the conditions which were less favourable for the development of rot agent, which were particularly expressed over the period from 2006 to 2009, when the number of the uredinia on leaves of this clone was significantly reduced (Table 1 and 2).

Table 1. *The average number of Melampsora spp uredinia per 1 cm^2 of leaf area of the observed clones in the period 2004-2009*

Clones / Year	2004	2005	2006	2007	2008	2009	Average number for the period 2004-2009
B229	0	0	0	0	0	0	0 (practically resistant)
PE 19/66	0	0	0	0	0	0	0 (practically resistant)
B81	0	0	0	0	0	0	0 (practically resistant)
Pannonia	0	0	0	0	0	0.05	0.01 (low susceptibility)
182/81	1.02	0.90	0.25	0.38	0.36	0.20	0.52 (average susceptibility)

Table 2. *The average number of Marssonina brunnea acervuli of the observed clones over the period 2004-2009*

Clones / Year	2004	2005	2006	2007	2008	2009	Average number for the period 2004-2009
B229	0.62	0.37	0.45	0.21	0.20	0.17	0.34 (low susceptibility)
PE 19/66	0.63	0.35	0.48	0.26	0.17	0.19	0.35 (low susceptibility)
B81	0.71	0.55	0.21	0.32	0.23	0.22	0.37 (low susceptibility)
182/81	0.69	0.98	0.38	0.12	0.35	0.39	0.49 (average susceptibility)
Pannonia	1.19	1.58	1.48	1.04	1.57	0,77	1.27 (high susceptibility)

The elements of growth (diameters and heights)

The clone PE 19/66 in the experiments conducted on the sample plots “Banov brod“ and “Kupinske grede“ had the greatest average diameter (23.6 and 21.87 cm) (Table 3), whereas in these two experiments the clone “ Pannonia“ had the smallest average diameters (19.83 and 17.77 cm). The diameters of all clones in the experiment on the sample plot “Tomasevac“ were smaller, which is probably the result of the lower rate of germination, since the plants were planted in the unfavourable climate changes. By the variance analysis the statistically significant differences between both clones and experimens were determined. The interaction between clone x and experiment was not statistically significant.

Table 3. *The diameter of the observed six-year-old clones in the simultaneous plantations*

Experiment	“Banov Brod“	“Kupinske grede“	“Tomasevac“	$LSD_{0,05}$= 1.747
	h_s (cm)	h_s (cm)	h_s (cm)	
cl.182/81	20.57	18.73	12.57	17.29 bc
cl. B81	22.40	18.93	14.77	18.70 abc
cl. B229	21.90	20.13	14.93	18.99 ab
“Pannonia“	19.83	17.77	13.83	17.14 c
cl. PE19/66	23.60	21.87	14,73	20.07 a
F	$F_{klon} = 68,44^{***}$	$F_{ogled} = 7,60^{***}$	$F_{klon\ x\ ogled} = 0,99^{ns}$	

Table 4. *The relative ratio of the diameter of newly-selected clones to standard in all three experiments (clone "Pannonia")*

		182/81	B 81	B 229	PE 19/66
"Banov brod"	d 1.3	20.57	22,40	21.90	23.60
	range	4	2	3	1
	N Pannonia	149%	162%	158%	171%
"Kupinske grede"	d 1.3	18,73	18.93	20.13	21.87
	range	4	3	2	1
	N Pannonia	135%	137%	146%	158%
"Tomasevac"	d 1.3	12.57	14.77	14.93	14.73
	range	5	2	1	3
	N Pannonia	91%	107%	108%	107%

The relative ratios of the diameter of newly-selected clones and clone to clone "Pannonia" show that only in the experiment Tomasevac the relative ratio of clone 182/81 was below 100%, whereas in two other experiments the relative relatio of all clones was above 100% (Table 4).

Table 5. *The heights of the observed six-year-old clones in the simultaneous plantations*

Experiment	"Banov Brod"	"Kupinske grede"	"Tomasevac"	$LSD_{0,05}$= 1.020
	h_s (cm)	h_s (cm)	h_s (cm)	
cl.182/81	17.07	17.03	11.60	15.23 c
cl. B81	17.50	17.23	12.33	15.69 abc
cl. B229	16.83	17.30	12.13	15.42 bc
"Pannonia"	18.10	17.93	13.30	16.44 a
cl. PE19/66	17,73	18,73	12,43	16.30 ab
F	F_{clone} = 68.44^{***}	$F_{experiment}$=7.60^{***}	$F_{clonexexperiment}$=$0{,}99^{ns}$	

In regard to the heights, there is a clear difference between the heights of the clones in the experiment "Tomasevac" and other two experiments (Table 5). The clone PE 19/66 in the experiment "Tomasevac" had the greatest height, although it did not significantly differ from the height of the clones B 229 and Pannonia in the experiment Kupinovo, or from the height of the clones B 81, „Pannonia" and PE 19/66 in the experiment Bosut. The significant differences in the height of the clones in the experiment Tomasevac were reported only between the clones Pannonia and 182/81. The variance analysis showed the statistically significant differences between the clones (F=68.44) and experiment (F=7.60). The interaction between clone x and experiment was not stastically significant.

Table 6. *The relative ratio of height of newly-selected clones and standard in all three experiments (clone „Pannonia")*

		182/81	B 81	B 229	PE 19/66
"Banov brod"	h	17.07	17.5	16.83	17.73
	range	4	3	5	2
	N Pannonia	94%	97%	93%	98%
"Kupinske grede"	h	17.03	17.23	17.30	18.73
	range	5	4	3	1
	N Pannonia	95%	96%	96%	105%
"Tomasevac"	h	11.60	12.33	12.13	12.43
	rank	5	3	4	2
	N Pannonia	87%	93%	91%	93%

The relative ratios of the height of the newly-selected clones to clone „Pannonia“ showed that in most cases the relative ratio was below 100%, except for the clone PE 19/66 in the experiment “Kupinske grede“ (Table 6).

According to Guzina et al. (1991) the interclonal genetic variabilities of heights and form factors are significantly less expressed in the poplars than the variability of diameter, so the average diameters at breast height are the reliable parameters for the assessment of the growth rate of the observed clones.

In the aim of the better acquaintance with the growth rate of the clones the reduction of the site impacts, and the technology of growing, the relative ratio of the diameter of the newly-selected clones and registered clone “Pannonia“ is presented in the Table 3.

The results point to the significant differences in the diameter of the newly-selected clones and the registered clone "Pannonia", which, among other things, can be attributed to the fact that these clones belong to the eastern cotton wood (*Populus deltoides* Bartr.), which is characterized by the higher increment in the juvenile phase in comparison with Hybrid poplar (*Populus x euramericana*), to which clone "Pannonia" belongs. It is possible that in the later stages the differences between the newly-selected clones and clone "Pannonia" will be reduced, as it is suggested by the results obtained by Markovic et al. (1986) in the researches which were conducted in the five to seven-year-old plantations,. In these researches the greater differences between the eastern cotton wood and Hybrid poplars were determined, in comparison with the differences reported by Guzina et al. (1991) in the plantations from eight to ten years old.

The characteristics of the observed clones

By using above methodology the basic characteristics of trees were researched, which implies the determination of the volume density, fiber length, and the chemical composition by groups of chemical compounds (Table 7).

Table 7. *The characteristics of the observed poplar clones*

Characteristic	cl.182/81	cl.B81	cl.B229	cl.Pannonia	cl.PE19/66
Basic volume density, kgm^{-3}	364	387	361	360	320
Bulk density kgm^{-3}	452	445	435	432	361
Fiber lenght, mm	1.019	1.032	1.022	1.047	1.011
Chemical composition, %					
Ash	0.87	0.69	0.96	0.91	1.28
Extractive substances	3.85	3.19	3.37	3.42	2.44
Clason lignin	23.21	24.02	24.61	23.72	23.75
Pentosans	19.87	20.36	19.66	21.93	20.82
Cellulose	52.17	51.69	50.91	50.02	50,17
Higher heating value, $MJkg^{-1}$	18.432	18.489	18,743	18.340	18.594

By comparing the volume densities, the lower volume density (both basic and absolutely dry) of clone PE19/66 was observed. The basic volume density of clone PE19/66 is by 18% lower in comparison with the average values of four other clones (441 kgm^{-3}), and the bulk density is by 13% lower than the average value (368 kgm^{-3}). It is probably the results of the increased volume porosity, which is caused by the fast growth, i.e. high volume increment of the above clone, which has been stated earlier. The basic volume densities of the observed clones range from 320 kgm^{-3} (min.) to 387 kgm^{-3} (max.), and the bulk densities from 361 kgm^{-3} (min.) to 452 $kg\ m^{-3}$ (max.). It is in accord with the specific wood weights of several poplar according to Goyal (1999), which range from 0.30 do 0.36, as well as with the specific wood weights of seven-year-old *P. balsamifera* L, which range from 0.343 to 0.371 (Ivkovic 1996).

The results of our previous researches of four-year-old *P. deltoides* are similar - volume density is 456 kgm^{-3}, as well the results of the researches of ten-year-old clone 457 - volume density

368 kgm^{-3} (Klasnja et al, 2003). These deviances can affect the biomass yield per area unit of the basic special-purpose energy plantations, when the above-ground biomass is the crucial factor for the quantities of the heating-energy, which can be obtained by their combustion. In addition, the higher heating value of all observed clones are within a very narrow range, from 18.340 $MJkg^{-1}$ to 18.743 $MJkg^{-1}$,which is accord with our previous researches, as well as with the data from the foreign references.

The chemical composition of the wood of the observed clones is very similar. The cellulose content is mainly within the limits which were reported in our previous researches (Klasnja and Kopitovic, 2006, Klasnja et al, 2007), which can be also found in the references, whereas the increased content (above 50%) can be the result of the tension wood, which is typical for this tree species. The lignin content is in accord with the values obtained in the previous in the previous researches of the wood of the similar age: the average lignin content of several nine-year-old *P. deltoides* clones is 22.7% (Kopitovic et al., 1996, Klasnja et Kopitovic, 1997, 2006). Alvarez and Tjeerdsma (1995) report that the average lignin content of nine-year-old wood is 18.6%, and Goyal et al. (1999) report that the average lignin content of several eight-year-old clones ranges from 16.6% to 26.4%

It is important to emphasize in the analysis of the chemical composition of the wood of the different poplar clones that the chemical composition can be influenced as early as in the first phase of the selection of clones. Namely, our previous researches of the chemical composition of wood of 40 four-year old clones ((*P. deltoides* Bartr., sekcija *Aigeiros*), proved that the factors of heritability in the wider sense for the content of lignin, total polysaccharides and extractive substances are very high and similar: the content of lignin is 0.936, content of polysaccharides is 0.937, and the content of extractive substances is 0.999, (Klasnja et al. 2003, 2005).

The interaction between clone x and experiment

The variance analysis of the elements of growth (diameters and stem heights) showed that the interaction between clone x and experiment was not statistically significant, which implies that the site conditions did not affect the elements of growth of clones.

DNA characterization of the poplar clones

Sixteen loci (12 PTR and 4 WPMS) were included in the genetic characterization of 4 agronomically significant clones. Based on the analysis by using SSR markers it was determined that both types of SSR markers can be efficiently used for the differentiation of the closely related genotypes of the *Populus sp.* species, i.e. for the determination of their intra- and interspecies connection. Our results are in accord with the results obtained by Rahman and Rajor (2002), Gomez et al. (2003) and Smulders et al. (1997). Table 8 shows that the markers PTR1 and PTR8, as well as WPMS3, WPMS5 and WPMS12 (PD=0.75) had the greatest power of discrimination for the observed 4 genotypes. as a result, these markers can be safely used in the determination of the genetic identity of the observed clones.

Table 8. *Microsatelites (SSRs), size range of the fragments (base pairs), the number of the detected alleles and power of dicrimination (PD) of the observed clones.*

Loci	Size range recorded (bp)	No. detected allels	Power of discrimination (PD)
PTR1	256-260	3	0,75
PTR2	213-296	5	0,625
PTR3	216-248	4	0,625
PTR4	155-357	3	0,625
PTR5	148-276	3	0,375
PTR6	221-349	4	0,625

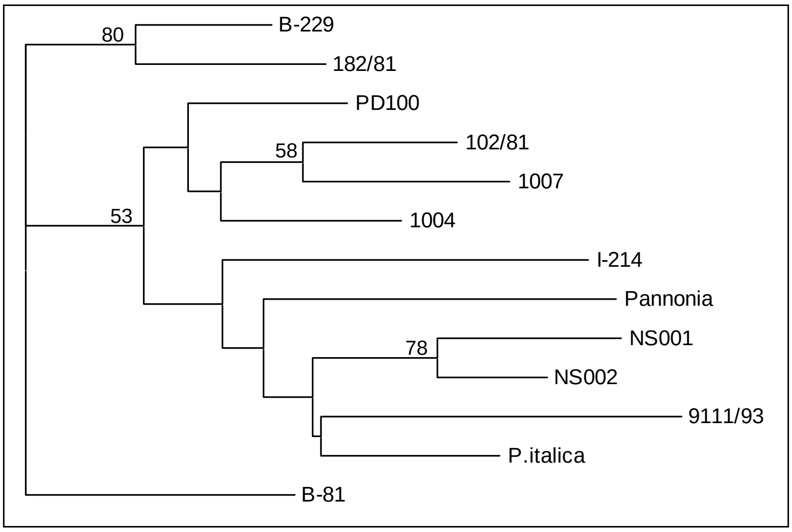
Loci	Size range recorded (bp)	No. detected allels	Power of discrimination (PD)
PTR7	236	1	0,375
PTR8	143-162	5	0,75
PTR11	64-153	3	0,625
PTR12	264-266	2	0,375
PTR14	156-205	5	0,625
PTR15	179-309	3	0,625
WPMS3	279-300	3	0,75
WPMS5	281-329	10	0,75
WPMS7	252-284	3	0,375
WPMS12	168-235	5	0,75
Total No. of alleles = 62, alleles/loci = 3,875			

Table 9. *SSR DICE's similiarity matrix*

	B-81	B-229	Pannonia	182/81	PE19/66	NS001	NS002	I-214	102/81	9111/93	P.italica	1007	1004
B-81	1.000												
B-229	0.600	1.000											
Pannonia	0.200	0.200	1.000										
182/81	0.400	0.700	0.300	1.000									
PD100	0.444	0.556	0.333	0.444	1.000								
NS001	0.105	0.111	0.273	0.111	0.375	1.000							
NS002	0.300	0.222	0.455	0.222	0.375	0.727	1.000						
I-214	0.222	0.222	0.300	0.333	0.375	0.333	0.444	1.000					
102/81	0.500	0.375	0.222	0.250	0.714	0.250	0.250	0.222	1.000				
9111/93	0.200	0.300	0.250	0.200	0.444	0.455	0.364	0.200	0.222	1.000			
P.italica	0.222	0.250	0.500	0.250	0.429	0.600	0.546	0.375	0.375	0.500	1.000		
1007	0.444	0.333	0.200	0.222	0.500	0.222	0.333	0.300	0.667	0.200	0.250	1.000	
1004	0.333	0.333	0.333	0.222	0.625	0.250	0.375	0.333	0.625	0.444	0.429	0.556	1.000

On 16 markers, 62 different alleles, or 3.9 alleles per loci were detected, which points to the high degree of polymorphism of the observed loci (Table 9). The stastical data procession showed the clear genetic differences between the clones. The genetically most similar clones are B-229 and 182/81 with the high Dice's similiarity coefficients, GS=0.7, whereas there are more differences between B-81 and PE19/66 (GS=0,44), Table 2. Based on SSR results, the cluster analysis divided clones into three groups (Fig.1). The clones B-229 and 182/81, which are most similar belongs to group 1, whereas the clone B81 is most different from the observed clones.

These results point to the genetic variability between the observed clones, and the degree of similiarities between their origins, and can be used as the important base for the breeding program planning, as well as for the determination of the directions of selection and breeding.



Graph 1. *UPGMA dendrogram of poplar clones constructed based on the similiarities between SSR fragments*

The results of these researches have pointed to the significant interclonal variability, which is reflected in all research parameters. The research parameters have the significant potential, in regard to the growth rate and susceptibility to the foliar diseases (*Melampsora spp.* i *Marssonina brunnea*). In regard to the observed physical, mechanical and chemical characteristics, as well as to the heating ability, the clones also have the great potential, i.e. they have the appropriate characteristics. These facts imply that the clones-candidates have the appropriate characteristics which enable the production of them. The genetical characterization of these clones showed the high degree of polymorphism of the observed loci, as well as the well-expressed genetic differentiation, which will enable the copyright protection after the registration of clones.

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SIGNIFICANCE OF GENETIC POTENTIAL OF DOUGLAS-FIR INTRODUCED PROVENANCES IN SERBIA FOR THE RANKING OF THEIR ADAPTATION TO CLIMATE CHANGES

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Abstract: *Douglas-fir (Pseudotsuga menziesii /Mirb./ Franco) provenance tests in Serbia consist of 29 provenances, originating from almost entire native range of this species. One experiment is in the area of Mt. Juhor (central Serbia) at the site of the montane beech forest (Fagetum moesiaca montanum Jov. 1976) and the other one is at Tanda near Bor (eastern Serbia), at the site of Hungarian oak and Turkey oak forests (Quercetum frainetto-cerris Rud. 1949). The gene-ecological variations manifested in the introduced material, most often as the modification variability of quantitative and qualitative characters, are the consequence of the interaction of the introduced material and the environmental conditions at the places of transfer. The scope of variations depends directly on climate, edaphic and coenological characteristics of the site where the experiments are established, as well as on the effect of the altitude and geographical coordinates of the original populations from which the introduced material originates. The growth and development of trees in test plantations is directly influenced by climate changes. With climate changes, the precipitation will become unstable and the frequency of unpredictable droughts will increase, which will have adverse effects on tree growth and increment of Douglas-firs grown at allochthonous sites in Serbia. The potentials and future directions of the intensive utilisation of the introduced material depend on the knowledge of the interaction of the above factors. The results of multiannual researches on the interaction of a complex of factors affecting the adaptation of Douglas-fir provenances contribute to: identification of ecological parameters essential for the selection of Douglas-fir provenances for the transfer from North America to the sites in Serbia; study of the scope of variation of economically significant quantitative properties, and as a selection criterion, for the ranking of provenances adaptable to climate changes and significant for wider cultivation in Serbia.*

Key words: Provenance tests, Douglas-fir, Serbia

ZNAČAJ GENETSKOG POTENCIJALA INTRODUKOVANIH PROVENIJENCIJA DUGLAZIJE U SRBIJI ZA RANGIRANJE ADAPTIVNIH NA KLIMATSKE PROMENE

Izvod: *Provenijenični test duglazije (Pseudotsuga menziesii /Mirb./ Franco) u Srbiji osnovan je od 29 provenijencija, koje potiču iz gotove celog prirodnog areala ove vrste. Jedan ogled je na području Juhora (centralna Srbija) na staništu planinske šume bukve (Fagetum moesiaca montanum Jov. 1976) i drugi u Tandi kod Bora (istočna Srbija), na staništu šuma sladuna i cera (Quercetum frainetto-cerris Rud. 1949). Gen-ekološke varijacije koje se na introdukovanom materijalu manifestuju, najčešće kao modifikaciona promenljivost kvantitativnih i kvalitativnih svojstava, posledica su interakcije unetog materijala i uslova životne sredine, tamo gde je transfer obavljen. Opseg vairanja ovih svojstava direktno je uslovljen klimatskim, edafskim, cenološkim karakteristikama lokaliteta gde su ogledi*

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20052 „Changes in forest ecosystems affected by global warming“

osnovani kao i uticajem nadmorske visine i geografskih koordinata originalnog porekla populacija iz kojih potiče introdukovani materijal. Rast i razvoj stabala u test kulturama direktno je pod uticajima klimatskih promena. Sa klimatskim promenama padavine će postati nestalne, a frekvencija nepredvidljivih suša će biti u porastu što će imati negativne efekte na rast i prirast stabala duglazije gajenih na alohtonim staništima u Srbiji. Mogućnosti i budući pravci intenzivnog korišćenja unetog materijala zavise od poznavanja interakcije navedenih činilaca. Dobijeni rezultati višegodišnjih istraživanja interakcije kompleksa faktora koji utičnu na adaptaciju provenijencije duglazije doprinos su za: utvrđivanje ekoloških parametara koji su bitni pri izbor provenijencija duglazije za njen transfer iz Severne Amerike na staništa Srbije; upoznavanje opsega variranja privredno značajnih kvantitaivnih svojstava, i kao selekcioni kriterijum za rangiranje provenijencija adaptivnih na klimatske promene i značajne za šire gajenje u Srbiji.

Ključne reči: Klimatske promene, provenijenični testovi, duglazija

1. INTRODUCTION

Douglas-fir *(Pseudotsuga menziesii)* is one of the most important and most valuable coniferous species in North America, and the main component of western forests in North America from the time of the Pleistocene. Fossil data indicate that there was no Douglas-fir natural distribution in the west part of North America. It was successfully introduced over the last 100 years.

Douglas-fir latitudinal range is the greatest of any conifer in the western North America. Its native distribution extends from 19^0 to 55^0 North latitude and it resembles an inverted letter V. From the apex in British Columbia, the shorter arm extends south along the Pacific Coast Ranges (for about 2200 km) to North latitude 34° 44' representing the range of the typical coastal or green Douglas-fir variety: *menziesii*; the longer arm stretches along the Rocky Mountains into the mountains of central Mexico over a distance of nearly 4 500 km, comprising the range of the other variety, *glauca*- Rocky Mountain Douglas-fir or blue. Nearly pure stands of Douglas-fir continue south from their northern limit on Vancouver Island in Canada through western Washington, Oregon, and the Coast Ranges of northern California as far as the Santa Cruz Mountains. In the Sierra Nevada, Douglas-fir is a common part of the mixed conifer forest as far south as the Yosemite region. The range of Douglas-fir is continuous through northern Idaho, western Montana, and north-western Wyoming and also in Bighorn Mountains. In north-eastern Oregon, and from southern Idaho south through the mountains of Utah, Nevada, Colorado, New Mexico, Arizona, extreme western Texas, and northern Mexico, the distribution becomes discontinuous.

Thanks to its usability value and wood properties as the building material, Douglas-fir is also known as: Red fir, Oregon pine and Douglas-spruce. The most widely recognized varieties are two varieties *P. menziesii* (Mirb.) Franco var. *menziesii,* as maritime Douglas-fir and *P. menziesii* var. *glauca* (Beissn.) Franco, known as Rocky Mountain Douglas-fir or blue Douglas-fir. The third variety, which is not so widely distributed, is named *cesia* or grey.

2. MATEARIAL AND METHOD

The Institute of Forestry established the provenance tests in Serbia (1978) to distinguish the best ecologically adapted and the most productive provenances.

The plot in central Serbia is on mountain Juhor (*Fagetum moesiaca montanum* Jov. 1976) at the altitude of 700 m above sea level (43.47°; 18.53°). The plot in Eastern Serbia is situated on oak site (*Quercetum farnetto-cerris* Rud.) at the altitude of 370 m, latitude 44.14° and longitude 22.10°. Experimental material is the collection of seeds of different Douglas-fir provenances, from Oregon to Washington (Table 1).

Table 1. *Geographical co-ordinates of the tested Douglas-fir provenances*

Provenance	Our mark number	Latitude (ºN)	Longitude (ºE)	Altitude (m)
Oregon 205–15	1	43,7	123,0	750
Oregon 205–14	2	43,8	122,5	1200
Oregon 202–27	3	45,0	122,4	450
Oregon 205–38	4	45,0	121,0	600
Oregon 204–16	6	45,0	121,0	1050
Oregon 205–16	7	44,0	123,0	150
Wasington 205–31	8	48,8	121,5	450
Wasington 204–07	9	49,0	119,0	1200
Oregon 205–13	10	43,8	122,5	1050
Oregon 205–18	11	44,2	122,2	600
Oregon 202–22	12	42,5	122,5	1200
Oregon 202–21	14	42,4	123,7	300
Wasington 202–17	15	47,6	121,7	600
Oregon 201–10	16	44,5	119,0	1350
Wasington 201–06	17	49,0	120,0	750
Oregon 202–19	18	45,3	123,8	300
Washington 204–09	19	49,0	119,3	900
Oregon 205–11	20	45,0	123,0	150
Oregon 205–45	21	44,0	122,0	900
New Mexico202–04	22	32,9	105,7	2682
New Mexico202–10	23	36,0	106,0	2667
Oregon 202–31	24	44,3	118,8	1500
Oregon 205–29	26	42,6	122,8	900
Oregon 205–08	27	42,7	122,5	1050
Oregon 205–22	28	45,0	121,0	750
Oregon 204–18	29	44,5	119,0	1500
Oregon 204–04	30	45,0	121,5	900
Washington 205–17	31	47,7	123,0	300
Oregon 205–17	32	44,0	124,0	450

Climate data for the localities Juhor and Tanda are taken from the archive of the Republic Hydro Meteorological Service (RHMS) of Serbia in Belgrade.

The characteristics of climate factors are calculated based on the data from the weather stations at Bor and Ćuprija.

The following values were calculated based on the above data:

- De Martonne aridity index (Vujević, 1953), for annual value:

$$IS = \frac{H}{t+10},$$

- and for monthly values

$$IS = \frac{12 \cdot H}{t+10},$$

- Lang's rain factor (Milosavljević, 1984):

$$KF = \frac{\Delta H}{t},$$

- Kerner's thermodromic coefficient (Milosavljević, 1984):

$$K = \frac{100(t_x - t_{iv})}{A} \cdot 100,$$

The percentage of seedling survival in individual Douglas-fir provenances in both experiments was determined by counting the survived plants. The standardised percentage of seedling survival deviation from the average survival at the given site was calculated for each provenance using the following formula:

$$Z_i = \frac{X_i - \overline{X}}{\sigma}$$

2.1 Climate

The native range of Douglas-fir extends in a wide variety of climatic conditions (Table 2). The coastal region of the Pacific Northwest has a maritime climate with typical characteristics: mild, wet winters and cool, relatively dry summers, a long frost-free season, and narrow diurnal temperature fluctuations (6° to 8° C; 43° to 46° F). Precipitation is mostly rain and concentrated in the winter months. Climate in the Cascade Range and Sierra Nevada tends to be more severe.

Table.2. *Climate data for the regions in Douglas-fir native range*

Region	**Temperature**			**Precipitation**	
	July	**January**	**Frost-free period**	**Annual**	**Snowfall**
	°C	**°C**	**days**	**mm**	**cm**
Pacific northwest					
Pacific coast	20 to 27	-2 to 3	195 to 260	760 to 3400	0 to 60
Cascades					
Sierra Nevada	22 to 30	-9 to 3	80 to 180	610 to 3050	10 to 300
Rocky Mountains					
Northern	14 to 20	-7 to 3	60 to 120	560 to 1020	40 to 580
Central	14 to 21	-9 to -6	65 to 130	360 to 610	50 to 460
Southern	7 to 11	0 to 2	50 to 110	410 to 760	180 to 300

Altitude has a significant effect on local climate. In general, temperature decreases and precipitation increases with increasing altitudes on both western and eastern slopes of the mountains. Winters are colder, frost-free seasons are shorter, and diurnal fluctuations of temperature are larger. In the northern Rocky Mountains, Douglas-fir grows in a climate with a marked maritime influence. Mild continental climate prevails in all seasons, except mid-summer. Precipitation is uniformly distributed throughout the year, except for a dry period in July and August. In the central Rocky Mountains, the climate is continental. Winters are long and severe; summers are hot and in some parts of the region, very dry. Annual precipitation is higher on the western sides of the mountains, it is mainly snow. Rainfall in the southern Rocky Mountains is generally lower in winter but higher during the growing season. Frost may occur in any month in the northern part of the range. Duration of frost-free period varies within the central and southern Rocky Mountain regions, even at the same altitude.

3. RESULTS

3.1. Climate characteristics of the locality

Along with soil properties, climate characteristic are the main ecological or site factors on which the introduction of a species is planned. Douglas-fir is a species which grows over a very wide variety of climatic conditions (Baldwin, 1973). To assess the species ecological adaptation, it is necessary to make an in-depth analysis of climate and soil conditions of target localities.

3.1.1. Climate characteristics of the locality Juhor

Management Unit Juhor is located in the transitional zone, in which the prevailing climate is under the effect of temperate continental climate of both lowland and upland mountainous parts of Serbia. The effect of temperate continental climate from the Pannonian Plain is more pronounced in winter, when cold air masses penetrate through the valley of the river Morava deep to the south. In spring, the effect of warm south winds is reflected in rapid snow melting, in the increase of water level on the rivers and in the faster growth of vegetation.

Based on the data at the weather station Ćuprija, the climate in the area of Juhor is characterised by strong gradient of continentality, because the Kerner's thermodromic quotient has a negative value (–0.83). De Martonne aridity index (30.1) indicates that this region belongs to exorheic type, with permanent water runoff. Lang's rain factor amounts to 59.45, which means that the climate in this area is humid and favourable for the development of steppes.

Mean annual air temperature is 10.9ºC. The warmest month is July with 20.9ºC, and the coldest month is January with –0.4ºC (Table 3) annual precipitation is 647.2 mm. The month with the highest precipitation is June, and the month with the lowest rainfall is August. Based on the monthly values of aridity index, the driest month is August, which, in addition to low rainfall, also has high air temperatures.

Table 3. *Climate characteristics - weather station Ćuprija.*

	Month / Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Mean monthly air temperature (°C)	Average	–0.4	1.7	6.0	11.3	16.4	19.4	20.9	20.6	16.4	11.1	6.0	1.1	10.9
	Max	3.6	7.2	10.2	14.9	19.6	22.8	23.6	25.1	20.7	15.9	10.2	4.3	12.4
	Min	–6.3	–4.5	0.8	6.5	12.9	16.9	18.6	16.7	13.6	7.7	0.0	–3.5	9.8
Monthly precipitation (mm)	Average	42.7	41.0	41.7	58.9	73.6	84.3	60.7	42.3	54.8	42.4	50.5	54.4	647.2
	Max	104.7	87.6	121.4	157.8	205.8	226.5	183.1	166.5	151.3	121.3	138.1	111.6	906.8
	Min	1.2	8.7	1.2	18.2	7.2	21.4	2.9	0.4	1.9	0.0	5.8	3.0	461.8
Aridity index	Average	59.63	45.42	32.46	33.48	34.28	34.89	23.76	16.82	25.43	24.59	39.00	60.62	31.02
	Min	2.88	9.76	0.81	9.14	3.18	8.05	1.05	0.14	0.87	0.00	4.67	3.16	20.69
	Max	219.24	119.45	93.99	91.92	100.80	96.38	71.34	63.83	70.37	75.03	110.48	146.68	43.60

3.1.2. Climate characteristics at the locality Tanda

The climate in this area is characterised by very strong continentality which is indicated by the low value of thermodromic quotient (K = 0.79). Lang's rain factor is 66.84, which means that this is the area of humid climate unfavourable for the development of forests. Annual value of aridity index at the weather station Bor is 33.44, which according to De Martonne (Vujević, 1953), means that this area belongs to exorheic type from which water permanently runs off and where agricultural crops do not require irrigation.

Mean annual air temperature is 10.9ºC. The warmest month is July with mean monthly temperature of 20.7ºC, and August with 20.3ºC. The coldest month is January with –0.2ºC (Table 4). Annual precipitation is 669.2 mm. The month with the highest precipitation is May (96.9 mm). The warmest months July and August also have the lowest mean monthly precipitation, wherefore these two months have the lowest values of aridity index.

Table 4. *Climate characteristics – weather station Bor*

	Month / Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Mean monthly air temperature (°C)	Average	–1.8	0.3	4.3	10.3	15.6	18.8	20.9	20.6	16.2	10.5	4.8	0.1	10.0
	Max	3.5	5.4	9.6	13.2	19.6	21.1	24.0	25.0	20.1	13.9	8.8	3.1	11.0
	Min	–7.6	–4.8	–0.9	6.1	12.4	16.8	18.7	17.3	12.3	7.9	–1.2	–3.4	9.2

	Month / Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Year
Monthly precipitation (mm)	Average	37.7	38.2	51.5	53.3	71.8	62.5	49.5	48.0	44.0	43.1	54.8	55.6	609.8
	Max	95.4	103.3	123.3	98.2	191.6	139.5	134.2	144.4	185.0	147.1	204.4	144.5	955.8
	Min	1.6	3.7	3.8	9.6	17.0	3.8	1.3	0.0	2.3	0.0	4.7	5.4	410.3
Aridity index	Average	74.18	52.37	46.28	31.96	34.40	26.39	20.08	19.10	21.02	25.80	47.24	71.81	32.60
	Min	2.06	9.52	2.73	5.07	6.89	1.47	0.46	0.00	1.07	0.00	3.56	6.89	19.54
	Max	477,00	159,23	116,50	66,95	99,53	62,46	53,32	58,54	95,69	98,61	193,13	219,74	48.27

3.2 Percentage of survived plants

The number and percentage of survivals in the experiment are some of the best indicators of the adaptation of introduced species, as well as the relation of genetic variation and the environmental gradient.

This is represented by Table 5 for the experiment on Juhor which consists of 20 provenances and Table 6 for the experiment at Tanda which consists of 29 provenances. The data are also presented in Diagram 1 for Juhor, and in Diagram 2 for Tanda.

The ranking differences of the same provenances at two localities show that climate conditions and site conditions indicate clearly the degree of plant adaptation.

Based on the research in Douglas-fir provenance tests at two sites in Serbia, it can be concluded that the percentage of Douglas-fir survival depends both on site conditions and on genetic adaptation of individual provenances to the given site conditions.

Generally, at the site of submontane beech at the locality Juhor, the survival percentage of all provenances was statistically considerably higher than that at the locality Tanda, i.e. at the oak site. This means that beech site provides more favourable conditions for the survival of Douglas-fir seedlings after afforestation.

At the locality Juhor, which is established at the site of submontane beech, the average number of seedling survivals accounted for 81.85 %. Of all the study provenances at this locality, no provenances had a statistically significantly higher seedling survival, at the significance level of 5%. The highest survival percentage was attained by the provenances 27, 26, 2 and 22. The seedling survival percentage of these provenances was higher than one standard deviation from the average survival at the beech site. For this reason, the above provenances can be recommended for the introduction at the beech site.

The percentage of seedling survival in Douglas-fir provenances 4,10, 23, 31, 16, 30, 18, was somewhat higher, and that of the provenances 18, 20, 3, 17 12, 15 and 1 was somewhat lower than the average at the beech site. In no provenances the difference in the percentage of seedling survival, compared to the average survival at this site, exceeds one standard deviation.

The percentage of seedling survival of Douglas-fir provenances 24 and 9 at the beech site was lower than the average survival of all the tested provenances at the beech site. The difference compared to the average survival at this site in provenance 24 exceeded one standard deviation, and in provenance 9 it exceeded two standard deviations. In provenance 9, the seedling survival percentage was statistically considerably lower than the average survival at the beech site, and the significance level was 5 %. This means that the provenance 9 should not be implemented, in any case, in the introduction of Douglas-fir at the beech site, and the provenance 24 should be avoided.

Table 5. *The percentage of survivals provenances on Juhor*

Provenance	Survival percentage Xi	Standardised deviation Zi
27	95.8	1.82
26	94.4	1.63
2	91.6	1.27
22	90.2	1.09
4	86.1	0.55
10	84.7	0.37
23	84.7	0.37
31	84.7	0.37
16	83.3	0.19
30	81.9	0.01
18	80.5	-0.18
20	79.1	-0.36
3	79.1	-0.36
17	77.8	-0.53
12	77.8	-0.53
15	77.8	-0.53
11	76.4	-0.71
1	75.0	-0.89
24	72.2	-1.26
9	63.9	**-2.34**
Average	**81.85 %**	
σ	**7.6761**	

Table 6. *The percentage of survivals provenances in Tanda*

Provenance	Survival percentage Xi	Standardised deviation Zi
21	98.62	1.55
3	97.23	1.45
4	97.23	1.45
8	91.68	1.04
10	90.28	0.94
22	87.52	0.73
27	87.52	0.73
6	84.72	0.53
31	83.35	0.43
7	81.95	0.32
26	81.95	0.32
16	81.93	0.32
15	81.93	0.32
23	80.50	0.22
2	77.80	0.02
18	77.78	0.01
24	76.38	-0.09
30	76.40	-0.09
11	75.02	-0.19
17	75.02	-0.19
32	75.00	-0.19
28	74.98	-0.19
9	69.43	-0.60
1	66.67	-0.81
14	65.25	-0.91
12	63.90	-1.01
20	63.90	-1.01
19	48.58	**-2.14**
29	37.50	**-2.96**
Average	**77.59 %**	
σ	**13.5358**	

Site conditions in the oak belt differ very much from the conditions in the beech belt. For this reason, the provenances which attained the highest percentage survival at the site of submontane beech, did not have such a high survival percentage also at the oak site.

The average seedling survival of all the tested Douglas-fir provenances at the oak site accounted for 77.59 %. Compared to the beech site, the variability of seedling survival percentage of different Douglas-fir provenances was considerably higher. At the oak site, the highest seedling survival was determined for the provenances 21, 3, 4 and 8. In these provenances, the seedling survival percentage was higher for one standard deviation than the average Douglas-fir survival at the oak site. For this reason, the above provenances are suitable for the introduction at the oak site.

Diagram 1. *Deviation of the percentage of survived plants of different Douglas-fir provenances from average survival on Juhor, in standard devaitions*

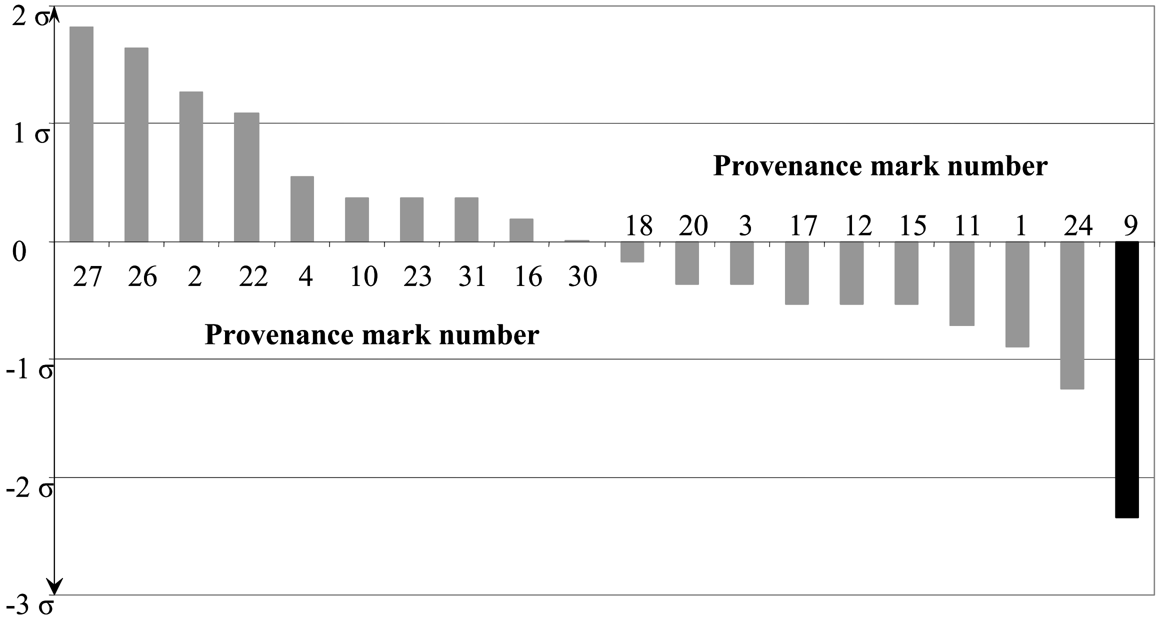
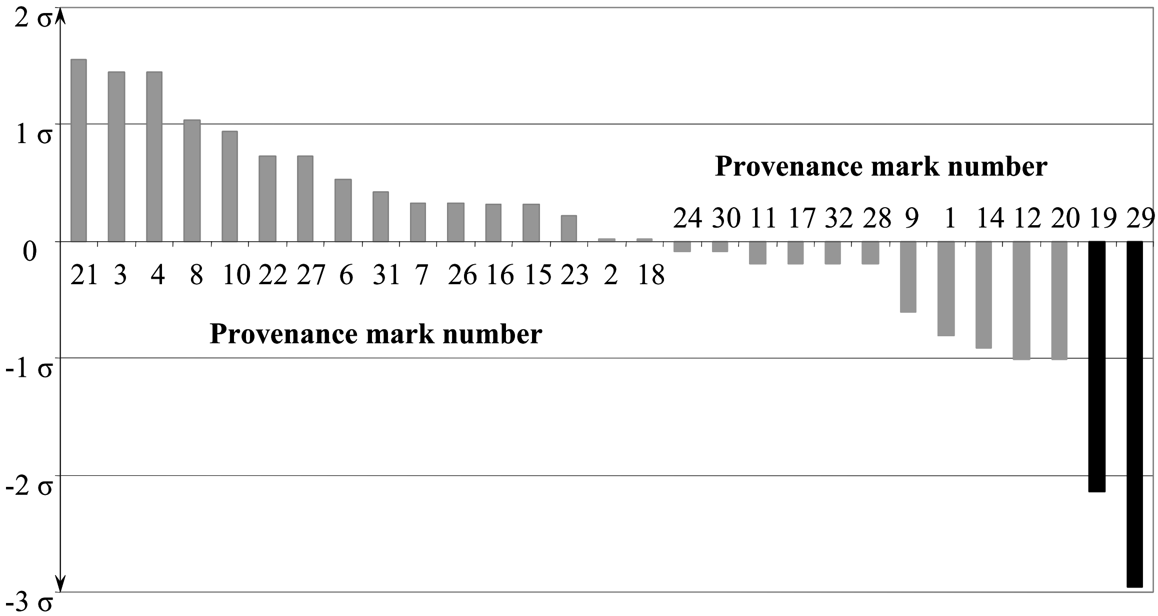


Diagram 2. *Deviation of the percentage of survived plants of different Douglas-fir provenances from average survival on Tanda, in standard devaitions*



In the provenances 12 and 20, the survival percentage was lower for one standard deviation than the average Douglas-fir survival at the oak site. For this reason, the above provenances should be avoided in the introduction at the oak site. In the provenances 19 and 29, survival percentage at the oak site was lower than the average for two standard deviations. The significance level of the difference in the survival percentage compared to the average in provenance 19 was 5%, and in provenance 29, the significance level accounted for 1%. This means that these provenances should never be introduced to the oak site.

The seedling survival percentage of other tested Douglas-fir provenances at the locality Tanda did not deviate more than by one standard deviation compared to the average for the oak site.

4. CONCLUSION

It was concluded that the percentage of survived Douglas-firs of different provenances varied in a very wide interval: provenance 27 (Oregon 205–08) accounted for 95.8 %, on Juhor and provenance 9 (Washington 204–07) accounted for 63.8 %

In the experiment at Tanda, the highest survival percentage was achieved by provenance 21 and it accounted for 98.62 % and the lowest survival was that of the provenance 29 and it accounted for 37.50%

Based on the previous study of the analysis of dependence of the survival percentage of Douglas-firs of different provenances on latitude, longitude and altitude (Lavadinović 1996), it was concluded that:

- with the increase of latitude, the survival percentage decreases insignificantly;
- of the total variability of survival percentage 35.2 % is explained by the effect of longitude and with the increase of longitude the survival percentage increases slightly;
- of the total variability of survival percentage, only 10.1% is explained by the effect of altitude, i.e. with the increase of altitude the survival percentage decreases;
- the variation in the survival percentage of biannual plants, 50 %.can be explained by the mutual effects of geographical coordinates and altitude.

Based on the results of the studied dependencies, it can be concluded that in the Douglas-fir introduction, the geographical characteristics of seed origin must also be taken into account.

Based on the results of the study of Douglas-fir introduction at the beech site in Serbia, we can recommend the provenances designated as 27, 26, 2 and 22, whereas the provenances 26 and 9 should not be introduced to the beech site, in any case. Provenances 21, 3, 4 and 8 are recommended for the introduction of Douglas-fir to the oak site, and provenances 12, 20, 19 and 29 should not be implemented.

The genetic differentiation among Douglas-fir populations is closely related to the environment (Rehfeldt, 1982). The ecology of the area reflects the biogeoclimatic diversity of Douglas-fire sites and populations in North America and Canada. The selection of provenances must be carried out during the process of species introduction to the new ecological conditions. Forest breeders know that and species introduction brings also the risk that the introduced species will not be productively adapted to the new ecological conditions and the provenances should be tested.

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SIGNIFICANCE OF GENETIC POTENTIAL OF DOUGLAS-FIR INTRODUCED PROVENANCES IN SERBIA FOR THE RANKING OF THEIR ADAPTATION TO CLIMATE CHANGES

Vera LAVADINOVIĆ, Vasilije ISAJEV, Zoran MILETIĆ

Summary

Douglas-fir *(Pseudotsuga menziesii)* is one of the most important and most valuable coniferous species in North America. Douglas-fir natural distribution in the west part of North America. Douglas-fir latitudinal range is the greatest of any conifer in the western North America. Its native distribution extends from British Columbia along the Rocky Mountains into the mountains of central Mexico establishing typical varietet of coastal and continental Douglas -fir. Such wide native range of Douglas-fir need to be tested by provenace test in the aim of selections the best adapted on climate, geological and vegetative conditions in Serbia. The Institute of Forestry established the provenance tests in Serbia to distinguish the best ecologically adapted and the most productive provenances orginated from Nort America. The number and percentage of survivals in the experiment are some of the best indicators of the adaptation of introduced species, as well as the relation of genetic variation and the environmental gradient. The ranking differences of the same provenances at two localities show that climate conditions and site conditions indicate clearly the degree of plant adaptation.

ZNAČAJ GENETSKOG POTENCIJALA INTRODUKOVANIH PROVENIJENCIJA DUGLAZIJE U SRBIJI ZA RANGIRANJE ADAPTIVNIH NA KLIMATSKE PROMENE

Vera LAVADINOVIĆ, Vasilije ISAJEV, Zoran MILETIĆ

Rezime

Duglazija *(Pseudotsuga menziesii),* je jedna od najvažnijih i najvrednijih vrsta četinara u Severnoj Americi, i glavna je komponenta zapadnih šuma Severne Amerike. Rasprostranjenje duglazije po geografskoj širini je najveće od bilo kog drugog četinara u zapadnoj Severnoj Americi. Areal koji počinje u Britanskoj Kolumbiji, duž obale Pacifika, preko Stenovitih planina do planina centralnog Meksika stvara varijetet primorske i kontinentalne duglazije. Tako širok prirodni areal vrste podrazumeva testiranje putem provenijeničnog testa u cilju izbora najadaptivnijih na klimatske, pedološke i vegetacijske prilike. To je bio i razlog osnivanja dva provenijenična testa u Srbiji od strane Instituta za šumarstvo sa originalnim poreklom semena duglazije, različitih provenijencija iz Severne Amerike. Broj i procenat preživljavanja biljaka u postavljenom ogledu, jedan su od najboljih pokazatelja adaptacije introdukovanih vrsta kao i odnos genetske varijacije i gradijenta životne sredine. Različitost u rangiranju istih provenijencija na dva lokaliteta pokazuju da klimatski uslovi i uslovi staništa jasno pokazuju stepen adaptivnosti biljaka.

THE ASSESSMENT OF ADAPTABILITY OF EUROPEAN SILVER FIR, NORWAY SPRUCE AND COMMON BEECH IN PROVENANCE EXPERIMENTS

Roman LONGAUER[1], Dušan GÖMÖRY[2], Marian PACALAJ[1], Diana KRAJMEROVÁ[2]

Abstract: *Climate change is expected to have largely unpredictable effects on forest ecosystems. Reliable information about adaptability of forest tree species is therefore critically important for planning any mitigation and adaptation measures.*

If more samples (provenances) from different source populations of a studied species are represented, a provenance experiment allows studying their reaction to changed sites, role of genetic factors and intraspecific variation. If a bigger set of provenances is tested on more plots in different environments, a general reference about the species' climatic adaptability and plasticity can be obtained.

Our study focused on 3 main species of the mountain forests of Central Europe: In Norway spruce, we evaluated growth and survival of 49 provenances on a series of 5 plots along an altitudinal gradient covering its whole cultivation range in Slovakia. In European silver fir, we compared 45 provenances at 2 plots in Central Slovakia. In common beech, growth, survival and vegetative phenology of 100 and 32 provenances were studied at 2 provenance plots established on typical beech sites in Slovakia.

To assess the reactions of provenances to transfer, we used the regression approach of Rehfeldt et al. (1999). Optimum transfer rates were derived from quadratic regressions between the survival, growth and phenology of individual provenances and/or species and ecodistances (differences in geographical coordinates or ecological variables between source populations and locations of trials). The emphasis was on the effects of climatic parameters including temperature, precipitation and vegetation period.

All three species tended to grow and survive better when their provenances are transferred to somewhat lower altitudes, where the positive effect of longer vegetation was more important than increasingly deficient precipitation. The altitudinal interval with positive responses was broader in common beech than Norway spruce. Within species, local provenances were not necessarily the best responding to changed site conditions regarding the growth (Norway spruce, silver fir), survival (all species), and vegetative phenology (common beech).

Key words: provenance experiments, adaptability, Picea abies, Abies alba, Fagus sylvatica

1. INTRODUCTION

Survival, growth, as well as the phenology and its control (photoperiod, temperature, both) are still more seriously viewed as indicators of adaptability of forest tree species. The latter is, at the same time and by no means, critically important for designing any practical mitigation and adaptation measures.

Provenance (common-garden) experiments, purpose of which is to study the behavior of samples of forest tree species (provenances) representing different source populations, may provide

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Acknowledgement: The study was supported by a research grant no. APVV-0441-07 of the Slovak Research and Development Agency.

very useful information in this respect: They allow studying their responses to the change of site conditions with focus on the role of genetic factors and intraspecific variation in their reactions. If more provenances are tested in a series of plots in different environments, a general reference about the species' climatic adaptability and/or plasticity can be obtained (e.g., MÁTYÁS 1996).

Pursuing the aforementioned assumptions, we evaluated the provenance experiments with Abies alba, Picea abies and Fagus sylvatica, established in different times using different experimental designs, trying to:

- Evaluate the effect of ecodistances between source populations and planting sites on the survival and growth of provenances;
- Compare weigths of various predictor variables – with a focus on the climatic factors;
- Obtain, where possible, more general information about the adaptability of the studied species to a climate change in a mountainous landscape.

The inclusion of climatic factors was possible thanks to the availability of a more detailed climatic model of Slovakia (HLÁSNY & BALÁŽ 2008). This model is based on records of temperatures from 170 and precipitation from 55 stations, and accommodates also mesoclimatic phenomena important for the mountainous landscapes, like:

- Local altitudinal gradients in temperature & precipitation.
- Slope aspect influencing, through insolation, also temperature and evaporation.
- Shading effects of mountain ridges influence precipitation.
- Specific inner-mountain climate patterns.
- Area-specific trends in the continentality.

The model has made more accurate estimates of many climatic variables possible, of which we focused on the mean temperatures, precipitation and annual number of days warmer than 0, 5 and 10 °C.

2. MATERIAL

European silver fir: Two provenance plots established in Central Slovakia in 1970 were evaluated: Dubová-Slovenská Lupča, altitude 600 m with 30 provenances, and Jedľová-Sihla, altitude 980 m, with 16 provenances.

Norway spruce: The series of 5 plots with 49 provenances, established along an altitudinal gradient from 450 and 1,270 meters in Central Slovakia. It is a spin-off of the IUFRO Experiment 1964-68. Of 49 provenances from all of Central and Southeast Europe, the effects of climatic variables were studied in 15 provenances from Slovakia, where the most detailed climatic data were available for the source populations.

European beech: The assessments were done at the Slovak plot (Tale, Central Slovakia, altitude 805 m a.s.l.) of the range-wide provenance experiment established in 1995 and 1998 under the coordination of the Federal Research Centre for Forestry and Forest Products, Hamburg, Germany. The series includes more than 200 provenances planted at 45 plots representing much of the natural range of this species. A complete assessment of the series was accomplished within the EU COST Action E52 "Evaluation of Beech Genetic Resources for Sustainable Forestry".

All provenance plots were established in a randomized complete block design with 4 (silver fir) or 3 (Norway spruce, common beech) repetitions.

3. METHODS

The height, diameter at the breast height and survival of provenances were assessed on the provenance plots at the age of 30 years in silver fir, 40 in Norway spruce and 10 in common beech.

Besides, the spring phenology (timing of budburst) was scored in common beech. Subsequently, the growth characteristics were tested against predictor variables defined as ecodistances (differences) between the source provenances and planting sites in:

- Geographic coordinates: latitude, longitude, altitude;
- Mean temperatures: Annual, April-September, July;
- Mean precipitation: Annual, April-September, July;
- Anual number of days with mean temperture over 0, 5 and 10°C.

In the case of Norway spruce, where a series of plots along an altitudinal gradient was evaluated, we used the regression approach of REHFELDT et al. (1999). It allowed to derive optimum transfer rate from a quadratic regression between the survival, growth or phenology of individual provenances (response variable) and/or species and ecodistance (predictor variable), as the ecodistance at which regression function reaches maximum.

4. RESULTS

European silver fir:

To make information about different sets of provenance at 2 provenance plots comparable, the heights, diameters and survival rates of individual provenances were expressed as a percentage of grand means for all provenances at a respective plot. At the both plots located in Central Slovakia, local provenances lagged behind those from other regions. Particularly the provenances from Northeastern Slovakia were performing better. These are considered to be a genetic transition between the Alpine and Balkan gene pools of Abies alba according to the studies based on mtDNA and isozyme gene markers (GÖMÖRY et al 2004, LONGAUER 2001). Despite of no parallel plots, correlations were found between the growth of provenances and ecodistances of source populations and planting sites in the environmental variables (Table 1).

Table 1. *Correlations between the mean height, DBH and survival of Abies alba, and ecodistances between planting sites and source populations of provenances in selected environmental variables (+ is positive, - is negative at P>95%).*

Variable	*Mean height*	*Mean DBH*	*Survival*
Δ Altitude	+	+	+
Δ Mean annual temperature	+	No	+
Δ Mean temperature of July	+	+	+
Δ Mean temperature May-September	+	+	+
Δ Number of days with temp. > 0°C	+	No	+
Δ Number of days with temp. > 5°C	+	+	+
Δ Number of days with temp. > 10°C	+	+	+
Δ Mean annual precipitatation	-	No	-
Δ Mean precipitaton of July	-	No	-
Δ Mean precipitation May-September	-	No	-

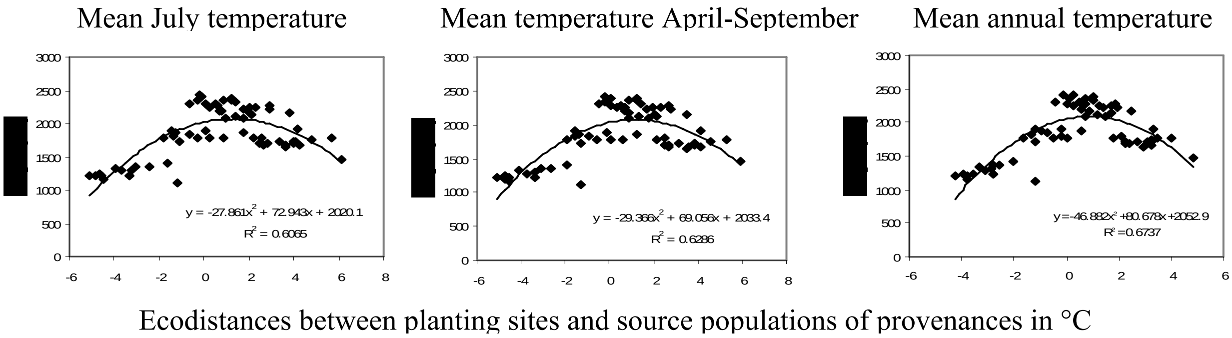
Norway spruce:

Information from 5 parallel plots conaining the same set of provenances planted along an altitudinal gradient has made a robust assessment of G×E interactions possible: The majority of autochthonous Norway spruce provenances tended to grow better at lower altitudes, in warmer climates with less precipitation. The exceptions were high-altitude provenances which grow and survive better when moved also upwards.

Table 2. *Correlations between the mean height, DBH and survival of Picea abies, and ecodistances between planting sites and source populations of provenances in selected environmental variables (+ means positive and - negative at P > 95%).*

Variable	*Mean height*	*Mean DBH*	*Survival*
Δ Altitude	+	+	+
Δ Mean annual temperature	+	+	+
Δ Mean temperature of July	+	+	+
Δ Mean temperature May-September	+	+	+
Δ Number of days with temp. > 0°C	+	+	+
Δ Number of days with temp. > 5°C	+	+	+
Δ Number of days with temp. > 10°C	+	+	+
Δ Mean annual precipitatation	-	No	-
Δ Mean precipitaton of July	-	-	-
Δ Mean precipitation May-September	-	No	-

Figure 1: *Regressions between the mean height of Picea abies and difference in mean temperatures between source populations of individual provenances and individual provenance plots.*



The maxima of individual regression functions indicate that regarding the growth of Norway spruce, the altitudinal optimum of Norway spruce is 120 m below the mean altitude of the source populations of provenances in Western Carpathians. The mean annual temperature is by 1,27 °C higher, number of warmer days almost 20 days despite the annual precipitation smaller by 106 mm. The growth and survival of provenances were most closely correlated with the ecodistances between source populations and plantation sites in the case of mean annual temperature (Table 2).

Table 3. *Growth and survival of provenances at the Slovak plot of the international beech experiment BFH 1998 at the age of 15.*

Variable	r^2	*Regression*	*Max f*
Δ altitude	0.596	$y = 20.74590 - 0.00338x - 0{,}00001x^2$	-120 m
Δ mean annual temperature	0,695	$y = 20{,}87847 + 0{,}48911x - 0{,}19216x^2$	+1,27 °C
Δ no of days with mean temp. over 10°C	0,570	$y = 20.75246 + 0.02214x - 0{,}00054x^2$	19,46 day
Δ annual precipitation	0,452	$y = 20.62452 - 0{,}00276x - 0{,}00001x^2$	-106 mm

European beech:

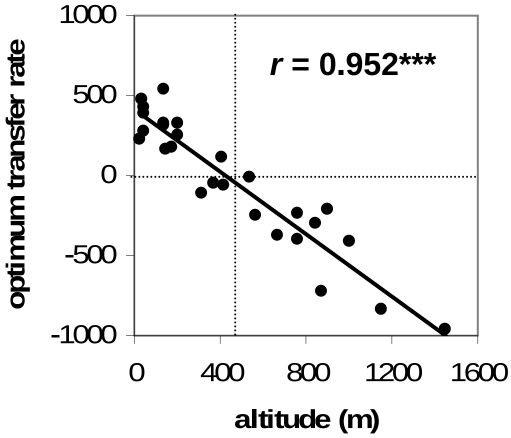
Clear geographic trends in the response of beech provenances to transfer in growth and survival were found. Significant negative correlations between the response and all types of ecodistances indicate that due to a considerable phenotypic plasticity, beech can survive in suboptimum conditions, although it remains adapted to the optimum ones.

Table 4. *Correlations between the optimum transfer rates considering height and survival response of Fagus sylvatica to transfer measured by ecodistances in selected environmental variables.*

Variable	*Height growth*	*Survival*
Longitude	–0.525***	–0.506***
Latitude	–0.742***	–0.531***
Altitude	–0.861***	–0.659***
Mean annual temperature	–0.624***	–0.887***
Total annual precipitation	–0.707***	–0.637***

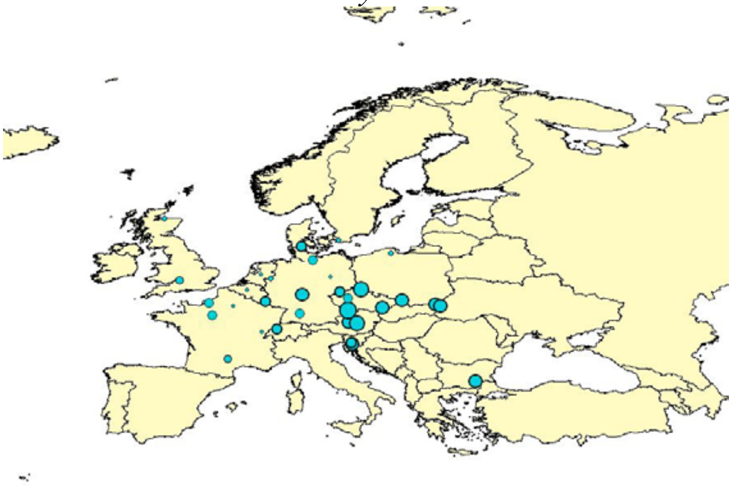
The optimal altitude for European beech defined as the altitude, where the local provenances prefer local climate (i.e. optimum transfer rate is zero) is 430 m, what is 250 m less the mean altitude of source populations.

Figure 2: *Regression of optimum transfer rates based on height-growth response to altitudinal transfer against the altitude of provenances*



Phenological traits exhibit a rangewide east-west trend. Eastern provenances flush earlier and also start autumn leaf discoloration earlier. Early flushing causes potential damage by late frosts in the spring (Fig. 3).

Figure 3: *Phenological response: Late frost damage at the Slovak plot of the beech experiment BFH 1998. The larger the circle on the picture, the stronger frost damage was observed in May 2007.*



5. DISCUSSION AND CONCLUSIONS

1) A major part of autochthonous of Abies alba, Picea abies and Fagus sylvatica tend to perform better in a warmer climate at lower altitudes than is the average of their ranges in Central Europe. This means that there exist climatic buffers in regard to the optimum altitude for the growth: approximately 100 m in Norway spruce and 250 m in the case of beech (GÖMÖRY, submitted).
2) Temperature increase and drought risk do not pose a direct and immediate threat to Norway spruce provided that:

- Precipitation is still sufficient,
- Pests and diseases can be controlled in Norway spruce - which is unlikely, however.

3) The factors of limiting ecoplogical importance at the receding (lower and southern) distribution limits are probably not the same in regard to different forest tree species. In Norway spruce, the effects of climate change are manifested by the increased pressure of insect pests and fungal diseases. In common beech and European silver fir, competition by other plant species (e.g. limiting their natural regeneration) is more important probably.

Methodological aspects: The first common garden experiments with forest trees date back to the beginning of the 20th century. It may be therefore a matter of question, whether conventional, low-tech field trials deliver any added value in comparison with experiments done in cotrolled conditions and using advanced technologies. Our results suggest that information from provenance experiments is relevant while several conditions are met:
- A set of provenances is representative of a species and derived from mostly autochthonous source populations. Robust provenance samples are important to avoid drift due to inadequate sampling. Therefore, several provenances would represent each region of provenance and each sample should comprise half-sib progenies of at least 10 trees.
- An experiment consists of a series of plots covering the range of environments where the studied species are present naturally or cultivated. For instance, a similar series of 5 plots with Norway spruce (belonging to the IUFRO Experiment 1972) suggests different linear trends just because its individual plots cover only the lower part of the altitudinal range of the studied species.

The chance to get reliable information for modeling of effects of climate change on forest tree species using provenance experiments was improved by the availability of regionally to locally adjusted climatic models (delivered, e.g., by the EU FP-6 project CECILIA „Central and Eastern Europe Climate Change Impact and Vulnerability Assessment").

Several limitations of provenance experiments need to be considered, however:

- Environmental factors, particularly the climatic ones, cannot be controlled
- Climate variables cannot be separated from other site characteristics (soil). Moreover, effects of precipitation cannot be studied along altitudinal gradients due to their co-linearity with altitude.

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AFFORESTATION, SILVICULTURE, FOREST ECOLOGY AND CLIMATE CHANGES

PLENARY LECTURES

International Scientific Conference
FOREST ECOSYSTEMS AND CLIMATE CHANGES
March 9-10th, 2010., Institute of Forestry, Belgrade

THE CLIMATE CHANGE AND FOREST ECOSYSTEMS

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Abstract: *The current global climate models were based on the data which prevents the detailed spatial structure of the variables, mainly temperature and precipitation above the homogenous areas. In the aim of the reduction of the disadvantages of the current global climate projections it is necessary to use the regional models and models of influnce in the forecasts in the aim of the quantification, accuracy and uncertainties . It is necessary to incorpate the results of these models in the activities which enable the timely adaptation to the climate change and their alleviation (if it is possible). Based on the models and scenarios it can be concluded that over a relatively short period the drastical change in the number and structure of the forest ecosystems in Serbia will occur. The previous concept of the multi-purpose planning system in each individual goal (general or specific) and methods for the achivement must be analyzed separately in regard to the climate change as one of the basic factors of risks. Given the above warning facts and the adverse effects of the climate change in the forest ecosystems and environment in general, these are not the goals for future but the obligations of the present. The guides to the forest management planning should determine the desirable characteristics of the management system at the operational level, and the guidelines for the forest management in a great detail determine the activities which should be used in the forestry.*

Key words: cllimate models, acumulated temperature, biotope, climatic scenarios, forest managemant

INTRODUCTION

The global changes are the changes in the inorganic world, as well as in the human activity and in the society in general, which occur as the result of the impact of the climate change, and intensify or weaken, which depends on their intensivity.

The climate change significantly influences the occurrence of the new approaches in the forestry, caused by the effects of the global and regional climate change (as a result of the study of the different climate scenarios, changes in the concentration of the gas with the “glass house“effect condition of the ozone layer, changes in the intensity of the ultraviolet radiation, etc.).

The results of these studies should be used for the determination of the following:

• Reaction of the forest ecosystems to the climate change;

• Impact of the climate change on biodiversity;

• Degree of the impact and reaction of the species to the climate change;

• Impact of the global climate change and the possibility of the creation of new species and sub-species for the conditions of the altered clime;

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20056 „High-resolution satellite images in the collection and processing of spatial information on forests and forest ecosystems“
Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20052 „Changes in forest ecosystems affected by global warming“

•Occurrence of weed and invasive species, insects, and plant diseases, etc.

The Earth will be faced up with the new large-scale extinction of the plant and animal species, similar to the extinction of the dinosaurs which occurred about 65 million ago. By the human activity many sites were destroyed, which are most frequently fragmented or damaged by the long-term pollution by the various sources.

In the previous century the increase of the global temperature pointed to the serious climate disturbances, caused by the anthropogenic influences, mainly by the combustion of the high quantities of fossil fuels and by the release of the carbon dioxide and other gases in the atmosphere, which made the effect of the "glass house". It is anticipated that it will cause the significant climate change in this century as well. The increase of the global average temperatures by 5 degrees by 2050 is anticipated. This global warming will cause the melting of the polar ice caps and mountain glaciers, as well as the significant increase in the ocean and sea levels. The global warming by the end of the century might cause the extinction of the quarter of the land plant and animal species.

By the application of the models the influence of the minimal, average and maximal possible global change of temperature on 1,100 plant and animal species, which inhabit certain regions, was determined.

Under the very moderate scenario (which is considered to be unrealistic by most researches), about nine percentage of the species would be threatened with the extinction, whereas the other would migrate to new areas fabourable for inhabiting. It means that out of about 10 million species, about one million would be doomed. By using the climate model with the average change (the moderate scenario) by 2050 between 15 and 37 percentage of the species would be in danger of extinction. Under the extreme scenario (which is most feasible due to the current anthropogenic activities), between a third and half of the land plant and animal species will be faced up with the complete extinction. Therefore, it is necessary to take serious and urgent actions aimed at mitigation of the effects of the climate change. In this regard, the emissions of the glass house gases must be reduced. In addition, the felling of the tropical forests and destruction of the forest ecosystems must be stopped. Finally, it is needed to find new and efficient solutions in the domain of energy, as well as to find new strategy for the reduction of the current concentrations of carbon dioxide in the atmosphere.

THE CHANGE OF THE CLIMATE CHARACTERISTICS

The average global temperature (of land and ocean) was by 2007 by 0.8^0C higher than the average global temperature in the pre-industrial period (average values for the period 1850-1899). Only for the land the average global temperature was higher by 1^0C. The growth of rate of the average global temperature increased by 0.1^0C per decade over the last hundred years, and by 0.2^0C in the previous decades. The best estimations for the projected global warming during this century are the further increase of the average temperature by 1.8 - 4^0C for the different scenarios (under the scenario E, the global air temparure above the sea and mainland can by 2090 increase even by 6.1^0C, with the increase of CO_2 concentration by 2030 by +90 to +140%).

Europe is getting warmer to a larger extent than the global average. The average annual temperature for continental Europe in 2007 was by 1.2^0C higher in comparison to the pre-industrial period, and for the combined areas of mainland and sea by 1^0C. Eight to twelve years between 1996 and 2007 were the warmest since 1850. By using the climate models, obtianed by the different scenarios of climate change, it is anticipated that the annual temperatures will increase by 1 to 5.5^0C in this century. In winter the greatest degree of warming is expected to occur in East and North Europe, whereas in summer in Southwestern and Mediterranean part of Europe.

The estimations, based on the climate modelling, under the moderate scenarios, point to the fact that the annual temperature in Europe by the end of the century will increase by 2.6^0C. The melting will not be uniform over the year; summer will be warmer by 3.5^0C, autumn by 2.2^0C, winter by 2.2^0C, and spring by 2.5^0C. Under the most unfavourable scenario, it is expected that the annual air temperature will increase by more than 5^0C.

The extreme cold weather conditions will be less frequent, and the extreme heats will be more and more frequent, as well as the increase of the frequency, intensity and duration of heat waves. The number of the frost and rainy summer days (under this scenario) will continue to decrease.

In Serbia, under the moderate scenario, the decrease of the quantity of precipitation by 15-25% is expected, whereas under the most unfavourable scenario the quantity of precipitation will decrease by even 50%.

It is expected that the strong rains will be more frequent in Europe. The intensity of the strong rains has increased over the last 50 years, even in the areas will lower quantity of precipitation (Central Europe and Mediterranean). In addition, the duration and frequency of the dry periods in South and Southest Europe will be prolonged.

The increase of the frequency, intensity, and duration of drought, which is the result of the increase of temperature, decrease of the summer precipitation and greater number of the longer drought periods, has been already registered in Serbia. This trend will be particularly expressed in Southeastern and Eastern Serbia.

The change of the climate parameters is more intensive than the natural ability of many species to adapt to the new conditions. It is particularly reflected in the fact that the areas have been fragmented, which will limit the shifts. The climate change during the mild winters caused the shift of numerous plant species in Europe to the north and higher altitudes. The mountain ecosystems in many parts of Europe are changing, the species which are adopted to the cold weather are being driven from their previous sites by the species which are adopted to the warmer climate. By the end of the 21st century, the distribution of the European plant species will have been shifted several hundred kilometers to the north, the range of the forests will be narrowed on the south and extended on the north, and 60% mountain plant species will probably disappear.

The accelerated leaf formation and blooming, which is the result of the climate change, was reported in 78% species (averagely 2.5 days per decade over the period 1971-2000). These trends will be accelerated over the following period.

THE CLIMATE CHANGE AND FOREST ECOSYSTEMS

The adverse effects will be particularly reflected in the occurrence of the extreme atmospheric events, such as drought, storms, extremely high temperatures, intensive erosion processes, as well as in the occurrence of the plant diseases and pests. Serbia is located in the area with the most frequent droughts. It is expected that the growing season will be prolonged.

Owning to the increase of the average annual air temperature the climate, and thereby, the vegetation zones, will shift to the poles and higher altitudes. The change of temperature by 1^0C will cause the shift of the vegetation to the north by 200 to 300 km, as well as the shift to the higher altitudes by 150 to 200 m.

Not only will the global warming cause the shift of vegetation to the poles and higher altitutes, but also the change of their structure. The desiccation of trees (forests) will be increased, due to the unfavourable ecological site conditions and the increase of the enthomological and phytopathological diseases. Furthermore, the climate change will also cause the alternations in the growth rate of some species,and hinder the natural regeneration,owning to the change in the site moisture. It is also expected that the wildfires and atmospheric catastrophies will occur more frequently.

The climate change will cause the changes in the natural ecosystems, not only in regard to their dislocation, but in their structure as well. The biological possibility of adaption will decrease, and the diversity will be limited. Therefore, the associations and species with the limited possibilities of adaptation are most endangered.

The greatest problem in the adaptation of the forests and shrub associations to the climate change is the rate of their alternations. However, it is expected that the application of the appropriate methods in the forest ecosystem management will alleviate the ecological and social-economical effects of the deterioration of forests.

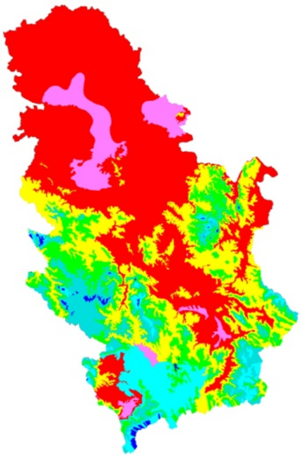
THE MODEL OF THE CLIMATE CHANGE BASED ON THE ACCUMULATED TEMPERATURES HIGHER THAN 5.6^{0}C

The system of classification of Serbian sites is based on EUNIS system of site classification. The site is defined as the "place inhabited by plant and animal species, which is above all characterized by the physical conditions (topography, plant or animal physionomy, soil characteristics, climate, water quality, etc), and then by the plant or animal species which live there".

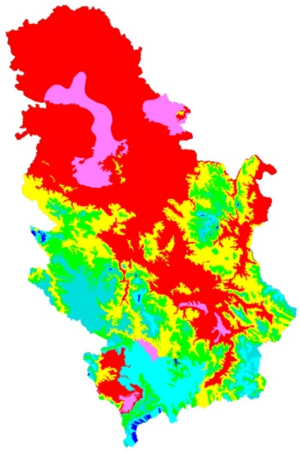
It is very important to monitor the changes of the ecological site conditions and their spatial distribution during the climate change. In order to achieve this goal, the model of change of the accumulated temperature >5.6^{0}C, depending on the increase of the anticipated temperatures by 1^0, 2^0, 3^0, 4^0 i 5^0 (Table 1 and Graphs 1-6) is constructed.

Table 1. *Model of the change of the accumulated temperatures >5.6^{0C} depending on the increase of the anticipated temperature*

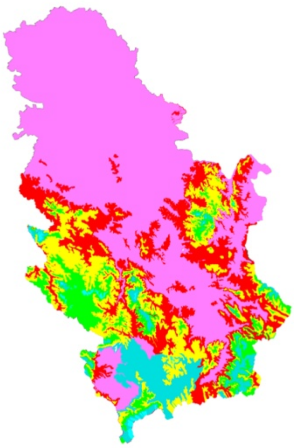
Altitude	Accumulated temperatures	The increase of temperatures by				
		1^0	2^0	3^0	4^0	5^0
100						
200						
300						
400						
500						
600						
700						
800						
900						
1000						
1100						
1200						
1300						
1400						
1500						
1600						
1700						
1800						
1900						
2000						
Above 2100	The altitudinal zones registered in Prokletijske Mountain and Miroc					



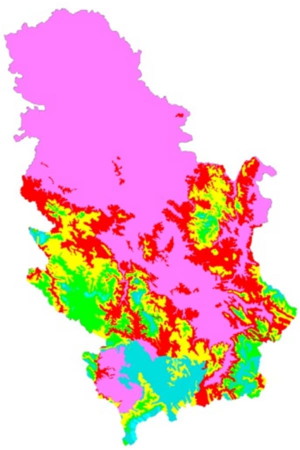
Map 1: *Accumulated temperature for the multi-annual average*



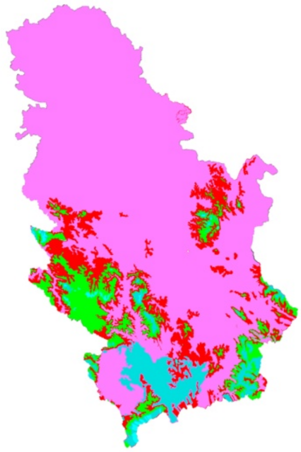
Map 2: *Accumulated temperatures for the increase by 1^0 in comparison with the multi-annual average*



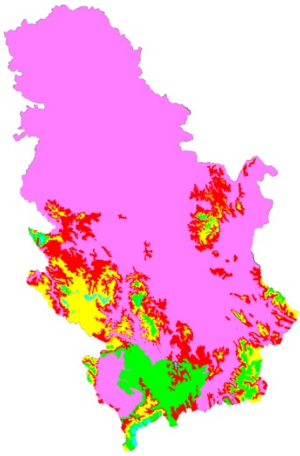
Map 3: *The accumulated temperature for the increase by 2^0 in comparison with the multi-annual average*



Map 4: *The accumulated temperature for the increase by 3^0 in comparison with the multi-annual average*



Map 5: *The accumulated temperature for the increase by 4^0 in comparison with the multi-annual average*



Map 6: *The accumulated temperature for increase by 5^0 in comparison with the multi-annual average*

Based on these parametes, as well as on the ecological characteristics of each individual sites and main species, the forecast of the survival of all forest and scrub sites registered in Serbia, has been made.

This model includes all site peculiarities: location, size of mountain massif, bedrock, type of climate, altitudes, exposition and microclimate conditions, possibility of extending of association (limited by the orographic conditions), etc. In this way the realistic forecast of the ecological conditions was obtained. The term SITE DISSAPPERANCE refers to the drastical change of the ecological site condtions in which the association lives today.

G – FORESTS AND FOREST SITES AND OTHER REFORESTED AREAS

G1 –BROADLEAF DECIDUOUS FORESTS								
G1.1 – Riparian willow (Salix), alder (Alnus) and birch (Betula) forests		**Climate**	**Altitude (m)**	**Increase of the air temperature**				
				1⁰	**2⁰**	**3⁰**	**4⁰**	**5⁰**
G1.111	Mid-European white willow forests (Salix alba)	MC	200-700	a, c,d	b,c, d	b,d	A	A
G1.1141	The continental willow (Salix) galleries on the recent alluvial deposits	P	Up to 250	a, b	b	A	A	A
G1.1142	The continental (Salix) galleries on the gley soils	P	Up to 250	a, b	b	A	A	A
G1.115	The fluvial willow and poplar forests	MC and CP	Up to 500	a,b	c	A	A	A
G1.116	The fluvial white willow (Salix alba) forests	MC and CP	Up to 300	a,b	c	A	A	A
G1.117	The fluvial black alder (Populus nigra) forests	MC and CP	Up to 500	a,b	c	A	A	A
G1.118	The fluvial gray poplar (Populus canescens) forests	MC and CP	Up to 300	a,b	c	A	A	A
G1.119	Fluvial mixed black poplar (Populus nigra) and white poplar (Populus alba) forests	ML	Up to 300	a,b	c	A	A	A
G1.1211	Mountain monodominant gray alder (Alnus incana) galleries	MC and M	600-1,400	a,b, c,d	a,b, c,d	b,c, d	b	A
G1.1212	Mountain gray alder (Alnus incana and black alder (Alnus glutinosa) galleries	MC and M	1,100-1,200	e,a	e,a	A	A	A
G1.1213	The mountain gray alder (Alnus incana) galleries with hornbeam (Carpinus betulus)	MC, H, and M	600-900	a,c, d	a,c, d	c,d	c,d	c,d
G1.2 – Ash-aspen (Fraxinus)-(Alnus) and oak - (Quercus)-elm (Ulmus)-ash (Fraxinus) forests along the little rivers								
G1.211	Ash-aspen (Fraxinus)-(Alnus) forests along brooks and springs							
G1.212	Ash-aspen (Fraxinus) - (Alnus) forests along the fast rivers							
G1.2121	Southeastern-European black alder (Alnus glutinosa) forests along the fast rivers	MC, H and M	400-1,400	b, c,d	b,c, d	b,c, d	c,d	A
G1.2231	Mixed forests of narrow-leaved ash (Fraxinus angustifolia) and pedunculate oak (Quercus Robus) along the great rivers	MC and M	Up to 250	a,b	a,b	a,b	A	A
G1.2232	Mixed forests of hairy-leaved ash (Fraxinus pallisae) and pedunculate oak (Quercus Robus) along great rivers	CW	Up to 40	a,b	a,b	A	A	A
G1.2233	Mixed forests of narrow-leaved ash (Fraxinus angustifolia), pedunculate oak (Quercus robus) and hornbeam (Carpinus betulus) along the great rivers	MC and CP	Up to 300	a,b	a,b	A	A	A
G1.2234	Hygrophilic pedunculate oak	MC and	Up to 300	a,b	a,b	A	A	A

	(Quercus robur) and hornbeam (Carpinus betulus) forests	CP						
G1.2235	Hygrophilic pedunculate oak (Quercus robur) and white poplar (Populus alba) forests	MC and CP	Up to 300	a,b	a,b	A	A	A
G1.2236	Hygrophilic pedunculate oak (Quercus robur) and black poplar (Populus alba) forests	MC and CP	Up to 300	a,b	a,b	A	A	A
G1.241	Hygrophilic common elm (Ulmus campestris) forests	CP	Up to 200	a,b	a,b	A	A	A
G1.4 – Broadleaved swamp forests which do not thrive on the acid peat								
G1.412	Steppe swamp black alder (Alnus glutinosa) forests	CP	Up to 300	a,b	a,b	A	A	A
G1.42	Swamp oak (Quercus) forests	MC and CP	Up to 100	a,b	a,b	A	A	A
G1.44	Swamp narrow-leaved (Fraxinus angustifolia) forests	CP	Up to 100	a,b	a,b	A	A	A
G1.5 – Broadleaved swamp forests on the acid peat								
G1.51	Birch (Betula) forests on sfagnum	M and N		e	A	A	A	A
G1.52	Swamp alder (Alnus) forests on acid peat	M and N		e	A	A	A	A
G1.6 – Beech (Fagus) forests								
G1.6911	Moesian monodominant montane beech forests	MCMH	40-1300	c,d	c,d	c,d	c,d	c,d
G1.6912	Moesian hilly beech forests with the common walnut (Juglans regia)	MCMH	30-300	b	b	A	A	A
G1.6913	Moesian hilly beech forests with linden (Tilia) spp.	MCMH and CP	200-600	c,d	c,d	c,d	c,d	c,d
G1.6914	Moesian hilly beech forests with sessile oak (Quercus petraea)	MCMH and CPH	400-800	c,d	c,d	c,d	c,d	c,d
G1.6915	Moesian hilly beech forests with European holly (Ilex aquifolium)	MCMH	400-800	c,d	c,d	c,d	c,d	c,d
G1.6916	Moesian hilly beech forests with butcher's broom (Ruscus aculeatus)	MCMH	250-450	c,d	c,d	c,d	c,d	c,d
G1.6917	Moesian hilly beech forests with tutsam (Hypericum androsaemi)	MCIH	350-600	c,d	c,d	c,d	c,d	c,d
G1.6921	Moesian montane beech forests with woodrush (Luzula) spp.	MCMM	600-1,600	c,d	c,d	c,d	c,d	c,d
G1.6922	Moesian mountane beech forests with moss	MCMM	700-1,400	c,d	c,d	A	A	A
G1.6923	Moesian montane beech forests with bilberry (Vaccinium myrthyllus)	MCMM	500-1,400	c,d	c,d	c,d	c,d	c,d
G1.6924	Moesian montane beech forests with dear hern (Blechnum spicant)	MCMM	500-1,400	c,d	c,d	c,d	c,d	c,d
G1.6925	Moesian montane beech forests with chestnut (Castanea sativa)	MC MIM	400-600	c,d	c,d	c,d	c,d	c,d
G1.6926	Moesian monodominant acidophilious beech forests	MCMM	600-1,200	c,d	c,d	c,d	c,d	c,d
G1.6931	Moesian montane beech forests with European hop hornbeam (Ostrya carpinifolia)	MCMIM	300-1,000	c,d	c,d	c,d	c,d	c,d
G1.6932	Moesian montane beech forests with autumn moor grass (Sesleria autumnalis)	MCMIM	600-1,200	f,b	f,b	f,b	F,b	A
G1.6933	Moesian montane beech forests with evergreen sedge grasslands (Sesleria rigida)	MCMIM	>1,000	f,b	f,b	f,b	f,b	A
G1.6934	Moesian montane beech forests with common yew (Taxus baccata)	MCMIM	800-1,100	f,b	f,b	f,b	A	A
G1.6941	Moesian monodominant montane beech forests	MCMM	500-1,600	c,d	c,d	c,d	c,d	c,d
G1.6942	Moesian montane beech forests with	MCIMM	650-750	c,d	c,d	c,d	c,d	c,d

	European holly (Ilex aquifolium)							
G1.6943	Moesian montane beech forests with cherry laurel (Prunus laurocerasus)	MCMM MCMSM	1,200-1,300	f,c, d	f,c, d	f,c, d	f,c, d	f,c, d
G1.6951	Moesian monodominant Subalpine beech forests	MCMSM	1,400-1,800	b,c, d	b,c, d	b,c, d	b,c, d	b,c, d
1.6952	Moesian Subalpine beech forests with Greek maple (Acer heldreichii)	MCLMS M	1,300-2,000	c	c	c	A	A
G1.6953	Moesian Subalpine forests of Greek maple (Acer heldreichii)	MCMSM SA	1,500-1,600	c	c	c	A	A
G1.6961	Moesian relict polydominant beech (Fagus) forests with Turkish hazel (Corylus colurna)	H	200-1,300	g,b	g,b	g,b	?	?
G1.6962	Moesian relict polydominant beech (Fagus) forests with maples (Acer spp.)	H	300-500	g,b	g,b	g,b	?	?
G1.6C	Illyrian (Fagus) forests							
G1.7 – Terhmophilous deciduous forests								
G1.7321	Pannonian forests of downy oak (Quercus pubences) and oriental hornbeam	CP	Up to 300	h	h	h	h	h
G1.7322	Pannonian forests of downy oak (Quercus pubescens) and oriental ash (Fraxinus ornus)	CP	Up to 300	h	h	h	h	h
G1.7341	Moeasian forests of downy oak (Quercus pubescens)and European hop-hornbeam (Ostrya carpinifolia)	StEX	Up to 300	h	h	h	h	h
G1.7342	Moesian forests of downy oak (Quercus pubescens) and sessile oak (Quercus petraea)	StEx	Up to 300	h	h	h	h	h
G1.7343	Moesian forests of downy oak (Quercus pubescens) and Turkey oak(Quercus cerris)	StEx	500-700	f,d	f,d	f,d	f,d	f,d
G1.7344	Moesian forests of downy oak (Quercus pubescens) with peony	StEx	Up to 700	f,d	f,d	f,d	f,d	f,d
G1.735	Illyrian downy oak (Quercus pubescens) forests			h	h	h	h	h
G1.7511	Moesian monodominant sessile oak (Quercus petraea) forests on limestone	StEx	Up to 700	f,d	f,d	f,d	f,d	f,d
G1.7512	Moesian monodominant sessile oak (Quercus petraea) forests on serpentinite	StEx	350-1150	i,c, d	i,c, d	i,c, d	i,c, d	i,c, d
G1.7513	Moesian sessile oak (Quercus petraea) forests on serpentinite with European hop hornbeam (Ostrya carpinifolia)	StEx	600-800	i,h	i,h	i,h	i,h	i,h
G1.7514	Moesian sessile oak Quercus petraea) forests on seprentinite with European hop hornbeam (Fraxinus ornus)	StEx	600-800	i,h	i,h	i,h	i,h	i,h
G1.7515	Moesian sessile oak (Quercus petraea) forests on serpentinite with forsythia (Forsythya europaea)	StEx	Up to 500	i,h, d	i,h, d	i,h, d	i,h, d	i,h, d
G1.7516	Moesian sessile oak forests (Quercus petraea) on serpentinite with winter heath (Erica carnea)	StEx	700-900	i,h	i,h	i,h	i,h	i,h
G1.7517	Moesian sessile oak (Quercus petraea) forests on serpentinite with Oriental horbeam (Carpinus orientalis)	StEx	250-800	i,d, h	i,d, h	i,d, h	i,d, h	i,d, h
G1.7518	Moesian sessile oak (Quercus petraea) forests on serpentinite with glossy buckthorn (Frangula alnus)	StEx	250-800	i,d, h	i,d, h	i,d, h	i,d, h	i,d, h
G1.7519	Moesian sessile oak (Quercus petraea) forests on serpentinite with prickly juniper (Junipersu oxycedrus)	StEx	300-700	i,d, h	i,d, h	i,d, h	i,d, h	i,d, h
G1.751A	Moesian sessile oak (Quercus petraea) forests on serpentinite with European smoke tree (Cotinus coggygria)	StEx	400-800	i,d, h	i,d, h	i,d, h	i,d, h	i,d, h

G1.751B	Moesian sessile oak kitnjaka (Quercus petraea) forests on the limestone with the manna ash (Fraxinus ornus)	StEx	Up to 500	f,d, h	f,d, h	f,d, h	f,d, h	f,d, h
G1.752	Moesian oak forests (Quercus dalechampii)	MCM	700-1100	b,c, d	b,c, d	b,c, d	b,c, d	b,c, d
G1.7531	Moesian Turkey oak (Quercus cerris) forests on the limestone	StEx	Up to 800	f,d	f,d	f,d	f,d	f,d
G1.7532	Moesian Turkey oak (Quercus cerris) forests on serpentinite	StEx	900-1,100	i,d	i,d	i,d	i,d	i,d
G1.755	Moesian European oak (Quercus pedunculiflora) forests	C	Up to 50	h	h	h	h	h
G1.757	Illyrial sessile oak (Quercus petraea) forests			h	h	h	h	h
G1.7611	Typical Hungarian oak and Turkey oak forest	MCM	Up to 600	h,d	h,d	h,d	h,d	h,d
G1.7612	Hungarian and Turkey oak forest with butcher's broom(Ruscus aculeatus)	MCM	Up to 300	h,d	h,d	h,d	h,d	h,d
G1.7613	The forest of Hungarian oak and Turkey oak with the hawkweeds (Hieracium) spp.	MCM	Up to 300	h,d	h,d	h,d	h,d	h,d
G1.7614	The forest of Hungarian oak and Turkey oak with Oriental hornbeam (Carpinus orientalis)	MCM	Up to 700	h,d	h,d	h,d	h,d	h,d
G1.7615	The forest of Hungarian and Turkey oak with hornbeam (Carpinus betulus)	MCM	Up to 750	h,d	h,d	h,d	A	A
G1.7616	The forest of Hungarian oak and Turkey oak with moss	MCM	Up to 650	b	b	A	A	A
G1.7617	The forest of Hungarian oak and Turkey oak with Italian pubescent oak (Quercus virgiliana)	UKM	Up to 500	h,d	h,d	h,d	h,d	h,d
G1.7618	The Hungarian oak and Turkey oak forest with sessile oak (Quercus petraea)	MCM	400-1,000	b,c, d	b,c, d	b,c, d	b,c, d	b,c, d
G1.7619	The forest of Hungarian oak and Turkey oak with pedunculate oak (Quercus robur)	MCM		h	h	h	h	h
G1.761A	The forest of Hungarian oak and Turkey oak with European Hop hornbeam (Ostrya carpinifolia)	MCM	Up to 600	f,h, d	f,h, d	f,h, d	f,h, d	f,h, d
G1.761B	The forest of Hungarian oak and Turkey oak with common walnut (Juglans regia)	MCM	Up to 500	f,h, d	f,h, d	f,h, d	A	A
G1.761C	Kosovsko-metohijska forest Hungarian and Turkey oak forest	MCM	400-760	c,d	c,d	c,d	c,d	c,d
G1.761D	The forest of Hungarian oak and Turkey oak with downy oak (Quercus pubescens)	MCM	Up to 400	h,d	h,d	h,d	h,d	h,d
G1.761E	The forest of Hungarian oak and Turkey oak with beech (Fagus)	MCM	Up to 400	b,d	b,d	A	A	A
G1.762	Moesian Hungarian oak forests (Quercetum frainetto)	C	Up to 350	h,d	h,d	h,d	h,d	h,d
G1.763	Moesian Italian pubescent oak (Quercus virgiliana) forests	MCM	Up to 700	f,h, d	f,h, d	f,h, d	f,h, d	f,h, d
G1.78	Macedonian oak forests (Quercus trojana)	SmMCM	300-800	h	h	h	h	h
G1.7A11	Pannonian forest of Hungarian oak (Quercus frainetto) and Turkey oak (Quercus cerris)	CP	Up to 300	h	h	h	h	h
G1.7A12	Pannonian forests of Italian pubescent oak (Quercus virgiliana)	CP	Up to 350	h	h	h	h	h
G1.7A14	Pannonian forests of pedunculate oak	CP	Up to 200	b	b	b	b	b

	(Quercus robur) on loess								
G1.7A15	Pannonian forest of sessile oak (Quercus petraea) and Turkey oak (Quercus cerris)	CP	Up to 400	b	b	b	b	b
G1. 7A16	Pannonian forests of sessile oak (Quercus petraea) and royal purple (Cotinus coggygria)	CP	Up to 300	h,d	h,b	h,b	h,b	h,b
G1.7A17	Pannonian Turkey oak (Quercus cerris) forests on loess	CP	Up to 250	b	b	b	b	b
G1.7A.18	Pannonian forests of Sessile oak (Quercus petraea) on erpentininte	StEx	300-350	i,b	i,b	i,b	A	A
G1.7C111	Monodominant European Hop hornbeam (Ostrya carpinifolia) forests on limestone	MCM or SmMCM	450-1,400	f,h, d	f,h, d	f,h, d	f,h, d	f,h, d
G1.7C112	European Hop hornbeam (Ostrya carpinifolia) forests on limestone with Manna ash (Fraxinus ornus)	MCM or SmM	500-1,100	f,h, d	f,h, d	f,h, d	f,h, d	f,h, d
G1.7C113	European Hop hornbeam (Ostrya carpinifolia) forests on limestone with maples (Acer) spp.	MCM or SmM	1,000-1,200	b,d	b,d	b,d	b,d	b,d
G1.7C114	European Hop hornbeam (Ostrya carpinifolia) forests on limestone with oaks (Quercus) spp.	MCM or SmM	400-1,400	f,h	f,h	f,h	f,h	f,h
G1.7C115	European Hop hornbeam (Ostrya carpinifolia) forests on the limestone with common walnut (Juglans regia)	MCM	400-700	f,b	f,b	f,b	f,b	f,b
G1.7C116	European Hop hornbeam (Ostrya carpinifolia) forests on the limestone with Turkish hazel (Corylus colurna)	SmMCM	600-1,200	f,b	f,b	f,b	f,b	f,b
G1.7C12	European Hop hornbeam (Ostrya carpinifolia) forests on erpentinite	MCM	700-1,000	i,h, c	i,h, c	i,h, c	i,h, c	i,h, c
G1.7C121	Monodominant European Hop hornbeam (Ostrya carpinifolia) forests on serpentinite	MCM	300- 800					
G1.7C122	European hop hornbeam (Ostrya carpinifolia) forests on erpentinite with sessile oak (Quercus petrea)	MCM	Up to 800	i,h, d	i,h, d	i,h, d	i,h, d	i,h, d
G1.7C211	Monodominant Oriental hornbeam (Carpinus orientalis) forests on limestone	MCM or SmM	300-1,450	f,h, d	f,h, d	f,h, d	f,h, d	f,h, d
G1.7C212	Oriental hornbeam(Carpinus orientalis) forests with lilac (Syringa vulgaris) on limestone	MCM	200-600	f,h, d	f,h, d	f,h, d	f,h, d	f,h, d
G1.7C213	Oriental hornbeam (Carpinus orientalis) forests with oaks (Quercus spp.) on limestone	MCM or SmM	200-600	f,h, d	f,h, d	f,h, d	f,h, d	f,h, d
G1.7C214	Oriental hornbeam (Carpinus orientalis) forests with maples (Acer) spp. on limestone	MCM or SmM		f,h	f,h	f,h	f,h	f,h
G1.7C215	Other hornbeam (Carpinus orientalis) forests on limestone	MCM or SmM		f,h	f,h	f,h	f,h	f,h
G1.7C22	Oriental hornbeam (Carpinus orientalis) forests on silicate	MCM or SmM	200-1,000	j,h, d	j,h, d	j,h, d	j,h, d	j,h, d
G1.7C221	Monodominant Oriental hornbeam(Carpinus orientalis) forests on silicate	MCM or SmM	300-1,000	j,h, d	j,h, d	j,h, d	j,h, d	j,h, d
G1.7C222	Oriental hornbeam (Carpinus orientalis) forests with lilac (Syringa vulgaris) on silicate	MCM or SmM	300-1,000	j,h, d	j,h, d	j,h, d	j,h, d	j,h, d
G1.7C223	Oriental hornbeam (Carpinus orientalis) forests with oaks (Quercus) spp. on silicate	MCM or SmM	200-400	j,h, d	j,h, d	j,h, d	j,h, d	j,h, d
G1.7C231	Monodominant Oriental hornbeam (Carpinus orientalis) forests on serpentinite	MCM	300-1,000	i,h	i,h	i,h	i,h	i,h
G1.7C3	Thermophile maple (Acer) forests	MCM	300-700	f,h,	f,h,	f,h,	f,h,	f,h,

				d	d	d	d	d
G1.7C4	Thermophile linden forests (Tilia)	CP or MCM	Up to 300	h	h	h	h	h
G1.7C5	European nettle tree (Celtis australis)	MCM	Up to 100	b	b	A	A	A
G1.7C6	Thermophile ash (Fraxinus) forests	MCM	300-700	f,d	f,d	f,d	f,d	f,d
G1.7C7	Pannonian steppe-forests with juniper and poplar trees (Juniperus) – (Populus)	CP		b	b	A	A	A
G1.7C9	Western Asian forest-steppe with wild fruit trees			h	h	h	h	h
G1.7D11	Monodominant forests of European chestnut (Castanea sativa)	SmM	200-800	j,d	j,d	j,d	j,d	j,d
G1.7D12	European chestnut (Castanea sativa) forests with sessile oak (Querceus petreaea)	SmM	Up to 200	j,d	j,d	j,d	j,d	j,d
G1.7D13	European chestnut (Castanea sativa) forests with common walnut (Juglans regia)	SmM	600-800	j,d	jd	jd	jd	jd
G1.7D4	Ilyrian forests of European chestnut(Castanea sativa)	SmM		!				
G1.8 – Acidophilious forests in which oaks are dominant (Quercus)								
G1.871	Moesian acidophilious sessile oak forests (Quercus petraea)	MCM	400-1,300	h,c, d	h,c, d	h,c, d	h,c, d	h,c, d
G1.872	Moesian acidophilious Turkey oak (Quercus cerris) forests	MCM	Up to 400	j,d	j,d	j,d	j,d	j,d
G1.8A	Continental sessile oak (Quercus petraea) forests	CP	Up to 500	j,h	j,h	j,h	j,h	j,h
G1.8B	Continental eastern oak (Quercus polycarpa) forests	CP	Up to 400	j,h	j,h	j,h	j,h	j,h
G1.9 – Non-riverine Forests with birch (Betula), common ash (Populus tremula), rowan(Sorbus aucuparia) or common hazelnut(Corylus avellana)								
G1.91B	Balkan birch (Betula) forests on non-marshy terrains	MCM	700-1,300	h,d	h,d	h,d	h,d	h,d
G1.922	Lowland nemoral common aspen (Populus tremula) forests		!					
G1.923	Montane sites of common aspen (Populus tremula)		!					
G1.924	Sub-Mediterranean sites of common aspen(Populus tremula)		!					
G1.93	Rowan forests (Sorbus aucuparia)		!					
G1.95	Common aspen (Populus tremula) and birch (Betula) forests with elder (Sambucus)	MCM	700-1,300	d	d	d	d	d
G1.A - Meso- and eutrophic forests with oaks (Quercus), horbeams (Carpinus), ashes (Fraxinus), maples (Acer), lindens (Tilia), elms (Ulmus) and related forests								
G1.A1A	Illyrian oak-hornbeam (Quercus) - (Carpinus betulus) forests	MCI	300-500	b,	b	b	b	b
G1.A1B1	Pannonian sessile oak-hornbeam (Quercus petraea) - (Carpinus betulus) forests	CP	200-500	b,	b	b	b	b
G1.A1B2	Pannonian pedunculate oak-sessile oak (Quercus robur) - (Carpinus betulus) forests	CP	80-300	b,	b	b	b	b
G1.A1C1	Moesian sessile oak-hornbeam (Quercus petraea) - (Carpinus betulus) forests	MCM	200-700	a,b	a,b	A	A	A
G1.A1C2	Moesian sessile oak-hornbeam (Quercus robur) - (Carpinus betulus) forests	MCM		h	h	h	h	h
G1.A1C3	Moesian Hungarian oak-hornbeam (Quercus frainetto) – (Carpinus betulus) forests	MCM		h	h	h	h	h
G1.A1C4	Moesian Turkey oak-hornbeam (Quercus	MCM-		h	h	h	h	h

	cerris) – (Carpinus betulus) forests	Sm						
G1.A1C5	Moesian mixed oak- hornbeam (Quercus) spp. – (Carpinus betulus) forests	UKM	Up to 200	h	h	h	h	h
G1.A22	Non-riverine ash (Fraxinus excelsior) forests with maples (Acer) spp.	MCM or CP	300-1,100	f,b, d	f,b, d	f,b, d	f,b, d	f,b, d
G1.A24	Non-riverine ash (Fraxinus excelsior) forests with lindens (Tilia) spp.	MCM or CP	200-900	f,b, d	f,b, d	f,b, d	f,b, d	f,b, d
G1.A32	Eastern hornbeam (Carpinus betulus) forests	MCM and CP	Up to 300	h,d	h,d	h,d	h,d	h,d
G1.A4611	Relict polydominant Turkish hazel (Corylus colurna) forests with European ash (Fraxinus excelisor)	MCM	300-1,100	g,b	g,b	g,b	g,b	g,b
G1.A4612	Relict polydominant Turkish hazel (Corylus colurna) forests with Balkan maple (Acer intermedium)	MCM	600-1,100	g,b	g,b	g,b	g,b	g,b
G1.A4613	Relict polydominant Turkish hazel (Corylus colurna) forests with oaks (Quercus) spp.	MCM	200-600	g,b	g,b	g,b	g,b	g,b
G1.A4614	Relict polydominant Turkish hazel (Corylus colurna) forests with lilac (Syringa vulgaris)	MCM	500-1,100	g,b	g,b	g,b	g,b	g,b
G1.A462	Relict polydominant forests in gorges and canyons in which oaks are dominant (Quercus) spp.	MCM	100-600	g,b	g,b	g,b	g,b	g,b
G1.A463	Forests in gorges and canyons with Serbian spruce (Picea omorika)	MCM	200-900	g,?	g,?	g,?	g,?	g,?
G1.A481	Monodominant walnut(Juglans regia) forests	MCM	200-500	g,?	g,?	g,?	g,?	g,?
G1.A482	Walnut forests (Juglans regia) with common alder (Alnus glutinosa)	MCM		g,f, ?	g,f, ?	g,f, ?	g,f, ?	g,f, ?
G1.A483	Walnut forests (Juglans regia) with European nettle tree (Celtis australis)	MCM	Up to 200	g,f, ?	g,f, ?	g,f, ?	g,f, ?	g,f, ?
G1.A484	Walnut forests (Juglans regia) with European Hop hornbeam (Ostrya carpinifolia)	MCM	Up to 500	g,f, ?	g,f, ?	g,f, ?	g,f, ?	g,f, ?
G1.A53	East European linden (Tilia) forests	MCM	Up to 300	h,d	h,d	h,d	h,d	h,d
G1.A61	Smooth-leaved elm (Ulmus minor) forests		!					
G1.A62	Scots elm (Ulmus glabra) and European white elm(Ulmus laevis) forests		!					
G1.B - Non-riverine common aspen (Alnus) forests								
G1.B2	Nemoral common aspen forests (Alnus)		!					

G3 – CONIFEROUS FORESTS								
G3.1 – Fir (Abies) and spruce (Picea) forests								
G3.1211	Dinaric calciphilious monodominant fir (Abies alba) forests		!					
G3.1212	Dinaric calciphilious fir (Abies alba) and spruce (Picea abies) forests	MCIMM	1,500-1,700	f,b	f,b	f,b	A	A
G3.1311	Dinaric acidophilious monodominant fir (Abies alba) forests	MCIMM	1,100-1,700	j,b,c,d	j,b,c,d	j,b,c	A	A
G3.1312	Dinaric acidophilious fir (Abies alba)and spruce (Picea abies) forests	MCIMM	1,100-1,500	j,b,c,d	j,b,c,d	j,b,c	A	A
G3.161	Moesian calciophilious monodominant fir (Abies alba) forests	MCMM	1,000-1,700	j,b,d	j,b,d	j,b,d	A	A
G3.162	Moesian calciphilious fir (Abies alba) and spruce (Picea abies) forests	MCIMM	1,500-1,700	f,b	f,b	A	A	A
G3.163	Moesian acidophilious monodominant fir (Abies alba) forests	MCMM	1,350-1,600	j,b,d	j,b,d	j,b,d	A	A
G3.164	Moesian acidophilious fir (Abies alba) and	MCMM	1,350-	b,c,d	b,c,d	b,c,d	A	A

	spruce (Picea abies) forests		1,600					
G3.17	Balkan-pontic fir (Abies) forests			e	e	e	e	A
G3.1E1	Southeastern Moesian spruce (Picea abies) forests	MCMM	1,200-1,800	A	A	A	A	A
G3.1E3	Pelagonide spruce (Picea abies) forests	MCMM	1,700-2,000	b	A	A	A	A
G3.1E41	Balkan acidophilious spruce (Picea abies) forests	MCMM	1,450-1,800	j,b,c,d	j,b,c,d	j,b,c,d	A	A
G3.1E42	Balkan calciophilious spruce (Picea abies) forests	MCMM	1,400-1,700	f,b,c,d	f,b,c,d	f,b,c,d	A	A
G3.1E51	Dinaric calciophilious spruce (Picea abies) forests	MCIMM	1,400-1,800	f,b	f,b	f,b	A	A
G3.1E52	Dinaric aciphoilic spruce (Picea abies) forests	MCIMM	1,300-1,800	j,b	j,b	j,b	A	A
G3.1E53	Dinaric serpentinitephilic spruce (Picea abies) forests	MCMM	1,700-2,000	i,b	i,b	i,b	A	A
G3.1G	Serbian spruce (Picea omorika) forests	MCIMMl	950-1,100	b	b	A	A	A
G3.4 – Scots pine (Pinus sylvestris) forests south from taiga								
G3.4C1	Dinaric Scots pine forests on limestone	MCMIM	800-1,000	f,c,d,	f,c,d,	f,c,d,	f,c,d,	f,c,d,
G3.4C2	Dinaric Scots pine forests on serpentinite	MCMIM	800-1,000	i,b,c,d	i,b,c,d	i,b,c,d	A	A
G3.5 – Austrian pine (Pinus nigra) foresrs								
G3.521	Western Balkans Austrian (Pinus nigra) pines on limestone	MCIMM		!				
G3.5221	Austrian pine (Pinus nigra) forests on serpentinite with winter heath (Erica carnea)	MCMIM	700-1,300	i,h,d,	i,h,d,	i,h,d,	i,h,d,	i,h,d,
G3.5222	Austrian pine (Pinus nigra) forests on serpentinite with (Potentillla alba)	MCMIM	700-1,200	j,h	j,h	j,h	j,h	j,h
G3.5223	Austrian pine (Pinus nigra) forests on serpentinite with (Euphorbia glabriflora)	MCMIM	900-1,200	j,h	j,h	j,h	j,h	j,h
G3.5224	Austrian pine (Pinus nigra) forests on serpentinite with (Sesleria serbica)	MCMIM	700-1,000	j,h	j,h	j,h	j,h	j,h
G3.561	Crimean pine (Pinus pallasiana) forests on limestone cliffs with common yew (Taxus baccata)	UKM	Up to 700	e	e	e	?	?
G3.562	Crimean pine (Pinus pallasiana) forests on limestone cliffs with (Sesleria rigida)	MCM	Up to 700	e	e	e	?	?
G3.563	Crimean pine (Pinus pallasiana) forests on limestone cliffs with (Carex humilis)	MCM	500-1,100	e	e	e	?	?
G3.58	Central Balkan Austrian pine Pinus nigra) – Scots pine (Pinus sylvestris) forests on serpentinite	MCMIM	600-1,300	j,h,d	j,h,d	j,h,d	j,h,d	j,h,d
G3.6 – Sub-Alpine Mediterranean pine forests (Pinus)								
G3.61111	Bosnian pine forests on limestone with purple hellebore (Heleborus purpurascens)	MCSmM	1,500-1,600	f,b,d	f,b,d	A	A	A
G3.61112	Bosnian pine forests on limestone with autumn moor grass (Sesleria autumnalis)	MCSmM	1,700	f,b,d	f,b,d	A	A	A
G3.61113	Bosnian pine forests on limestone with greater wood rush (Luzula sylvatica)	MCSmM	UFL	f,b,d	f,b,d	A	A	A
G3.61114	Bosnian pine forests on limestone with greater meadow rue (Thalictrum aquilegifolium)	MCSmM	UFL	f,b,d	f,b,d	A	A	A
G3.61115	Bosnian pine forests on limestone with	MCSmM	UFL	f,b,d	f,b,d	A	A	A

	(Verbascum nikolai)							
G3.61116	Bosnian pine forests on limestone with mosses	MCSmM	UFL	f,b,d	f,b,d	A	A	A
G3.61117	Bosnian pine forests with lichens	MCSmM	UFL	f,b,d	f,b,d	A	A	A
G3.61118	Bosnian pine forests on limestone on nitrificated soil with nettles (Urtica) spp.	MCSmM	UFL	f,b,d	f,b,d	A	A	A
G3.6112	Bosnian pine forests on limestone with (Genista radiata)	MCSmM	UFL	f,b,d	f,b,d	A	A	A
G3.6113	Bosnian pine forests on limestone with (Rhamnus fallax)	MCSmM	UFL	f,b,d	f,b,d	A	A	A
G3.6121	Bosnian pine forests on serpentinite with (Ptilotrichum dieckii)	MCSmM	1,480-1,750	i,b,d	i,b,d	A	A	A
G3.613	Bosnian pine forests on silicate	MCSmM	UFL	j,b,d	j,b,d	A	A	A
G3.62111	Bosnian pine forests on silicate with (Wulfenia blecicii) (= (Wulfenia carintiaca) auct. Balc.)	MCSmM	1,500-2,100	j,b	j,b	A	A	A
G3.62112	Macedonian pine forests on silicate with (Ajuga pyramidalis)	MCSmM	1,500-1,800	j,b,d	j,b,d	A	A	A
G3.62113	Macedonian pine forests on silicate with (Potentilla verna s.l.)	MCSmM	UFL	j,b,d	j,b,d	A	A	A
G3.6212	Macedonian pine forests on the silicate with spruce (Picea abies)	MCSmM	1,500-1,900	j,b	j,b	A	A	A
G3.6213	Macedonian pine forests on silicate with alpenrose (Rhododendron ferrugineum)	MCSmM	1,800-2,100	j,b	j,b	A	A	A
G3.6214	Macedonian pine forests on silicate with mountain pine (Pinus mugo)	MCSmM	1,500-1,900	j,b	j,b	A	A	A
G3.6215	Macedonian pine forests on silicate with bilberries (Vaccinium myrtilllus)	MCSmM	UFL	j,b	j,b	A	A	A
G3.622	Macedonian pine forests on limestone	MCSmM	UFL	f,b	f,b	A	A	A
G3.631	Mixed Bosnian pine and Macedonian pine forests	MCSmM	1,700	b	b	b	A	A
G3.632	Mixed Bosnian and Macedonian pine forests with other pines (Pinus) spp.	MCSmM	UFL	b	b	A	A	A
G3.633	Mixed Bosnian and Macedonian pine forests with spruce (Pice abies) and fir (Abies alba)	MCSmM	UFL	b	b	A	A	A
G3.9 – Coniferous forest in which cypresses (Cupressaceae) or yewa(Taxaceae) are dominant								
G3.93	Greek juniper (Juniperus excelsa) forests	Me i SubMe	i,h	i,h	i,h	i,h	i,h	i,h
G3.97	Western-Palaearctic common yew(Taxus baccata) forests		i					
G3.99	Prickly juniper (Juniperus oxycedrus) forests	Me	h	h	h	h	?	?
G3.E - Nemoral bog coniferous forests								
G3.E3	Balkan Scots pine peatmoss forests (Pinus sylvestris)	MCMM and MCIMM	!					
G3.E51	Dinaric spruce (Picea abies) forests on sfagnum peat	MCMM and MCIMM		b	b	A	A	A

G4 – MIXED BROADLEAF AND CONIFEROUS FORESTS								
G4.1 – Mixed bog forests								
G4.11	Balkan mixed bog forests of common alder and Serbian spruce	Transitory-Moderate Continental-Illyrian-Moesian-	1,000-1,100	b	?	?	?	?

		Mountain						
G4.12	Mountain gray alder (Alnus incana) galleries with spruce (Picea abies)	Moderate – climate – mountain	1,400-1,500	e,b	e,b	A	A	A
G4.4 – Mixed Scots pine(Pinus sylvestris) - birch – (Betula) forests There are no concrete phytocoenological data on the forest sites in which Scots pine and birch are dominant. However, since both species are very common in Serbia, and even at some places form their monodominant forests, it can be expected that the small isolated fragments of this type of soil can be found in our country as well.			!					
G4.5 – Mixed Scots pine (Pinus sylvestris) – beech (Fagus) forests There are no concrete phytocoenological data on the forest sites in which Scots pine and beech are dominant. However, since both species are very common in Serbia, and even at some places form their monodominant forests, it can be expected that the small isolated fragments of this type of soil can be found in our country as well.			!					
G4.6 – Mixed fir (Abies) spruce (Picea) beech – (Fagus) forests								
G4.611	Mixed beech – fir forests on silicates	CM	600-1200	j,b,c,d	j,b,c,d	j,b,c,d	A	A
G4.612	Mixed beech- fir forests on carbonates	CM	900-1,600	f,b,c,d	f,b,c,d	A	A	A
G4.613	Mixed beech-fir forests on serpentinites	CM	600-1,300	i,b,c,d	i,b,c,d	A	A	A
G4.62	Mixed beech-fir-spruce forests	CM	900-1600	j,b,c,d	j,b,c,d	A	A	A
G4.63	Mixed beech-spruce forests	CM	900-1,600	j,b,c,d	j,b,c,d	A	A	A
G4.64	Mixed beech – fir- pine-Serbian spruce – forests	CM	1,000-1,100	j,b,c,d	j,b,c,d	A	A	A
G4.65	Mixed beech-fir-spruce-Serbian spruce- forests	CM	1,000-1,100	f,b,c,d	f,b,c,d	A	A	A
G4.66	Mixed beech-fir-spruce-pine-forests	CM	1,000-1,100	b,c,d	b,c,d	A	A	A
G4.7 – Mixed forests of Scots pine and acidophilious oaks (Quercus)								
G4.71	Sub-contintental nemoral pine-oak (Pinus) – (Quercus) forests	MCM or SmM	500-1,100	!				
G4.G - Mixed forests of Austrian pine (Pinus nigra) and calciphile broadleaves								
G4.G1	Mixed forests of Austrian pine (Pinus nigra) and European Hop hornbeam (Ostrya carpinifolia)	MCM or SmM	500-1,100	h	h	h	h	h
G4.G2	Mixed forests of Austrian pine (Pinus nigra) and Turkish hazel (Corylus colurna)	MCM or IM	500-1,100	h	h	h	h	h
G4.G3	Mixed forests of Austrian pine (Pinus nigra) and sessile oak (Quercus petraea)	MCIM	600-1,100	i,h	i,h	i,h	i,h	i,h
G4.H - Mixed Bosnian pine – Macedonian pine – beech forests (Pinus heldreichii) - (Pinus peuce) - (Fagus)								

G4.H1	Mixed beech-Bosnian pine forests	MCM	1,400-1,600	f,b,c,d	f,b,c,d	f,b,c,d	A	A
G4.H2	Mixed beech-fir -Bosnian pine forests	MCM	UFL	b,c,d	b,c,d	b,c,d	A	A
G4.H3	Mixed beech-spruce-Macedonian pine forests	MCM	UFL	b,c,d	b,c,d	b,c,d	A	A
G4.H4	Mixed sessile oak- Bosnian pine forests	MCM	UFL	b,c,d	b,c,d	b,c,d	A	A

F – HEATHLAND, SCRUB SITES AND TUNDRA

F2 – ARCTIC, ALPINE AND SUB-ALPINE SCRUB SITES								
F2.1	Snow-patch dwarf willow scrub							
F2.11	Boreo-alpine acidocline snow-patch (Salix herbacea) scrub	BrAl	1,900-2,500	j,b	j,b	A	A	A
F2.12	Boreo-alpine calcicline snow-patch (Salix polaris)scrub	BrAl	>1,800	f,b	f,b	A	A	A
F2.2	**Evergreen alpine and sub-alpine heathlands and scrub sites**							
F2.21	Alpine dwarf ericoid wind heaths	BrAl	>1,900	j,b	j,b	A	A	A
F2.223	Sarplaninske (Rhododendron kotschyi) heaths	BrAl	>1,900	j,b	j,b	A	A	A
F2.231	Balkan sub-alpine scrub formations in which (Juniperus sibirica) (= (Juniperus nana)) is dominant	BrAl	1,500-2,000	b,c	b,c	b,c	b,c	A
F2.232	Balkan sub-alpine scrub formations in which Sub-alpine spruce(Picea abies subalpina) is dominant	BrAl	1,700-1,900	j,b	j,b	j,b	A	A
F2.233	Balkan sub-alpine mixed scrub formations with junipers and subalpijske deciduous scrubs	BrAl	1,500-1,700	f,b	f,b	A	A	A
F2.24	Alpigenous high-mountain visokoplaninske (Empetrum – Vaccinium) heaths	BrAl	1,900-2,100	b	b	b	A	A
F2.26	(Bruckenthalia) heaths	BrAl	1500-2000	j,b,c	j,b,c	j,b,c	j,b,c	A
F2.27	Apline (Arctostaphylos uva-ursi) and (Arctostaphylos alpinus) heaths	BrAl	>1,600	b,c	b,c	b,c	b,c	A
F2.29	(Dryas octopetala) mats	BrAl	!					
F2.2A1	Balkan high-mountain heaths with bog bilberry (Vaccinium uliginosum)	BrAl	>1,700	b,c	b,c	b,c	b,c	A
F2.2A2	Balkan high-mountain heaths with bilberries (Vaccinium myrthyllus)	BrAl	1,700-2,000	j,b,c,d	j,b,c,d	j,b,c,d	j,b,c	A
F2.2B	Alpine highmountain (Genista) and (Chamaecytisus) heaths	BrAl		e,b	b	b	A	A
F2.3	**Sub-alpine and oroboreal scrub sites**							
F2.31	Mountain srcrub sites of alder (Alnus)	BrAl	1,280-1,900	j,b,c	j,b,c	j,b,c	A	A
F2.321	Balkan sub-alpine scrub sites of Silesian willow (Salix sileisaca)	BrAl	1,400-1,800	f,b,c,d	f,b,c	f,b,c	f,b,c	A
F2.322	Dinaric sub-alpine scrub sites of Waldstein willow (Salix waldsteniana)	BrAl	>1,500	f,b,c	f,b,c	f,b,c	f,b,c	A
F2.323	Dinaric sub-alpine scrub sites of (Salix appendiculata)	BrAl	1,900-2,000	j,b	j,b	A	A	A
F2.35	Subalpine Balkan scrub sites of (Genista radiata)	BrAl	1,500	c,d	c,d	c,d	c,d	A
F2.4	**Scrub sites of mountain pine (Pinus mugo)**							
F2.471	Pelago-Dinaride scrub sites of	BrAl	1,700-	f,b,c,d	f,b,c,d	f,b,c,d	A	A

	mountain pine (Pinus mugo) on limestone		2,400					
F2.472	Pelago-Dinaride scrub sites of mountain pine (Pinus mugo) on serpentinite	BrAl	1,700-2,000	i,b,c,d	i,b,c,d	i,b,c,d	A	A
F2.48	Balkan-Rhodopide scrub sites of mountain pine (Pinus mugo)	BrAl	1,400-1,920	b,c	b,c	b,c	b,c	A

F3 –MODERATE AND MEDITERRANEAN MONTANE SCRUB SITES								
F3.1	**Moderate thickets and scrub sites**							
F3.16	Scrub sites of common juniper (Juniperus communis)			h	h	h	b	b
F3.17	Hazel thickets (Corylus)			h	h	b	b	b
F3.2	**Mediterranean -montane broadleaf deciduous thickets**							
F3.2411	Pannonian deciduous blackthorn (Prunus spinosa) thickets	SAPC	80-200	h	h	h,d	h,d	h,d
F3.2412	Pannonian deciduous hawthorne (Crataegus) thickets	SAPC	80-200	h	h	h,d	h,d	h,d
F3.2413	Pannonian deciduous European dwarf cherry (Prunus fruticosa) thickets	SAPC		h	h	h,d	h,d	h,d
F3.2414	Pannonian deciduous Dwarf Russian almond (Amygdalus nana) thickets	SAPC		h	h	h,d	h,d	h,d
F3.2415	Pannonian deciduous royal purple (Cotinus coggygria) thickets	SAPC		h	h	h,d	h,d	h,d
F3.2416	Pannonian deciduous wild privet(Ligustrum vulgare) thickets	SAPC		h	h	h,d	h,d	h,ds
F3.2421	Forsythia (Forsythia europaea) shrubs	MeI	300-1,200	i,h,c,d	i,h,c,d	i,h,c,d	i,h,c,d	i,h,c,d
F3.24221	Balkan shrubs of lilac jorgovana (Syringa vulgaris) on limestone	SubM-SubC	200-1,400	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c
F3.24222	Balkan shrubs of lilac (Syringa vulgaris) on serpentinite	SeAr-MC (SubC)		i,h,	i,h,	i,h,	i,h,	i,h,c,d
F3.24223	Balkan shrubs of lilac (Syringa vulgaris)on silicate	SubMe-SubK	400-1,000	j,h,c,d	j,h,c,d	j,h,c,d	j,h,c,d	j,h,c,d
F3.2423	Balkan sub-contintental deciduous hawthorn (Crataegus) thickets	SubMe-SubC		h	h	h	h	h
F3.2424	Balkan sub-continental deciduous blackthorn (Prunus spinosa) thickets	SubMe-SubC		h	h	h	h	h
F3.2425	Balkan sub-continental deciduous European dwarf cherry (Prnus fruticosa) thickets	SubMe-SubC	Up to 600	f,h,d	f,h,d	f,h,d	f,h,d	f,h,d
F3.2426	Balkan sub-continental deciduous Dwarf Russian almond (Amygdalus nana) thickets	SubMe-SubC	800-1,000	f,h	f,h	f,h	f,h	f,h
F3.2427	Balkan sub-continental deciduous Jerusalem thorn (Paliurus spina-christii) thickets	SubMe-SubC	200-300	h,d	h,d	h,d	h,d	h,d
F3.2428	Balkan sub-continental deciduous royal purple (Cotinus coggygria) thickets	SubMe-SubC		h	h	h	h	h

F3.2429	Balkan subcontinental deciduous rose (Rosa) spp. thickets	SubMe-SubC	1,000 - 1,200	f,h,d	f,h,d	f,h,d	f,h,d	f,h,d
F3.242A	Balkan sub-contintental deciduous rock cherry (Prunus mahaleb) thickets	SubMe-SubC	150-550	f,h	f,h	f,h	f,h	f,h
F3.242B	Balkan sub-continental deciduous bladdernut (Staphyllea pinnata) thickets	SubMe-SubC		h	h	h	h	h
F3.242C	Balkan sub-continental deciduous Oriental hornbeam (Carpinus orientalis) thickets	SubMe-SubC	100-1,400	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d
F3.242D	Balkan sub-continental deciduous Montpellier maple (Acer monsepssulanum)and manna ash (Fraxinus ornus) thickets	SubMe-SubC	200-700	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d
F3.242E	Balkan sub-continental deciduous European Hop hornbeam (Ostrya carpinifolia) thickets	SubMe-SubK	500-1400	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d	f,h,c,d
F3.242F	Balkan sub-continental deciduous (Frangula rupestris) thickets	SubMe-SubC	300-500	f,h	f,h	f,h	f,h	f,h
F3.3	**Sub – continental and contintental evergreen thickets**							
F3.31	Pannonian evergreen common juniper (Juniperus communis) thickets	SAPC	80-200	h,d	h,d	h,d	h,d	h,d
F3.32	Balkan sub-continental evergreen common juniper (Juniperus communis) thickets	SubMe-SubK		h	h	h	h	h
F3.33	Balkan sub-continental evergreen prickly juniper (Juniperus oxycedrus) thickets	MeI	300-1,200	i,h,c,d	i,h,c,d	i,h,c,d	i,h,c,d	i,h,c,d
F3.34	Balkan sub-continental evergreen Greek juniper (Juniperus excelsa) thickets	SubMe-SubC		h	h	h	h	h
F3.4	**Mountain and sub-alpine deciduous thickets**							
F3.41	Balkan mountain and sub-alpine deciduous thickets with (Rhamnus fallax)	M		b,c,d	b,c,d	b,c,	A	A
F3.42	Balkan mountain and i subapline deciduous thickets with (Lonicera alpigena)	M		b,c,d	b,c,d	b,c,d	A	A
F3.43	Balkan mountain and sub-alpine deciduous thickets with (Sambucus racemosa)	M		b,c,d	b,c,d	b,c,d	A	A
F3.44	Balkan mountain and sub-alpine deciduous goat willow(Salix caprea) thickets	M		b,c,d	b,c,d	b,c,d	A	A

F4 – MODERATE SCRUB HEATHS								
F4.2	**Dry heaths**							
F4.22	Sub-atlantic Calluna) – (Genista)heaths	HuMC (I)		f,b	f,b	f,b	A	A
F4.27	Southeast European dry heaths with (Erica herbacea)	MeI	50-1,400	h,c,d	h,c,d	h,c,d	h,c,d	h,c,d
F5 -MAQUIS, MATTORAL I THERMO-MEDITERRANEAN SCRUB SITES								
F5.3	**Pseudomaquis**							

F5.31	Greek-Balkan pseudomaquis	Me-SubMe		h,d	h,d	h,d	h,d	h,d
F7 –SPINY MEDITERRANEAN HEATHS (PHRYGANA, HEDGE-HOG HEATHS AND RELATED VEGETATION OF COASTAL CLIFFS)								
F7.4	**Hedge-hog heaths**							
F7.481	Moesian (Astragalus angusiifolius) hedge-hog heaths	Me-SubMe		f,h	f,h	f,h	f,h	f,h
F9 – RIVERINE AND FEN SCRUBS								
F9.1	**Willow scrubs (Salix) by brooks and lakes**							
F9.111	Orogenic rosemarry willow (Salix eleagnos) scrubs			b	b	b	b	b
F9.112	Orogenic purple willow (Salix purpurea) scrubs			b	b	b	b	b
F9.113	Orogenic bay willow (Salix pentandra) scrubs			b	b	b	b	b
F9.12	Lowland and hilly willow (Salix) shrubs by brooks and little rivers			b	b	b	b	b
F9.131	Moesian low shrubs with false tamarisk (Myricaria germanica)			b	b	b	b	b
F9.132	Southeastern-dinaric scrubs with (Myricaria ernesti-mayeri)			b	b	b	b	b
F9.2	**Fen and bog willow (Salix) scrubs**							
F9.21	Low-land fen and bog willow scrubs with (Salix cinerea)			b	b	b	b	b
F9.22	Low-land fen and bog willow scrubs with (Salix triandra)			b	b	b	b	b
F9.23	Low-land fen and bog willow scrubs with (Salix rosmarinifolia)			a,b	a,b	a,b	a,b	A
F9.24	Low-land mixed fen and bog willow scrubs with (Salix) spp.			a,b	a,b	a,b	A	A
F9.25	Mountain peat willow scrubs with (Salix rosmarinifolia)		1,200-1,500	b	b	A	A	A
F9.3	**South river galleries and thickets**							
F9.31	Galeries with (Nerium oleander), (Vitex agnus-castus) and (Tamarix)			!				
F9.4 – Desert false indigo (Amorpha fruticosa) thickets in Serbia and Vojvodina: allochthonous species which originates from North America, today it spreads intensively on the banks of the valley rivers, and push out the autochthonous species.				h	h	h	h	h

The symbols in the columns of the Table refer to the following:
a – decrease of the level of the ground waters; b – narrowing of altitudinal range; h –altitudinal range extension ; c – the shift of the lower limit of the distribution to the higher altitudes; d – shift of the upper limit of the distribution to the higher altitude; e – site of very limited altitudinal range; ! – the association has not been registered in Serbia but the occurrence of it can be expected;
f – occurs on the limestone bedrock; i – occurs on the serpentinite bedrock; j- occurs on the silicate bedrock; g- relict association; ? – out of reach of model ; A – site disapperance
The symbols which refer to the climate characteristics:
MC – moderate continental; P – Pannonian ; CP–continental Pannonian ;M– mountain; H–Hilly;N –North; MCM–moderate continental Moesian; MCI–moderate continental Illyrian; MCMH –moderate continental Moesian hilly; MCIH –moderate continental Illyrican hilly; MCMM –moderate continental Moesian mountain; MCMIM – moderate continental Moesian-Illyrian mountain; H- hidden from extreme climate KV –continental Vlaska; CPH–continental Pannonian hilly ; MCIMM –moderate continental Illyrian Moesian mountain; MCMSu –moderate continental Moesian sub-mountain; MCMSmSa –moderate continental Moesian Sub-Mediterranean Sub-Alpine; StEx – sub-thermophile exposured terrains; C–most continental climate in Serbia; SmMCM sub-Mediterranean moderate continental Moesian; SmM –sub-Mediterranean Moesian ; MCMEM –moderate continental Moesian mountain; MCSuM –moderate continental sub-Mediterranean mountain; Me -Mediterranean; SubMe –sub-Mediterranean; IM – Illyrian-Moesian; MCIM –moderate continental Illyrian-Moesian ; BrAl –boreal alpine; SAPC –semi-arid Pannonian continental; MeI – Mediterranean influence ; SubC –sub-continental; SeAr – semi arid;

The table presents the decrease of the number of forest sites by the change of temperature. There are 210 forests site in Serbia, and by the increase of temperature by 1^0 the number of sites reduces at 198, and by the increase of temperature by 2^0 it reduces at 192.The increase of temperature by 3^0 reduces the number of sites at 159, and by 4^0 at 131. By the change of temperature by 5^0 the number of sites decreases at 116, i.e. by 44.8%.

One hundred and sixty sites of broadleaf deciduous forests in Serbia have been registered in Serbia. By the increase of air temperature by 1^0 the number of them decreases by 4.4%, by the increase of temperature by 2^0C it decreases by 6.2%, by the increase by 3^0 it decreases by 20.6%, by the increase by 4^0 , or 5^0C it decreases by 40% .

Out of 32 sites of coniferous forests, the increase of air temperature by 1^0C will decrease their number by 12.5%, the increase by 2^0C will decrease it by 18.7%, the increase by 3^0C by 25%, the increase by 4^0C by 65.6%, and the increase by 5^0C by 68.7%.

Out of 18 sites of mixed broadleaf and conifer forests, the increase of air temperature by 1^0 will decrease the number of sites by 5.5%, the increase by 2^0C by 11.1%, the increase by 3^0C by 55.5%, the increase by 4^0C or 5^0C by 83.3%.

Table 2. *The change of the number of the forest sites in Serbia as a result of the change of air temperature*

Sites	**Number of sites**	**The number of sites after the change of temperature by**				
		1^0	**2^0**	**3^0**	**4^0**	**5^0**
G1 Broadleaf deciduous forests						
G1.1	11	11	11	3	2	0
G1.2	8	8	8	2	1	0
G1.4	3	3	3	0	0	0
G1.5	2	2	0	0	0	0
G1.6	25	25	25	23	18(2!)	7(2?)
G1.7	76	76	76	72	69	69
G1.8	4	4	4	4	4	4
G1.9	6	2(4!)	2	2	2	2
G1.A	24	22(2!)	21	21	21	21
G1.B	1	(1!)				
Total G1	160	153	150	127	96	96
G3 Coniferous forests						
G3.1	16	15(1!)	13	12	1	0
G3.4	2	2	2	2	1	1
G3.5	9	8(1!)	8	8	8	8
G3.9	3	2(1!)	2	2	1(1!)	1(1)
G3.E	2	1(1!)	1	0	0	0
Total G3	32	28	26	24	11	10
G4 Mixed broadleaf and deciduous forests						
G4.1	2	2	1(1!)	(1?)	(1?)	(1?)
G4.6	8	8	8	1	0	0
G4.7	1	(1!)				
G4.G	3	3	3	3	3	3
G4.H	4	4	4	4	0	0
Total G4	18	17	16	8	3	3
Total	210	198	192	159	131	116

Out of 72 sites of scrub sites, by the increase of temperature by 1^0or $2^{0,}$ the number of sites decreases at 70. By the increase of temperature by 3^0 the number of the scrub sites decreases at 64, by 4^0at 51. By the increase of temperature by 5^0 the number of scrub sites decreases at 41, i.e. by 43.0% in comparison with the current situation.

Table 3. *The change of the number of the scrub sites in Serbia by the change of air temperature*

Sites	Number of sites	The number of sites after the increase of temperature by				
		1^0	2^0	3^0	4^0	5^0
F2.1	2	2	2	0	0	0
F2.2	12	11(1!)	11	8	5	0
F2.3	5	5	5	4	3	0
F2.4	3	3	3	3	1	0
F3.1	2	2	2	2	2	2
F3.2	23	23	23	23	23	23
F3.3	4	4	4	4	4	4
F3.4	4	4	4	4	0	0
F4.2	2	2	2	2	1	1
F5.3	1	1	1	1	1	1
F7.4	1	1	1	1	1	1
F9.1	6	6	6	6	6	6
F9.2	5	5	5	5	3	2
F9.3	1	(1!)				
F9.4	1	1	1	1	1	1
Total	72	70	70	64	51	41

The anticipated effects of the climate change in regard to the forest ecosystems, forest associations and types of trees, scrubs, and ground vegetation are the following:

- the shift of the limit of some forest types in regard to the latitude and altitude;
- the different natural distribution of the areas covered by different types of forests in regard to the latitude and altitude;
- probably, in the long-term, the defeat of some associations, their "abandoning" of the race and disapperance;
- the different composition of some plant associations with the disapperances of some and occurrence of some other species in regard to layers and social position;
- the change of the reaction of some tree species to the light;
- the forest associations will be more exposed to the different adverse effects, which are direct or indirect results of climate change, which implies that the higher degree of risks of the expected adverse effects which is posed to the relict, rare and endangered forest associations and main types of trees by which they are recognizible.
- generally speaking, the above effects will directly affect the possibility of preservation of biological diversity and reality of the rational management of these resources.

The above expected effects will also directly influence the possibility and intensity of sustainable forest management planning.

GUIDES TO THE SUSTAINABLE USE OF RESOURCES IN FORESTS AND FOREST ECOSYSTEMS IN THE AIM OF ALLEVIATION OF THE NEGATIVE INFLUENCES OF THE CLIMATE CHANGE

During the process of preservation forest ecosystems and establishment of new forests, it is necessary to take care of the sites, mosaic-like pattern of vegetation, biological diversity and landscape.

During the establishment of new forests the following elements should be taken into account:

- For the reforestation and establishment of green areas which are out of forests exclusively the autochthonous tree and bush species should be used.

- It is necessary to prevent the spread and/or apply the methods for the destroying of the invasive species, which disturb the natural plant associations. In Serbia the following species are regarded as invasive: box elder (Acer negundo), Chinese sumac (Ailanthus glandulosa), desert false indigo (Amorpha fruticosa), common hackberry (Celtis occidentalis), green ash (Fraxinus pennsylvanica), honey locust
- (Gledichia triacanthos), wolfberry (Lycium halimifolium), woodbine (Parthenocissus inserta), black cherry (Prunus serotina), black locust(Robinia pseudoacacia) (Panjkovic et al ., 2005).
- The plantations of black locust, common hackberry, and Chinese sumac on the natural sites can be a good choice in the beginning, but later, after the several feelings and chopping, it is hard to elimante them, since they spread in an uncontrolled way and causes great problems in the environment protection. The problem of the regeneration of sessile oak forests in the fluvial areas, which are favourable for the spreading of the seeds of invasive species (Amorpha fruticosa, Fraxinus pennsylvanica), is well-expressed. In these areas desert false intigo form compact scrub formations.
- The cultivars and clones should not be used on natural or partly altered natural sites, particularly within the protected natural areas.
- To take care not to destroy the sensitive or endangered natural ecosystems, suchs as: wet meadows, shallow bogs, natural mixed forests, saline soils, steppe, etc.
- The extending of forest areas to the pastures, meadows, bogs and reeds is in contrast to the preservation of mosaic-like pattern and ecosystem diversity of the natural sites, as well as with the protection of the sites of rare species.
- The protection of steppe and saline soils is the priority and they are on list of Directive 92/43/EEC, Annex I of the European Council, as the typical sites of Pannonian region. Many plant and animal species on the steppe and saline soils are endangered and protected by law as rare species in Serbia.
- The extending of the forest plantations and field-protective zones should be directed to the change of the purpose of the ariable areas of lower quality.
- When the autochthonous species cannot be used for the formation of wind-proof zones by the channels and roads, the poplar and willow clones can be used, as well as the clones of allochtonous tree species.

The field-protective, anti-erosion (eolic and water erosion) zones should be favoured, in the aim of the preservation and increase of the fertility and yield of the agricultural and other soils, as well as the other forest areas with the protective function (imision forests).

The agricultural soils of the lower productivity (starting from IV category), which are endangered by erosion or chemically burdened, should be afforested, but the change of the purpose of soil should be preceeded by the analysis of the possible consequences.

One of the greatest disturbing factors at the global, national, and regional levels, refers to the loss and fragmentations of the natural sites. The connection of the isolated sites by the eccological corridors should enable the preservation of the dynamics of populations and living associations, as well as the processes which take place at the level of regions. The ecological corridors connect the spatial units of the isolated natural sites, and enable the seasonal migrations and exchange of the genetic material between the partly isolated and/or distant sites. They are bordered by natural vegetations, and field-protective zones, water flows and their valleys in combination with the vegetation zone are natural ecological corridors. The preservation of the accessibility of the ecological corridors is of the crucial importance to the preservation of the biodiversity of certain area.

In the aim of the alleviation or the elimination of the adverse anthropogenic influences it is needed to form the protective zones, which are important to the preservation of the biodiversity out of the protected natural areas as well. The formation of the protective green zone would be fabourable for the biodiversity of the agricultural areas, since they enable the survival of the endangered bird species (brids of prey, owls, etc), and mammals (insectivores), and they provide the places in which the singing birds, which feed on the agricultural areas, can build the nests.

The extremely thick trees, the trees with the well-developed crowns, the trees with cavities, nests, etc. (which were deliberately or accidentially left in the stand) have the great ecological importance. The quantity, condition and the structure of the dead wood and stumps, which remain in the forests is the significant ecological information, which points to the degree of naturalness of the stand. They are the environment for the whole range of animals and organisms, the indicators of the degree of naturalness of the stand, they increase biological diversity, the aesthetical value of forests, as well as the spatial diversity, etc.

The biological diversity implies the diversity of living organisms which inhabit land and water, as well as the diversity within the different species, between species and ecosystems. The biodiversity is no longer the total diversity of forms and phenomena of the plant and animal world, but the diversity of the functions of the living organisms. In order to preserve the planet and harmonious cohabitation of man and nature, the world should be directed to two main aims: preservation and sustainable use of biodiversity.

The solutions to the sustainable use of biodiversity components:

- Formation of the mixed stands of autochthonous forests species, and the use of the autochthonous tree and bush species in accord with the potential vegetation of the area for the reforestation
- Extension of the new plantations and field-protective zones should be directed to the change of the purpose of the areable areas of lower quality
- Preventation of spread and application of methods for the suppression of the invasive species, if necessary
- Avoid the use of cultivars and clones on the natural or partly altered natural sites, particularly within the protected natural areas.
- The poplar and willow clones, as well as the clones of the autochthonous tree species should be used for the formation of water-proof zones by channels and roads, when the autochthonous species cannot be used.
- In the aim of the preservation of mosaic-like pattern and ecosystem diversity of the natural sites the spread of the forest areas to the pastures, meadows, bogs and reeds should be prevented.
- The steppe and saline sites should become priority in the selection of the areas for protection
- Forbid the use of the invasive species during the new afforestations and the formation of the protective green areas.
- Conversion of the plantations in the protected natural areas into the natural forest stands by the change by the autochthonous species
- Preservation of accessibility of the ecological corridors of some areas
- Formation of the forest plantations with the autochthonous species, which will serve as the buffer zone around the protected natural areas.

THE CREATION OF THE INFORMATION SYSTEM IN THE AIM OF THE MONITORING OF CONDITION AND CHANGES IN THE FOREST AND FOREST ECOSYSTEMS

The information system is the model of real condition and by using the information from this system the fast diagnosis can be made, as well as the forecast of the development, and based on this knowledge the adequate decisions can be made. The effective use of the models in practice mainly depends on the number and accuracy of the output data and information. The quality and quantity of data, as well as the accuracy of information depends upon the well-organized system of collection and data procession. Therefore, the process of input parameters has to be the integral part of the mathematical model. The system which can bring into an accord the great quantities of information about certain geographical locations is the Geographical Information System (GIS). GIS enables the complex analysis and modeling, so even in the areas where no measurements are performed certain phenomena and effects can be forecasted.

As the environmental system is very complex, permanently active and dynamic, the knowledge of its parameters is necessary so that the different decisions and conceptions of the use of space and environmental protection can be recommended by using models.

In order to achieve this goal, the Institute of Forestry created the information system on collection and procession of the spatial data on forests and forest ecosystems by the use of the satellite photos of high resolution (Ratknic, 2008). The information system is divided into XIX thematic units (BLOCKS):

a) OROGRAPHIC CHARACTERISTICS – BLOCK I
b) GEOLOGICAL AND PEDOLOGICAL CHARACTERISTICS - BLOCK II-BLOCK II
c) DEAD LAYER AND HUMIFICATION - BLOCK III
d) SOIL EROSION, GROUND WATER AND FLOODING - BLOCK IV
e) SITES - BLOCK V
f) THE PURPOSE OF SOIL - BLOCK VI
g) DATA ON SPECIES - BLOCK VII
h) SITE CHARACTERISTICS - BLOCK VIII
i) QUALITY OF TREES AND SITE - BLOCK IX
j) CONDITION OF JUVENILE FORESTS - BLOCK X
k) PRIVATE FOREST MANAGEMENT - BLOCK XI
l) REGENERATION AND REFORESTATION - BLOCK XII
m) FOREST TENDING MEASURES - BLOCK XIII
n) THICK AND ECOLOGICALLY SIGNIFICANT TREES - BLOCK XIV
o) DEAD WOOD AND STUMPS - BLOCK XV
p) DEGREE OF BIOLOGICAL DIVERSITY - BLOCK XVI
q) SOURCE OF FOOD FOR WILD ANIMALS - BLOCK XVII
r) PROTECTION AND PRESERVATION OF BIODIVERSITY - BLOCK XVIII
s) THE RIMS OF FORESTS AT THE BORDER FOREST/ NON-FOREST - BLOCK XIX

CONCLUSION

The current global climate models were based on the data which prevents the detailed spatial structure of the variables, mainly temperature and precipitation above the homogenous areas. In the aim of the reduction of the disadvantages of the current global climate projections it is necessary to use the regional models and models of influnce in the forecasts in the aim of the quantification, accuracy and uncertainties. It is necessary to incorpate the results of these models in the activities which enable the timely adaptation to the climate change and their alleviation (if it is possible).

Based on the models and scenarios it can be concluded that over a relatively short period the drastical change in the number and structure of the forest ecosystems in Serbia will occur. The previous concept of the multi-purpose planning system in each individual goal (general or specific) and methods for the achivement must be analyzed separately in regard to the climate change as one of the basic factors of risks. Given the above warning facts and the adverse effects of the climate change in the forest ecosystems and environment in general, these are not the goals for future but the obligations of the present.

The guides to the forest management planning should determine the desirable characteristics of the management system at the operational level, and the guidelines for the forest management in a great detail determine the activities which should be used in the forestry.

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International Scientific Conference
FOREST ECOSYSTEMS AND CLIMATE CHANGES
March 9-10th, 2010., Institute of Forestry, Belgrade

THE TASKS OF SILVICULTURE IN REGARD TO THE CURRENT CLIMATE CHANGE

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Abctract: *The numerous previous researches point to the fact that the current climate change, global warming of the planet, and the endangerment of the environment, have a great impact on the plant species or communities, which are reflected in certain physiological limitations, individual extinction, as well as the possible disappearance of some species. In these circumstances the role of the forest ecosystems and their complex ecological impact play an indispensable role in the stabilization of the biosphere functions. In order to fulfill its role, the condition of the forest has to be functionally optimal for the concrete site conditions. In the aim of the avoiding the traps of formalism and theoretical support for the nature protection only by the increase of the number and area of the protected natural resources, this goal can be achieved only by materializing the concept of "active protection" – by the application of the specific silvicultural methods, i.e. by the the close to nature silviculture. The term* ***"close to nature silviculture"*** *refers to the permanently sustainable and economically justified silvicultural methods, which are adapted to the natural processes, and aimed at the preservation of the nature, biodiversity and genetic variability, improvement of the condition, optimal use of the site potential, and the increase of the forest productivity.*

The improvement of the current condition of the forests is one of the tasks of the forestry science and profession, particularly in regard to their ecologic importance. During the selection of the silvicultural methods, owning to the great coeno-ecological and structural diversity of forests, the schemes of any kind cannot be applied, and the methods should be selected after the realistic and comprehensive study of the site condition, and the definition of the functionally optimal condition in the concrete site conditions.

The basic forest-silvicultural methods would imply the increase of the areas covered by forests, improvement of the forest condition, application of the silvicultural form, and the reclamation of the degraded forests, which would mean the application of the suitable silvicultural methods depending on the concrete site conditions and stand characteristics. In this way their stability and vitality would be preserved, and, at the same time, the anticipated forest functions would be performed in the best way, the impact on the alleviation of the climate change would intensify, and the forests would adapt to the altered climate conditions much faster.

1. CURRENT CLIMATE CHANGE

The current climate change is mainly the result of the adverse effects of the mankind on the elements of the climate systems. The atmosphere is most subject to the climate change, since the composition of it alters as a result of the uncontrolled combustion of the fossil fuels. The increased "glass house effect" led to the increase of the average global air temperature, by 0.6°C in comparison with the pre-industrial period, and the last decade of the past century was warmest since the beginning of the temperature measurement.

The increase of temperature causes the shift of the temperature and precipitation regimes. There are indications that the continuance of the previous uncontrolled anthropogenic influences in

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20052 „Changes in forest ecosystems affected by global warming"

the 21st century will have the dramatic effects on the global economy, society and human environment (www.hidmet.gov.rs/podaci/meteorologija, 2010).

The Intergovernmental Panel on Climate Change (IPCC) was founded by the World Meteorological Organization (WMO) and United Nations Environment Programme in 1988. It permanently and in a balanced way monitors the scientific, technical and social-economic pieces of the pieces of information, relevant to the understanding of the scientific bases of the risks posed by the anthropogenic climate change, potential impacts of this change, as well as of the options for the alleviation of the climate change and adaptation to the altered climate conditions. More than 2,500 appointed scientists and experts from the whole world are involved in the activities of IPCC.

The work group II of IPCC (WG2 IPCC) in 1990 anticipated the following scenario (hypothesis) of the possible climate change in the future:

1. Double effective increase of the carbon dioxide (CO_2) in the atmosphere by 2025 - 2050;
2. The global increase of the average temperature by 1.5 to 4-5^{o} C;
3. Unequal global distribution of the increase of temperature - small increase in the tropic regions (by the half of the presented global values), and the greater increase in the polar regions - double increase of the presented values;
4. The sea level will increase by 0.3-0.5 m until 2050 and by 1 m until 2010, and by 1 m until 2010, and the temperatures of the ocean surface will increase by 0.2 - 2.5^{o}C (Krstic, 1999).

In the fourth report of the work group I of IPCC (WG1 IPCC) 2007 (www.hidmet.sr.gov.yu, 2010) the following facts are stated:

- In the period after 1750 the measurable changes of the energy sum of atmosphere occurred (the glass house effect increased by 2.9 W/m^2, and only 0.12 W/m^2 is attributed to the impact of the natural factors, i.e. the change of solar energy);
- The last decade of the 20th century and 1998 were the warmest periods of the last millennium;
- The year 2006 was the sixth-warmest year in the period 1861-present, with the average positive deviance +0.42^{o}C, in comparison to the average value for the period 1961-1990;
- In South Europe, the region to which Serbia belongs, the trend of the decrease of the precipitation by 20% was registered at some sites. In Serbia, over the period 1950-2005, the sharpest drop of the precipitation (about 120 mm at the annual level) was registered in Negotinska valley;
- In many world regions the changes in the intensity and frequency of the occurrence of the climate extremes, such as drought, floods, tropical cyclones, storm weather, followed by hail, snow blizzards and avalanches, the waves of the extremely high air temperatures, frost, strong rain of short duration, wildfires, were registered;
- Furthermore, the projections of the climate change for Europe show the decrease of the quantity of precipitation in Southeast Europe by 1% per decade. The decrease of the precipitation will be most intensive in the warm half of the year, and by the above scenario it would decrease by 22% by the end of the century;
- The further increase of the anthropogenic emission of the gases with the glass house effect will cause the additional global warming of the atmosphere by 1.9-4.6^{o}C by the end of the 21st century in comparison with the pre-industrial level, and the projected rate of the change of temperature in the 21st centrury will be 0.3^{o}C per decade higher than any rate of the change of the air temperature in the past 10,000 years, which was caused by the natural factors;
- Even in the case of the radical reduction of the emission of the gases with the glass house effect, the average global air temperature will increase by 0.6^{o}C by the end of the century;
- The different increase of the air temperature in some regions would be followed by the different regional changes in the precipitation regime, variability of the local climate, changes in the intensity and frequency of the climate extremes; the shift of the climate zones towards the poles and greater altitude;

- In South Europe, the region to which Serbia a belongs, along with the further trend of the increase of the air temperature, in the next period the further decrease of precipitation followed by the reduction of the number of the days with snow and snow layer, the decrease of the water drainage, soil humidity, and the availability of the water resources, is anticipated.

According to Jovanovic (1954), Wagner states that in Europe from the beginning of the XIX century the temperature has increased by 1°C per century. Over the past 100 years the average global increase of the temperature was 0.6° C, and the further increase of it is anticipated (Root et al., 2003).

1.2 Climate change in Serbia

The current climate change has been registered in Serbia from the very beginning of the measurement of the climate elements.

Milosavljevic states that in Belgrade the average annual temperature for the period 1888-1916 was 11.1°C, and over sthe period 1917-1950 it was 11.8 °C, which is the increase by about 0.7°C (Jovanovic, 1954).

The Republic Hydrometeorological Service of Serbia (www.hidmet.sr.gov.yu, 2010) presents the following basic climate characteristics in Serbia in regard to the climate change:

The highest temperatures over the period 1961–1990 were measured in July, and ranged from 37.1 to 42.3°C in the lower regions, whereas in the mountain regions the highest temperatures ranged from 27.6 to 34.0°C. In August the measured highest temperatures ranged from 37.4 to 40.3°C. The lowest temperatures were registered in January, and ranged from -30.7 to -21.0°C in the lower regions, whereas in the mountain regions the lowest temperatures ranged from -35.6 to -20.6°C.

The characteristics of the temperature extremes which have been registered from the beginning of the measurement: the highest temperature, +44.9°C, was measured on July 24th in 2007 in S. Palanka, and the lowest temperature, -39.5°C was measured on January 13th in 1985 in Pester Plateau. The summer of 2008 in Serbia was characterized by extremely high temperatures, and the deviation from the normal temperatures ranged from 1.5°C in Novi Sad, to 2.5°C in Belgrade. In the most parts of Serbia June is extremely warm, July is warm, and August is very warm. The highest registered temperature in the summer of 2008 was 39.1°C in Valjevo, on August 15th. The number of the tropical days was above average for summer, and in August this number was even double the average. The heat wave, as the extreme climate event, was registered in the most parts of Serbia, from June 21st to June 27th.

The year 2000 was the driest year, when only 223.1 mm of precipitation in Kikinda was measured in Kikinda, whereas 1937 was the most rainiest year, when even 1,324.5 mm od precipitation was measured in Loznica. The greatest monthly quantity of precipitation was registered in June of 1954 in Sremska Mitrovica, 308.9 mm. The greatest daily quantity of precipitation was registered on October 20th in 1955 in Negotin, 211.1 mm.

The Figure 1 presents the average annual temperature for GMS Belgrade, by the deviation of the temperature from normal range for the standard period 1961–1990. The solid line presents the 5-year moving average for the period 1886-2005, and the columns present the deviations from the normal range for every year. The global trend of the increase of temperature, which is particularly expressed in the last decade of the last century and continued by 2005, is clearly visible. By the mid-20th century, the temperature was below the normal range, and since then until 1990 it varied within the normal range, and later it varied considerably above the normal range. The post-2000 period has been warmest since the beginning of the temperature measurement in Serbia.

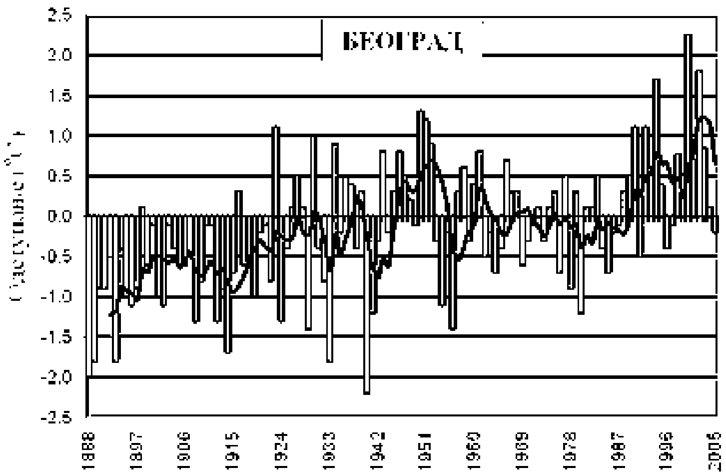

Figure 1. *The deviation of the average annual temperature from the normal range for the standard period 1961–1990 for GMS Belgrade*

2. THE IMPACT OF THE CLIMATE CHANGE ON THE FOREST ECOSYSTEMS – THE PRESENT KNOWLEDGE ON THE FUTURE IMPACTS

The percentage and distribution of certain types of forest vegetation is mainly adapted to the current climate conditions. The anticipated climate change will be undoubtedly reflected in the forests, which particularly refers to the anticipated changes of temperature (high temperatures in summer, warmer winters, the more frequent spring and autumn frost), change of the quantity of precipitation (frequency and duration of drought), stronger winds, etc. Since forests spend the great quantities of the atmospheric CO_2, for the photosynthesis, the decrease of the areas covered by the forest, the potent absorbent, can have the adverse effects which will be reflected in the strengthening of the so-called "glass house effect" (Krstic, 1999).

The work group II of IPCC (WG2 IPCC, 1990) concluded that the above global and regional climate change would be reflected in the following way:

- Increase of the imission would double, and the ecological conditions would change, which would result in the physiological and biological changes of the living organisms;
- It would be harder for the forests to adapt and their decay would increase;
- The survival of the numerous species of flora and fauna would be endangered, particularly in the most sensitive (semiarid) regions, where many species are "closed" in their limit;
- Many biological communities, which are adapted to certain conditions, would be endangered and exposed to stress (terrestic ecosystems, mountain, polar, and island communities);
- The relatively small climate change would cause the great problem in regard to the water resources in many regions, particularly in the arid and semiarid areas.

In the latest, Fourth Scientific Report of the Work Group I (WG1 IPCC, 2007), it is emphasized that the anticipated rate of the global warming in the next decades will pose the greatest problem during the process of adaption to the altered climate conditions in the near future.

The above anticipated climate change, generally speaking, would affect the floral ecosystems in a following way (WG2 IPCC, 1990):

- New temperature regime and decrease of the quantity of precipitation – the forest ecosystems would be more sensitive, particularly in the arid and semiarid areas;
- Forest soil would be warmer and drier, which implies that the development and survival of many species would be limited;

- Forest characteristics – their stability will be endangered, the composition of forests will be disturbed, and the decrease of humidity would be critical to the development of the juvenile plants and root system, so in this phase it will be faced up with the stress;
- The creation of the new studies (new researches) of the relations between the plants and site, bioecological characteristics of the species, genetic variability, impact on the climate change on forest, etc, will be needed.

The interaction between the climate change and air pollutants would be particularly stressful for the trees (plants), and would be reflected in the following ways: the increase of the damages caused by insects and fungi; reduction of the genetic diversity in forests; increase of the risk and damages caused by wildfires; the decrease of the vitality of forests; desiccation (extinction) of some tree species. As a result, the forest management methods would have to be adapted to the altered environmental conditions – the new knowledge and strategies in the forest management would be needed; the formation of the new climate zones would influence the formation of new forest ecosystems (important changes of the composition of forests), it will be needed to define new altitudinal ranges, etc...

In the latest Report of the Second Work Group (WG2 IPCC, 2007) the following conclusions are made (www.hidmet.gov.rs/podaci/meteorologija, 2010):

A) Many natural ecosystems are affected by the climate change, particularly by the increase of air temperature, due to the global warming: the shift of the zones with certain plant and animal species to the north and to the greater altitudes; from the early 1980s, the trend of the leaf formation of the vegetation and the prolongation of the duration of the growing season; the important changes in many physical and biological systems – above 89% is consistent with the direction of the anticipated changes of the reaction to the global warming.

B) Many ecosystems which are able to naturally adapt to the climate change will lose this capacity owning to the unprecedented combination of the climate change, followed by the disturbances (such as floods, drought, wildfires, insects, ocean acidification), and other factors of the global changes (changes in the ways in which soil is used, pollution).

In average 20-30% plant and animal species will disappear if the temperature increases by more than 1.5 – 2.5°C. The increase of temperature by more than 1.5-2.5°C, and the corresponding increase of CO_2 concentrations, implies the great changes in the structure and functions of ecosystem, ecological interactions of the species and geographical distribution of species, with the dominant adverse effects on biodiversity, and services connected to the ecosystems.

The wide range of the influence of the current climate change, which refers to the following phenomena, has been registered in Europe for the first time: the retreat of glaciers, prolongation of the growing season, shift of the distribution of species. The types of the climate change which have been described are consistent with the anticipated climate change. It is expected that the climate change will magnify the differences in the European natural resources. Many organisms and ecosystems will have difficulties adapting to the climate change (it is anticipated that in some regions up to 60% current species will have disappeared by 2080, by the scenario of the highest emissions). Some forms of adaptation to the reported and projected climate change have occurred already, but they are still fragmentary and minor in the comparison with the needs.

According to Root et al. (2003) despite of the fact that various species adapted to the climate change during their evolution, the current more intensive types of the climate change are very important and has a great influence on the wild species (from the simplest organisms to trees) and on their ecosystems. The numerous previous researches point to the fact that the climate change, particularly abrupt increase of temperature, has the great impact on numerous species (above 80% of species) or on communities, which are reflected in certain physiological limitations, individual extinction, and the possible disappearance of some species. Based on the data from 1986, 20% of European forests were visibly damaged by the imission of the harmful gases, and the damages of forests increase owning to the climate extremes (dry periods, low winter temperatures), temperature inversions, etc. (Pintaric, 2004).

Provided that the average annual temperature in Serbia from the beginning of the 19th century to present (about the mid 20th century – remark of the author) has increased by 1.5^{o}C, it will be in harmony with the current climate which is typical for two places with the altitudinal difference equals to 300 m, or 3 degree-distance, based on the latitude. Undoubtedly, the previous conditions were more favourable for the forest (Jovanovic, 1954).

The possible effects of the silvicultural methods are the deterioration and decomposition of the "productive forests", as a result of the natural succession , the greater percentage of the natural forests of pioneering (more resistant) species, such as fir, aspen, etc, i.e. decrease of the forest biodiversity, reduced stability and vitality of the forests, the greater risk of the abiotic and biotic adverse effects, the limited possibility of the application of the suitable methods of natural regeneration and tending measures of forests, the greater need for the combination of the natural and artificial regeneration, etc.

3. ECOLOGICAL IMPORTANCE OF THE FOREST AS THE STABILIZATION FACTOR FOR THE FUNCTIONING OF BIOSPHERE

The knowledge of the history of our forests from the recent and distant past is the starting point and the necessary condition for forming an opinion on their current condition and role, by which the local climate change in Serbia can be partly explained. According to Jovanovic (1954), in discussions about the relation between the climate and plant cover in Serbia, it should raise the question whether the current climate is the same as the climate which was dominant a century ago. It addition, both secular climate change and the climate change which probably occurs as a result of the alternation of the plant cover of Serbia (forest disappearance), by the drainage of greater water areas, and other factors, should be taken into account. Undoubtedly, the area covered by forests in Serbia was much greater in the early 19th century, which is proved by the claims of numerous travel writers who passed through Serbia: "Travel writers had the impression that Sumadija and the whole of Serbia was a depopulated country, almost overgrown with forests"; "Serbia must have been almost completely covered by forests in the past"; "Everything reminds you of the land from the past, after the creation", "except for some rocky grounds and places where the villages and town are overgrown with forests". The impressions about the great water areas were similar: "Macva is affected by the frequent flooding of Sava and Drina rivers, that covered it during the longer rains by bogs and marshes, which almost never dry"; "the valleys are mainly fertile, but abundant in marshes, out of which some lakes are formed, mostly in Rudnicka and Pozarevacka counties"; "Valley of Morava river is subject to the discontinuous bogs and marshes". In this way the conditions "permanent spread of the humid atmosphere" were created, which were undoubtedly more favourable for forests.

According to Popov (1994) Deliblatska sands is the result of the anthropogenic influence in the very region, but also in the wider surrounding area, reflected in the drainage of the marshes, regulation of rivers, digging of the channels, reforestation. The stable forest and steppe ecosystems were mainly developed, and some parts of the Pannonian Plain was covered by marshes, so it can be safely assumed that the climate was more humid.

It is known that the intensive industrialization is the main cause of the current process of the global warming owning to the increased emission of the carbon dioxide, and that the natural environment is endangered by the contamination by the different pollutants, reflected in the air pollution by the gaseous agents, mineral dust, heavy metals, soot, smoke, etc. In such conditions, in the aim of the preservation of the conditions of the human existence, the forests play an indispensable role, since they are the stabilization factor of the balance between the tendency of the greater endangerment of the environment, and the normal functioning of the environment. The need for the multifunctional use of forests is increasingly expressed, and as a result in the future the increasing number of the areas covered by soil will lose the principal function of timber production, since the so-called "multibeneficial" functions will become increasingly important: protective-regulative, sanitary-hygienic, recreational-health- tourist, aesthetic-decorative, etc.

According to Pintaric (2004) the data from the references estimate that the productive function accounts for only 20%, and in the extreme conditions for only 10%, and social-useful (multibeneficial) functions for 61% of the total forest functions (Papanek), or that the ratio of social-beneficial to productive function is 3:1 (Mantel); that only climatologic value of forest in Germany accounts for 10-14% of the total value (Tamargadze).

The climate factors are the environmental conditions on which to a certain extent depend the occurrence and survival of forest and other plant formations in certain area, as well as their distribution. The forest also occurs as the strong indirect ecological factor, which causes the great changes of the basic climate elements – light, air temperature, mobility of the air masses, the great impact on microclimate – climate conditions in the forest and its very vicinity, which are the result of the impact on the forest on the vicinity (Bunusevac, 1951).

The great areas which were covered by forests in Serbia must have alleviated the current climate extremes (Jovanovic, 1954). It is estimated that the areas covered by forests in Serbia in the early 19th century accounted for about 80%,, i.e. that the devasted and cleared forests account for about 60% of the territory.

3.1. The influence of the forest on the climate

It is known that the forest as the most complex ecosystem is the potent global modificator of the climate, with the particularly great impact on its immediate vicinity, so it is very significant for the environment conditions and other ecosystems in general.

The previous knowledge and data obtained from the literature sources showed that the influence of the forest of the **"climate nature"** is reflected in the alleviation of the temperature extremes, decrease of the temperature in comparison with the open space by a few degrees, and increase of the air humidity. Also, it influences the quantity, structure and distribution of the precipitation, the formation of the wind fields and the air flows in the forest and its vicinity, etc, and the localities in the forests, at which the canopy openness occurs, have the great influence on the soil warming, or the increase in the air cooling and on the formation of the so-called "frost pits".

Nowadays, owning to the growing global ecological crisis forests along with their ecological characteristics have the special role in the regulation of the natural environment, because of its protective-regulative and sanitary-hygienic functions, and, generally speaking, are the "lugs of the Earth". The forests, as most advanced type of vegetation have a crucial influence on the climate of the wider area and microclimate of its site. In this process the forest is the potent indirect ecological factor, which caused the important changes of the basic climate elements. The macroclimate of certain area can not be greatly influenced, since it is determined by the latitude, altitude, relief, vicinity of the sea, etc, i.e. the forest cannot causes significant change of the annual quantity of precipitation, temperature, etc. However, the climate characteristics within the forest and its immediate vicinity, i.e. the microclimate can be regulated. On the other hand, human activities and the application of different types of silvicultural thinning, can to a great extent regulate the microclimate in the forest.

The impacts of the forest of the **"non-climate nature",** better-known as the sanitary-hygienic function of the forest, are particularly important in the industrially developed areas, where the soil, water, atmosphere, vegetation and human population are exposed to the increased contamination by the different pollutants and solid and gaseous agents. The physiological process of photosynthesis in the green plants, with the simultaneous "consumption" of the great quantity of carbon dioxide is very important to the reduction of the “glass house effect”, since the forests, according to Otorepec (1991) spend 42% of the atmospheric CO_2, which absorbs the heat and is considered to be the main cause of the increase of the radiation.

The forests have a great influence on the protection from the imission of gases and solid particles. The permanent protection, which the forest provides in the form of the “combing” of the solid particles, is much valued. According to Pintaric (2004) the researches in this sense showed the following: the area of the trees by which the harmful particles are retained is twenty times greater in comparison with the grasses, and ten times greater in comparison with the bushes; beech forests can retain and filtrate 68 tons of dust per year; one 30-year-old horse chestnut tree can retain 120 kg of dust an 80 kg of aerosols per year; when the air, which contains 1,000 mg of sulfur dioxide per $1m^3$ by the influence of the wind passes through the middle-age beech forests covering an area of 1ha , it is completely purified.

4. THE NECESSARY FOREST-SILVICULTURAL METHODS IN THE CONDITIONS OF THE ALTERED CLIMATE

The forest growing in this sense is the phyto-technique, i.e. eco-technique, which should be sometimes used in order to intensify certain function of the forest. The intensifying of the achieving of the targeted goals of the multi-functional forest growing can also be achieved by the application of the **close to nature silviculture**, which implies the permanently sustainable and economically justified silvicultural activities limited by and conditioned by the natural processes (Krstić et al, 2006; Govedar et al, 2006).

In regard to the estimation of the possibility of the growing stock for the alleviation of the climate change and of the improvement of the environment, the following questions can be raised:

- Is the current degree of reforestation sufficient to provide the positive influence of the forest of the fulfillment of the ecological role – the alleviation of the climate change, protection and improvement of the environment?
- Is the condition of the growing stock satisfactory?

According to WGII IPPC (1990), - the data from 1980, the forests account for about 31% of the land, i.e. about 10% of the Planet Earth. The average amounts of land covered by forests are the same in developed and undeveloped regions – about 1/3 of the total area.

The American and Canadian forests account for 16% of the total forests on the planet Earth; the forests in the former Soviet countries for 21%, African forests for 20%, and Latin American forests for 24% (Columbia Encyclopedia).

Based on the data of the National Forest Inventory from 2009, the forests of Serbia cover an area of 2,252,400.0 ha, which accounts for 0.3 ha per a capita. Therefore, the Serbia is regarded as the country which is averagely covered by forests, and the areas covered by forests in Vojvodina account for 7.1%, whereas in central Serbia for 37.6%. It means that the areas covered by forests have increased by 5.2% in comparison with 1979.

The significant indicator of the condition of forests and their ability to perform the anticipated functions, which also implies the ability to alleviate the climate change, is the forest condition in regard to the origin, preservation, composition and quality. The condition of the forests in Serbia, without the autonomous provinces, is the following:

- The forests occupy an area of 2,098,400.0, which accounts for 37.6 %, and the other forest soil for 6.0%.
- The state-owned forests account for 51% and the privately-forests account for 49% of the total forests;
- The dominant silvicultural form of the forests are coppice forests, which account for 66.0%, high forests for 27.8%, and the artificially established stands for 6.2 % of the area;

- In regard to the composition, the pure broadleaf stands account for 58.1% of the forests, the mixed broadleaf stands for 29.6%, pure conifer stands for 9.1%, mixed conifer forests for 0.7%, mixed broadleaf and conifer stands for 2.5%;

In regard to the structural form, the even-aged forests account for 91.0% of the forests, multi-aged for 8.0%, selection forests for 0.9%, and virgin forests for 0.1%;

- The preserved stands account for 70.9% of forests, thinned stands for 26.8%, and devastated stands for 2.3%.

The presented condition of the forests, as well as the different percentages of the stands of certain categories, in regard to the silvicultual methods, impose the need for the definition of the appropriate silvicultural treatment, which is the result of its silvicultural needs, for each concrete situation. Using the presented condition of the growing stock as a starting point, and based on the analysis of the growing stock, it is necessary to apply the following silvicultural methods:

- The increase of the areas covered by forests, since the current percentage of the areas covered by forests is not satisfactory;
- The change of the silvicultural form of the forest – coppice forests should be transformed into the high forests, and the current ratio should be shifted in favour of high forests;
- By reclamation of the degraded coppice forests, devastated forests, shrubs and thinned stands the condition of these forests should be improved.

The degradation of forests and forest land, or the devastation of them in great areas, influenced by numerous factors, are the obstacles to achieving these goals. Their condition is often unsatisfactory in regard to the site condition (density, degree of canopy closure, composition, origin), quality, stability, vitality, health condition, etc. The results of these facts are unsatisfactory productivity function and all other functions of forests. On the other hand, the possibility for the improvement of this condition points to the fact that the problem should be tackled seriously in the future, and imposes the need of the amelioration of the forestry science and profession (Krstic, 2006).

By the application of the suitable silvicultural methods, the condition of the current forests should be improved so that it become optimal, by which their stability and vitality should be preserved, and at the same time the other anticipated functions of the forests will be performed.

The Work Group III of the Intergovernmental Panel on Climate Change (WGIII IPCC, 2007) presented the key technologies and activities for the alleviation of the climate change in some sectors, stating that the changes in the way of life and model of behavior can contribute to the alleviation of the climate change in all sectors.

In the sector forestry / forests the key technologies and activities aimed at the alleviation are projected to be commercial, and refer to: reforestation; regeneration of forests; forest management; decreased deforestation; management by the exploitation of the wood products; use of the forest products for the bioenergy as a substitution of the fossil fuels. It is stated that there is no universally applicable list of the methods for alleviation; the methods should be valued for individual ecosystems and adaptations. The methods and instruments which have proved to be ecologically efficient in certain sector, or at least in the series of the national instances: financial stimuli (national and international) for the increase of the forest areas, for the decrease of the forest clearing and proper forest management, decrees on the use of soil and application. The key limitations include the lack of capital for investment and rent of the soil.

Owning to the unsatisfactory percentage of areas covered by forests, the Spatial Plan of the Republic of Serbia implies the large-scale activities aimed at the **reforestation of bare soil** and of abandoned agricultural areas affected by the erosion, establishment of the suburban and protective forests, recultivation of tailing dumps, etc. It was anticipated that as a result of these reforestations by 2010 the areas covered by forests should reach 31.7 % , which was not achieved. The long-term plan anticipates that the optimal areas covered by forests in Serbia will account for 41.4 %. The **artificial regeneration of forests** is in some cases necessary and justified, since, owning to the endangerment of the forest as the natural ecosystem, the abundance of the seed yield and frequency of sporulation decreased.

In order to achieve the above goal, the main directions of the improvement of the conditions of forests and forestry in Serbia, are, among other things, based on the development of the seed-nursery production, for both afforestation of the new areas and for the artificial renewal of the forests and reclamation of the degraded forests. The planned tasks of the conversion of the forest facilities, as well as of the satisfaction of the needs in the materialization of the afforestation plans, impose the need of the ensuring and providing of the quality, health and selected forest seed and sedling material, of the suitable orientation and quality. Therefore, one of the most important tasks is the knowledge of the orientation of seed obtained from the genetically superior forest populations and trees. The rich biodiversity of Serbia, in which the autochthonous broadleaf species are dominant, enabled the determination of numerous seed facilities of 73 species of forest trees.

The strategy of the **preservation of biodiversity** and genetic resources of the economically most valuable tree species imposed, as the primary task to the forestry in Serbia, the preservation of the national values (wealth) of the natural forests. By the long-term management of the seed stands, which implies the frequent application of the suitable methods of genetic reclamation, the seed facilities, out of which the selected seed material of the known orientiation is obtained, are defined.

In accord with the current legal regulations in Serbia, there are 478 protected natural areas in Serbia, which occupy an area of 547,723.71 ha, or account for 6% of the total area of the Republic. The forest and forest land occupy significant areas of the majority of the protected natural areas: national parks, parks of nature, natural reserves, natural monuments (Ostojić i Vukin, 2007). The greatest part of the protected natural areas in the state-owned forests is managed by the State Enterprise "Srbijasume" (97), and they occupy an area 245.954 ha, which means that they account for about 48% of the total protected areas in Serbia, out of which the forests occupy the greatest area (Aleksic and Jancic, 2006).

According to Jaksic (2004) the protection of the endangered plant species and their associations implies the application of series of methods and techniques, from the domains of fundamental biology, law and legislation, as well as from the domain of the applied biological disciplines, such as forestry, agriculture, pharmacy, etc. All these activities can be divided into three groups: scientific base of the protection of the endangered plant species; administrative-legal base of protection; active methods of protection (*in situ* and *ex situ* protection, reintroduction by the return of the plant species to the former sites from which they disappeared), the introduction by the introduction of the species out of the range of its natural altitudinal zone.

The common characteristic of all silvicultural activities based on the “forest growing which is close to nature” is one of the main factors of the stability of forest ecosystems, which implies the protection and preservation of biodiversity (Govedar et al, 2006). In regard to biodiversity, among other things, it is important to get familiar with the condition of the endangered species of flora and fauna in forests. The majority of these forests are under the strict or moderate regimes of protection. Their reduction (the decrease of biodiversity) can be regarded as the warning, when it is needed to alter the forest-silvicultural methods aimed at the protection of biodiversity. Two main approaches to the preservation of biodiversity in forests are:

- Practical application of the forest growing which is close to nature in the current industrial forests,
- Protection of the sensitive and rare ecosystems (mainly within the forests of the special purpose).

A special attention should be paid to the adequate **silvicultural methods in forest plantations** and artificially established stands. Their current condition is characterized by the different degree of density, quality, health condition, productivity, succession of vegetation by the introduction of the autochthonous vegetation. During the establishment of the conifer plantations many mistakes were made, and the main problems of the management occur because the plantations were established on the sites of the different productive capacity, which sometimes to a great extent exceeds the needs of the species which were used; frequently on the sites of other tree species; by different planting density (the number of seedlings per hectare); on the sites of conifer species, which poses a great problem of the disturbance of the newly-established plantations by shoots and lateral shoots of the autochthonous and undesirable species. In addition, there is also a great problem of the silvicultural neglect and of the different practice of maintanance and care.

The proposed **silvicultural-reclamation methods** for the optimization of the condition of these forests must be based on its current condition, importance to the fulfilment of the above expected functions of forests and endangerment by the abiotic and biotic factors. During these processes the following facts have to be taken into accounts (Krstic and Stojanovic, 1999):

- The need for the application of these methods in a great area (several thousand hectares), which is associated with the economic and technical problems, forest openness, workforce hire, etc – spatial dimension;
- The long-term production process, i.e. much time is needed for the significant change of the forest condition – time dimension;
- The very limited possibility of the acceleration of the production process, which is associated with the biological characteristics of trees – biological-norm dimension.

In order to improve the condition of the current growing stock of our forests, the the following suitable silvicultural-reclamation treatments – methods should be applied:

1. Methods aimed at the formation of new, quality stands – timely natural regeneration of the mature stands and the artificial regeneration, if possible,
2. Methods aimed at the improvement of the condition of current forests
   - equal and regular felling as the forest tender measure;
   - reclamation of condition in high degraded forests;
   - transformation of coppice forests into higher silvicultural form (amelioration of the degraded forests).

The condition of **forests of high silvicultural form** which occupy great areas are unsatisfactory, which is reflected in great percentage of the thinned mature stands without the juvenile forests (mainly covered by overgrown weeds) and juvenile stands with the stagnant old trees –grain layers. This unfavourable condition can be improved by the application of the suitable silvicultural methods (Stojanovic and Krstic, 2000), which would imply the following:

- Natural regeneration by the application of necessary supportive measures;
- Repair planting in stands which were thinned to a lesser extent;
- Removal of the grain layers from the regenerated stands.

Reclamation of the degraded forests is based on the basic regular patterns and principles of the forest management in general, and can be achieved by the application of the most advanced methods of agrotechniques, forest-silvicultural methods and protections and thereby initiate and activate the increase of productivity of the different forms of degraded forests, and at the same time provide and intensify the other benefits obtained from forests, reflected in the multi-beneficial functions of the forest.

In regard to the transformation of the coppice forests into high forests the following dilemmas are needed to be solved:

- On which areas the transformation should be applied immediately, by the reconstruction felling (direct conversion) and artificially regenerate the forests by the same species (restitution) or by the introduction of other species by the suitable site conditions (substition).
- On which areas the conversion of the silvicultural form should be anticipated – transformation.

In the quality stands on the good site it is only justified to convert the silvicultural form, when the stand reach maturity (rotation) of the highest production of timber volume and sporulation maturity. In bad stands (stands of the lower quality and health condition, of the decreased stand density) on good sites, of the insufficient diameter increment, it is economically justified and profitable to convert it into the higher silvicultural form by the reconstruction. Bad stands on the bad site, the condition of which is the result of the unfavourable orographic and edaphic conditions, have the lowest priority and until furthest notice should be placed on the waiting list.

The degree of urgency is determined by the quality of stand, and the degree of priority by the site conditions. If the stand is of higher quality, the degree of urgency is more visible. In addition, if the site conditions are more favourable, it has higher priority. The bad stands on the good site has the highest degree of urgency and priority, then the good forests on good site, whereas the bad forests on bad site has the lowest degree of urgency and priority.

The silvicultural needs in the forests of special purpose refer to the forest-silvicultural problems in forests, which are permanently or temporary excluded from the regular forest management, and in which the classic methods of forest management cannot be applied. Based on the importance and type of management, in the broadest sense of the term, the forests of the special purpose are defined, as all forests and forest soils which are of different importance than to the role of timber production and other forest products (Zachar, 1956). The basic function of these forests is protection; then the forest growing in the extremely unfavourable site conditions; protected natural resources (national parks, park-forests, etc); forests with the health role (in the vicinity of spas and natural health resorts); forests with the well-expressed tourist-recreational functions; forests for the other special purposes which require the special type of management – seedling stands, special-purpose plantations, forests in the hunting grounds and game farms, the forests with the scientific-educational purposes, forests which protects from the view or from the approach, located in the vicinity of the military facilities, etc. In these forests the distinction should be made between the function and functional type of the forest. The function type of forests refers to all forestswith the specific function, for instance, industrial (productive) forests, water- protection forests, anti-imission forests, etc. The functional type of forests is the specific form of forests of the suitable form and structure (structure, composition, mixture), which is the precondition for the optimum efficiency (functioning) of certain function type of forests. In each defined function type of forest, in order to form and preserve the functional type of forests, the suitable silvicultural methods are applied, by which the defined aims will be achieved at the best way (Krstic, 2008).

The specific way of management, which is adapted to the purpose, aimed at the intensification of their protective and other functions, is applied in these forests. The goal of the intensification of the achievement of the defined aims of the multi-purpose forest management, can be achieved by the application of the forest growing which is close to nature, in which the effort is made to optimally use the natural site capacity for the preservation of nature, biodiversity, improvement of condition and increase of the productivity of forests. In the professional literature the term "conservation" is frequently used for the protection and preservation of the natural resources. According to Vlatkovic (2001), the experts who study the environment problem interpret the term "conservation" in a different way from the experts who study the management of the renewable natural resources. In the first case it is defined as "continuous" use or simply as the "prudent use of resources". In forestry practice the conservation implies the permanent management of forest resources in a way by which their value does not deteriorate over a long period. The proponents of the environmental protection (out of forestry profession) consider that the conservation implies that the "natural" ecosystem is not used, i.e. that it refers to the intact areas.

The proving and insisting on the other functions of forests have become the symbol of prestige, so the exaggerations in this sense give the false information to the public and stir the irrational conflict with the forestry profession. The protective-regulation functions are very important, but the basic question can be put: Are the so-called "universally-beneficial" functions of forests really in contrast to the productive function, and are the virgin forests the most stable ecosystems. The exaggerated laicity of the problem of functions of forests created a false dilemma: intact or industrial forests, and the intact forests imply the forests which spontaneously develop, i.e.

has the form of virgin forests. Certain researches showed that these forests are not the most stable forest ecosystems. By contrast, the professional forest management provides the stable, health and high-productive forests (Nikolic and Stojanovic, 1990).

In order to **prevent the regression succession** of vegetation and its deterioration in the ecosystems which are altered by the anthropogenic activities, by the application of “active protection“ their condition can be improved by the selective use of the suitable silvicultural methods, which are adapted to the natural processes.

The forest growing is based on the autochthonous forest associations, i.e. on the potential natural vegetation, by the application of all other methods which contribute to the ending of the process of the regression succession and process of the degradation of forest ecosystems. The growing of autochthonous forest flora and fauna and the use of the secondary forest products are brought in accord with the basic activities of forestry.

Today, in the world countries with the developed forestry, the view that in the domain of the silvicultural operations it is needed to use the numeric parameters as the orientation indicators to a greater extent during the application of these methods, is dominant. In this regard, in the scientific literature a large number of the different norms in the form of the numerically expressed forms (formulae), tables, graphs, etc, which enable the substitution of the subjective estimates and impressions, i.e. descriptive formulations, by the measurable indicators, are present.

These norms are based on the relations between the concreate stand elements – on the ratio of tree height to the diameter, or to the basal areas, as well as the ratio of the tree height and the distances between the trees, etc. Jevtic, 1992; Krstic, 1997 et al.). By the use of the concrete – local site conditions and stand characteristics, with the satisfactory accuracy rate, in an **analytical way**, the direction of silvicultural needs and suitable operations in the stand can be determined. These methods by no means should be considered to be obligatory during their determination, since the universal “recipe“ for forest tending, which can be equally applicable for all forests and in all environmental conditions, cannot be applied.

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The significance and role of the future forest growing refers to the sustainable forest management. The modern concept of the sustainable forest management implies the harmony between the preservation, use and improvement of the condition, i.e. harmony between the use of natural resources in the forest, productive potential of site, and genetic potential of forest tree species, by the preservation of productivity, stability and vitality of forests, protection of forest ecosystems and natural biodiversity, as well as the preservation of the current natural rarities – relict and endemic species and forest communities.

All forest-silvicultural methods and activities must be based on the preservation and formation or more or less natural, intensively tended and stable forests, in the aim of the intensifying of all expected functions. The necessary silvicultural methods should be accompanied by all other ecologically directed methods in the aim of the preservation of the ecological role of forests.

The basic forest-silvicultural methods would imply the increase of the areas covered by forests, improvement of the forest condition, application of the silvicultural form, and the reclamation of the degraded forests, which would mean the application of the suitable silvicultural methods depending on the concrete site conditions and stand characteristics. In this way their stability and vitality would be preserved, and, at the same time, the anticipated forest functions would be performed in the best way, the impact on the alleviation of the climate change would intensify, and the forests would adapt to the altered climate conditions much faster.

By the good organization of work during the above silvicultural activities, in the phase of felling and harvesting of the wood assortments from the forests, the great damages of juvenile trees, mature trees and soil, should be prevented.

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CLOSE TO NATURE ARTIFICIAL REGENERATION OF EXTENSIVE CALAMITY CLEARINGS

Anna TUČEKOVÁ[1]

Abstract: *Results of research on close to nature technological procedure of artificial regeneration in form of sowing to "vegetation cells" are presented in the paper. In the time of crisis it is one of possible cheaper procedures of artificial regeneration of extensive clearings, especially in case of the lack of high quality planting stock. In Slovakia we have been verifying this technology in 12 localities of calamity and extreme clearings being affected by climatic changes. Success of sowing to „„vegetation cells" " has been tested for 11 tree species as Norway spruce, European larch, Scots pine, silver fir, European beech, Sycamore maple, pedunculate oak, black alder, black locust, common ash, and Swiss stone pine. In case of high quality seed with good germination energy, the seed of tested tree species germinated with 85-100% success. Germinated seedlings survive without any greater problems, damage, mostly in good health condition. They have favourable conditions in the „cells" during vegetation period, which is affected by climatic changes, without any greater temperature or moisture fluctuations. Some of them already during the first vegetation period reach the height of plastic cover (conifers), while broadleaves exceed by their heights plastic cover by about 5-15 cm. After the fourth year some broadleaves reach height of 60 cm up to 200 cm (beech, oak, alder) and conifers 50 cm up to 75 cm (pine, larch).*

Key words: extensive calamity clearing, sowing and "vegetation cells"

1. INTRODUCTION

Growing proportion of salvage felling due to extensive calamity in spruce stands in Slovakia has been a great challenge for foresters especially what concerns processing of great volume of wood from salvage felling as well as not less serious problems of effective regeneration of calamity clearings. Vast clearings are frequently located in conditions with very difficult access and extreme climatic conditions what makes the success of artificial regeneration even more difficult. Forest researchers search for and test several progressive methods and procedures that would contribute to deal with the mentioned problem as best as possible. Research team from the National Forest Centre – Forest Research Institute Zvolen has gained first encouraging results from testing improved progressive methods and procedures of calamity clearings reforestation. Based on preliminary calculations their application may save almost 50% of costs in forest practice. Moreover they are not demanding, they are ecological and close to nature management measures.

During forest regeneration after extensive calamities any possibility of using natural regeneration is welcomed and recommended. It should be suitably complemented by artificial

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Acknowledgements: The paper could be written thanks to the project 0628-07 of the Agency for Support of Research and Development (APVV) entitled "Progressive procedures of planting stock cultivation and artificial regeneration of forest stands after large scale calamities" and the project 0456-07 "Effect of wind calamity and subsequent management on the development of forest ecosystems in Tatra Mountains".

regeneration. Final aim of forest regeneration is establishment of horizontal and vertical structure of stands, which could secure sufficient ecological stability and thus also resistance against many other stressing factors.

Extensive tasks in artificial forest regeneration after November wind calamity in 2004 in Slovakia caused those foresters had to proceed rationally and use the latest results of forest science. Regeneration of forest communities affected by natural disasters requires considerably different approach than usual artificial forest regeneration, mainly due to great changes in the ecological conditions of areas being regenerated. In case of unexpected calamities there is not prepared sufficient amount of high quality planting stock for area regeneration. Changes in ecological conditions after such disasters is abrupt and radical and therefore these facts should be considered not only in selection of tree species and quality of planting stock but also in choosing technological procedures for forest regeneration. In general, the rule, that with deteriorating conditions of the environment also demands on selection of suitable plants are growing, should be followed. Already first work in forest nurseries decide about success or failure of artificial forest regeneration. Planting stock that will be used for artificial forest regeneration should be of high quality what concerns its genetic, morphological and physiological characteristics.

One of possibilities to reach at calamity clearings as smallest losses as possible after the first reforestation is utilization of higher percent of containerised plants, which adapt better and have substantially smaller losses than non-containerised plants on the same sites.

It is obvious that particularly physiological state of tree species, mainly roots, is a determining factor of survival. It should be stressed that also planting stock, which was not subjected to physiological stress, may have high percent of losses at extensive clearings. Recently drought and high temperatures have primarily caused this fact in spring. Therefore it is necessary to pay attention to the ways of securing sufficient water for newly established forest plantations. One of solutions is use of hydro absorbents in artificial forest regeneration (TUČEKOVÁ 2004, SARVAŠOVÁ 2003).

Other possibility of increasing survival rate of plantations following spruce stands disintegration is fertilization and liming of forest plantations. These measures are costly and they are used mainly in areas where soil environment should be modified (acidity reduction) and lacking nutrients complemented (under conditions of Slovakia's forest first of all magnesium and calcium). After the change in site conditions in the site there may be expected accelerated mineralization and subsequent release of nutrients due to deforestation.

On large-area calamity clearings it is necessary to obtain in fertile years the greatest possible supply of seed and use it effectively mainly when cultivated high quality planting stock is in sufficient. One of possibilities of the best possible use of such seed is direct sowing at clearings. Sowing is one of close to nature methods of forest regeneration that is the closest to natural regeneration. Though this procedure is one of the first methods of artificial regeneration it was not applied more extensively in forest practice. Reasons are obvious, very high losses caused by biotic and abiotic agents or problems with protection of young seedlings against weed pressure. Non-traditional sowing to "vegetation cells" (technology proposed by Ing. Štreit, patented in the Czech Republic) may partially eliminate the mentioned negative factors.

In past there was used a Swedish method of spruce sowing. It was manual or mechanized soil preparation, and then sowing of spruce seeds and their covering by a special plastic cone, which secured suitable hydrothermal conditions for germination and growth of seedlings. Due to the effect of atmospheric precipitation the cone disintegrated during two years and seedlings that reached the height almost 20 cm could continue in their growth. This technology was tested also in the Czech Republic but it failed in successful establishment of stand mainly due to lack of moisture during seed germination, slow disintegration of cones and weed competition as well.

Ing. J. Štreit proposed a new technology of forest regeneration, namely seed sowing into "vegetation cells" that should secure not only suitable physical and chemical conditions but also proper hydrothermal regime for the development of young seedlings and seedlings (MAUER, PALÁTOVÁ, RYCHNOVSKÁ 2005).

This technology has been tested in the Czech Republic in last years. In Slovakia we have complemented this technology, in cooperation with its author, by using supportive substances like microbiological soil conditioner, hydro absorbent namely due to significant changes in climatic conditions and in soil root layers in calamity areas (TUČEKOVÁ, 2009). Soil bacteria being added to substrate affect favourably through own activity the changes in soil in an area of newly formed root system. It means that they activate soil processes, bind nitrogen from the air and soil and stimulate its total mineralization and nitrification as well as affect total content of microbial biomass. Hydro absorbents retain moisture in the area of seed germination (TUČEKOVÁ 2007).

Testing of the technology of sowing to “vegetation cells” was performed during five vegetation periods in 13 stands in 15 tree species on very acidic, acidic, moderately rich as well as extremely poor dry sites located from the altitude 200 m up to 1.100 m. We deal in the paper also with results of this technology verification.

The aim of the paper is to evaluate the results of sowing to ”vegetation cells“ and to compare them with the results of planting on calamity clearings in TANAP as well as in conversion of low quality hornbeam stands.

2. MATERIALS AND METHODS

Research plots, which have been evaluated, were established on calamity clearings in TANAP (Tatra Mts. National Park) by sowing to “vegetation cells”. There were used seeds of eleven tree species as Picea abies L. Karst., Larix decidua L., Pinus sylvestris L., Abies alba L., Fagus sylvatica L. Acer pseudoplatanus L., Quercus petraea Mattusch Liebl., Alnus glutinosa L., Fraxinus excelsior, Betula pubescens Hhrh. and Pinus cembra L..

In conversion of low quality hornbeam stands (from coppice) seeds of Quercus petraea Mattusch Liebl. were used in the technology of sowing to “vegetation cells”.

In technological procedure of sowing to “vegetation cells” a hole deep 10 cm is made manually to parent soil (or with use of some mechanism) and diameter of used cell is about 8 cm. About 5 cm thick layer of organic matter – sowing substrate (substrate with admixture of slightly wetted perlite, hydrogel and soil conditioner) is put to the hole. On sowing substrate compressed manually seeds are sown and covered by perlite or another substrate. The “vegetation cells” are placed on prepared organic matter and covered by a layer of mineral soil. Vegetation cell is of plastic material with circular section (diameter 8 cm, height 15 cm). There have appeared ideas to change plastic material by ecological one, which would disintegrate within two years after application. If needed sowings, especially of large seeds (broadleaved species), may be protected against rodents by using wired covers that are placed on the top of plastic cone. Also in whole-area application of chemical spraying against weed it is possible to protect germinated seedlings by removable plastic cover.

At the end of vegetation periods (1st-5th year) state and development of sowings was analysed on research plots and the results were compared with the ones from classic artificial plantation. Parameters of aboveground parts were processed statistically (one factor variation analysis) and differences were tested by means of t-test. In evaluation of sample trees an attention was concentrated on deformation of root systems connected with non-observance of technological discipline during cultivation in forest nursery and during planting as well. Results of research from two chosen research plots are presented in the paper (1st EP Dolný Smokovec - Tatra mts.– sowing at calamity clearing in National Park (TANAP) and 2nd EP Rimavská Sobota – conversion of hornbeam stands).

3. RESULTS AND DISCUSSION

Fig. 1 illustrated the development of survival of seedlings from sowing to “vegetation cells” and following evaluation of their growth parameters at EP Dolný Smokovec I.

Germination and survival of tree species seedlings during two vegetation periods was high, 95-100%. Higher losses of beech seedlings (30%) were caused by higher moisture content in the area of cell (mould). In the second year after sowing all seedlings grown out of cell whereas coniferous seedlings reached height of 35 cm (larch) and of broadleaved species alder had on average the height of almost 70 cm. In following years tree species had regular increments and in the 5th year conifers had the height more than 80-100 cm (larch, pine) beech reached 65 cm height and alder even 250 cm. Health condition of all surviving individuals from sowing was good without any significant damage to aboveground parts.

Plastic cells had been already after the 2nd vegetation period overgrown by seedlings so they could be removed (they were left only for better orientation during evaluation, treatment, mowing of intensively growing grass and herbaceous layers). Seedlings had already formed favourable hydrothermal regime under plastic cover of cell therefore also their increments were regular and comparable with the increments obtained from seedbeds in nurseries. In past there was used a special sowing on “peat plates” to create suitable physical and chemical conditions for the development of germination leaves. Peat plates were placed on soil surface that was covered by plastic cones to secure hydrothermal regime (PUTMAN, ZASADA 1986, MAUER MUSIL 1989, SOLBRAA 1997). But applying this special procedure in forest practice failed.

Root system of sown tree species developed favourably without deformations, which are accompanying phenomenon with a high percent of non-containerised plants after transplanting. Roots have outgrown the substrate to surrounding mineral soil without any damage and limits.

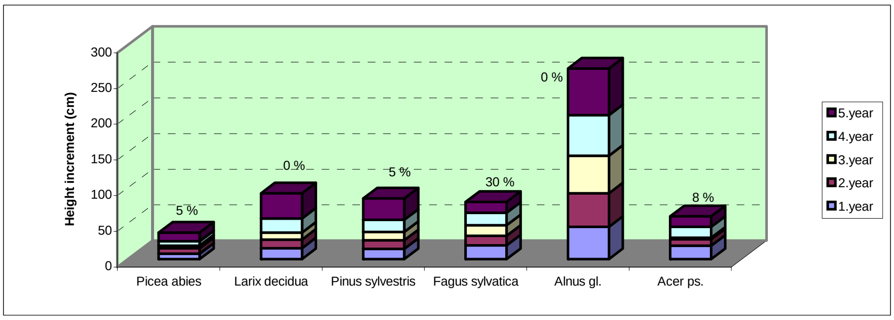

Fig. 1. *Losses (in %), course of height increment (in cm) of juvenile individuals from the sowing to “vegetation cells” after the 1st – 5th year (EP Dolný Smokovec I)*

If we compare five-year old individuals of tree species from sowing with planting of the same tree species (spruce, larch, pine, beech, maple) on surrounding calamity clearings, we may state not only higher looses for planting (by 60-70%) but also more unfavourable development and whole adaptation process of tree species individuals. Seedlings in ”vegetation cells“ do not suffer after germination any shock as they suffer in plantations in the first three years. Terminals of the individuals planted out are frequently dried in the 1st year and therefore even after growing of substitution terminal average height increments of individuals are significantly lower (e.g. annual height increment of pine from sowing is about 12-40 cm whereas after planting out pine individuals have on average in the 1st year height increment about 5 cm and in the 2nd year about 9 cm, in the 3rd up to the 5th year 10-15 cm. (Fig. 2).

Root system of older non-containerised plants of pine (2+3) and larch (2+2) was deformed already during cultivation in nursery. Due to non-observance of technological discipline in planting there was caused repeatedly deformation of great root system (long, natural root system compressed to the area of hole). Serious deformations of the root system caused in the course of transplanting of large-sized plants are a negative side of planting, which does not occur in sowing. Necroses and fungi have frequently attacked deformed root system, mostly damaged and bent roots or broken parts of roots, in first years after planting. The stability of future stands is influenced negatively as well.

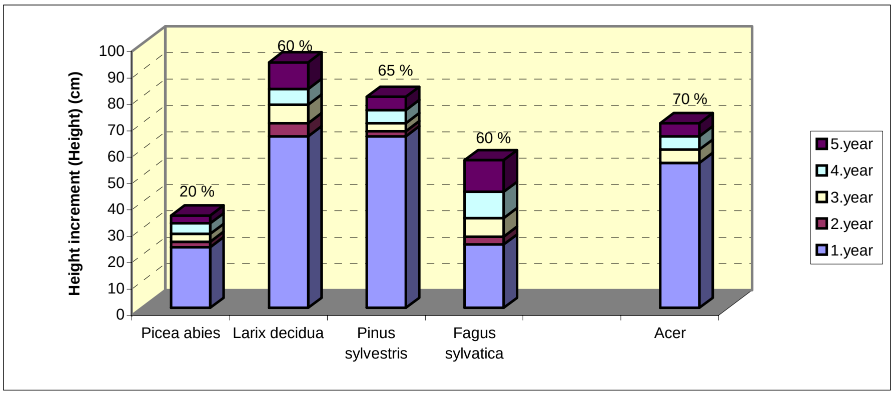

Fig. 2 *Losses (in %), height (in cm) of plants during planting and course of their height increment (in cm) after the 1st-5th year (EP Dolný Smokovec I)*

On second research plot Rimavská Sobota (conversion of hornbeam – Fig. 3a) sowings of Quercus petraea Mattusch Liebl. in "vegetation cells" also demonstrated positive results of development in comparison with classic sowing on small plots as well as with slit planting of oak. Differences in mean parameters of height in individual variants were statistically significant (Tab. 1). Losses in "vegetation cells" when compared with losses in tradition sowing were significantly lower (by 10-20%). Strong negative effect of lack of precipitation during the 1st vegetation period caused higher losses in sowing (without hydrogels application) and in transplanting of oak plants as well. Manager from affiliated forest enterprise in Rimavská Sobota (Fig. 3b) was also satisfied with height parameters (150-170 cm) of oak in the 4th year after sowing to "vegetation cells".

Table 1. *Course of the height of oak after sowing and planting after the 1st-4th year and losses after the establishment of experimental plot (EP) at Rimavská Sobota*

Variant of sowing (planting) - oak	**Height after 1st year**	**Height after 2nd year**	**Height after 3rd year**	**Height after 4th year**	**Losses after 1st year**
"vegetation cells" +BactoFil B	17.3±2.4 [a]	35.2±2.8 [a]	68.5±2.7 [a]	170.5±3.0 [a]	1
"vegetation cells"	16.3±2.6 [a]	30.4±1.9 [a]	48.3±2.9 [a]	155.0±3.1 [a]	3
"vegetation cells" without substrate	10.0±2.0 [b]	22.0±1.7 [b]	37.1±3.0 [b]	90.3±3.4 [b]	10
classical sowing -control	12.7±2.1 [b]	26.5±2.8 [b]	35.2±3.2 [b]	88.5±3.4 [b]	12
Slit planting	**32.5**	**30.4**	**33.8**	**59.5**	**35**

3a **3b**

Fig. 3a, 3b. *Establishment of EP Rimavská Sobota and oak in "vegetation cells" after the 4th year*

4. CONCLUSION

Regeneration of large clearings after calamity is possible also by a very simple and close to nature technology as is sowing for example to „vegetation cells“. Moreover, this technology is not demanding economically and is suitable regarding biological and ecological aspect as well.

Success of sowing to “vegetation cells” is providing there is available high quality seed with good germination power very favourable. Seeds of all tested tree species germinated in 85-100%. It was confirmed that for sowing seed of highest quality had to be used (it is necessary to know seed germination, germination power). Also pre-sowing preparation of seeds that require that must be consistent. With large seeds it is possible to use perlite or substrate, which was used in sowing, for small seeds wetted perlite proved well. It is very good to admixture to substrate hydrogels, which create favourable hydrothermal regime in the cell. In sowing large-sized seeds (as beech nuts, acorns) 2-3 seeds are proper to use for one cell, with smaller seeds (e.g. conifers) 5-7 seeds. Germinated seedlings survive without any great problems, damages to them, mostly in good health condition. They have during vegetation period created favourable conditions without any greater temperature and moisture fluctuations (similarly to small folia covering). Some of them already during the 1st vegetation period reach the height of plastic cover (conifers), broadleaved outgrow the plastic cover by about 5-15 cm. Results of research show that regeneration in juvenile stage of slow growing fir has not proved well. Technology of regeneration by sowing to „vegetation cells“ shows as one of suitable procedures of forest artificial regeneration, mainly with lack of high quality planting stock whereas hydrogels and soil conditioners containing soil bacteria may be used as well.

Our findings and results also from other calamity clearings suggest that this technology has good presuppositions for broader application, mainly on extreme localities in sowing large-sized broadleaved seeds or with lack of high quality planting stock on vast clearings after calamity.

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FACILITATION PROCESS AND SPROUTING ABILITY AS SILVICULTURAL TOOLS IN THE FRAME OF CLIMATE CHANGE

Elias MILIOS[1]

Abstract. *As a result of global warming foresters are to face a new ecological reality. A great shift of forest types will be observed in southern Europe. Many species and forest types will move northwards, while in mountainous areas forest zones are expected to shift upward. Moreover, many ecosystems will either be degraded or collapse. In the frame of climate change, silviculture has to develop practices in order to a) facilitate the gradual transition from one forest type to another, b) preserve ecosystems and forest types as well as c) restore degraded ecosystems as a result of global warming. The imitation of species and ecosystems responses against disturbances and abiotic stress will reinforce this effort. Modified silvicultural systems, in which species sprouting ability and seedling sprouts are incorporated in regeneration procedure, have to be developed and applied to forests where species are in danger of extinction or the abiotic conditions are harsh. In addition, sprouting has to be used in the restoration of degraded ecosystems. Another process that can be incorporated in restoration and reforestation activities is facilitation among plants by creating specific microhabitats with a favorable microclimate. Furthermore, facilitation during the stand regeneration in shelterwood systems may be used in more cases and in more species than at present. More research is needed in south Europe regarding: a) species sprouting ability and b) the role of facilitation in the establishment of many species in various environments. In addition, practices that use facilitation or sprouting in silvicultural systems or restoration activities must be checked in both silvicultural practice and research trials.*

Key words. Sprouting ability, facilitation, ecosystem preservation, restoration, global warming

INTRODUCTION

The global warming is going to create a new ecological reality. A great shift of forest types will be observed. Many species and forest types will move northwards (in the north hemisphere), while in mountainous areas, forest zones are expected to shift upward (see Perry 1994, Perry et al. 2008). Climate change having fundamental influences on availability of water and heat regimes strongly affects growth behavior and distribution of plants and forests (see Nahm et al. 2006, Jump et al. 2006, Perry et al. 2008).

The implications of climate changes in southern Europe will have many aspects. One of them is the changes of the species ranges. For example, *Fagus sylvatica* forests and stands will shift to higher elevations in southern Europe (see Penuelas and Boada 2003, Jump et al. 2006), regardless of the fact that beech provenances from southern Europe are considered to be better adapted to drought (Nahm et al. 2006, Fotelli et al. 2009). Milios and Smiris (2001) state that the zones of vegetation in Rhodope mountains in Greece are expected to shift upward varying from a few to

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several hundreds meters. This will result in the replacement of *Fagus sylvatica* by *Querus dalechampii* in many locations.

On the other hand many ecosystems will either be degraded or collapse mainly in the Mediterranean region. According to Perry et al. (2008) if temperature increases, in areas with no increase in total precipitation, the forests will become drought stressed in years of below – average precipitation. In the Mediterranean region there are many ecosystems in dry or semi - dry climates, as a result in many of them regeneration of many species will be problematic.

Biological diversity is one of '*the best tools to mediate an orderly transition of community types*' (Perry 1994). Perry et al. (1990) mention that the transition from one community type to another will be facilitated on condition that there is sufficient overlap between old residents and migrants.

In this frame, silviculture has to develop practices in order to a) facilitate the gradual transition from one forest type to another, b) preserve ecosystems and forest types and c) restore degraded ecosystems as a result of global warming. The imitation of species and ecosystem responses against disturbances and abiotic stress will reinforce this effort.

In this article, sprouting ability and facilitation process are suggested as tools for silvicultural practice in forests or forest areas where species are in danger of extinction or the abiotic conditions are harsh.

SPROUTING ABILITY AND SPECIES REGENERATION

All woody angiosperms can regenerate naturally from vegetative sources while conifers are less adapted to reproduce by vegetative means (Barnes et al 1998). Sprouts typically develop into shoots after a disturbance when growth of the tree crown is disturbed or roots are injured (Jones and Raynal 1988, Kozlowski et al. 1991, Barnes et al. 1998, Kozlowski 2002). Sprouts arise from dormant and adventitious buds from aboveground portions of an established tree or from adventitious buds in roots (Kozlowski et al. 1991, Smith et al. 1997). Practically, stump sprouts and root suckers are the main forms of sprouts that contribute to the regeneration of forest stands (Dafis 1986). Sprouts are considered to be an essential component of some silvicultural systems (Ky-Dembele et al. 2007, O'Hara et al. 2007, Valbuena- Carabana et al. 2008), since they constitute a significant source of regeneration.

In the traditional forestry sprouting ability is the base of coppice silviculture which creates low forest (Smith et al 1997). The higher growth rates of sprouts in youth compared to seedlings of equal age made the coppice system very popular in the past and led to the adoption of short rotations. Both in Europe and Greece the coppice system developed a bad reputation because repeated coppicing with short rotations was associated with ecological disadvantages (see Dafis 1992).

But sprouting ability influences both ecological processes and species competition ability. According to Kozlowski et al. (1991) the ability of angiosperms to sprout is possibly one of the reasons for their dominance over conifers in abundance since the Cretaceous Period. Sprouting ability influences the recovery of forests after disturbances (Peterson 2000, Masaka et al. 2004). Kennard et al. (2002) make a reference to the fact that the larger root systems of sprouts offer more surface area for water and nutrient uptake and possibly extend deeper into the soil than seedling root systems. Bond and Midgley (2001) claim that sprouting ability can have major impacts on plant populations, since the turnover of populations is being reduced, the effects of a disturbance are minimized and the dependence on seeds for population maintenance might become negligible. Therefore, sprouting ability is regarded a mechanism for ecosystem stability maintenance after disturbances (see also Milios and Akritidou 2003).

Forest practice has to use these traits of sprouts in order to create modified silvicultural systems in order to a) facilitate the gradual transition from one forest type to another and b) preserve ecosystems and forest types.

In particular, in places with an upward or northern shift of a broadleaved species as a result of global warming, the species regeneration establishment gradually will be reduced and will appears adequately only in a favorable but rare combination of abiotic conditions. Such conditions can be, for example in rather rainy and not too warm (for the new climate) summers. In the most of the summers there will be a sparse establishment of seedlings. If there are not other species to occupy the growth space or if their density is very low and there is not a sufficient overlap between old residents and migrants, then forest practice must preserve the initial species at least for a period. In this case, the regeneration procedure, in shelterwood systems, has to incorporate preparatory cuttings where, apart from of the known reasons (crown development and seed production, decomposition of the humus layer etc.), the main objective will be the establishment of advance regeneration at least when we have shade or semi shade tolerant species. In a later treatment, taking place (after some years) when the weather conditions in spring and early summer are favorable, the seeding felling will be applied. After the seeding felling, in parallel to the establishment of seedlings, the advance regeneration plants must be cut to the base in order to stimulate the development of sprouts. These sprouts will supplement the seed origin regeneration in order to have successful stand regeneration (see also Papalexandris and Milios 2010). Most of these sprouts would be seedling sprouts since they would have been sprouted from stumps having a diameter of less than 5 cm (Smith et al. 1997). Seedling sprouts are often superior to seedlings since the new shoots grow more rapidly as a result of their established root systems and the stems tend to be straighter because they escape in less time from the height zone in which agencies act that create deformities (Smith et al. 1997). When there are multi-stemmed sprout origin trees, these can be become single stemmed or two stemmed through gradual thinnings.

Another possible procedure in order to stimulate the establishment of advance regeneration, that will supplement the seed origin regeneration, is to promote, through the appropriate technique for each species, the development of root suckers. According to Nyland (1996) these new trees in some species often persist in the understory for long periods. In any case, forest practice has to promote the development of advance regeneration and to cut it in order to create sprouts.

The same approach can be followed in the case we want to preserve a forest type or a species for any reason in a region.

Moreover in the frame of restoration of degraded ecosystems the trees of the existing species having sprouting ability must be cut in order to promote sprout development instead of planting conifers. If the density of the existing plants is low, a combination of planting, cutting and sprouting must be used. The pre-established root system of sprouts enables them to persist in dry periods. This trait acts as an advantage of sprouts particularly in dry regions where water is seasonally limited (Kennard et al. 2002).

All these mentioned above are general guidelines since the exact treatments have to be adapted to the local ecological and site conditions. There can be many variations regarding the specific treatments in different stands or in different mixtures of species. In any case, basic knowledge must be used. Thus trees must be cut during the dormant season in order to have vigorous sprouting or when food reserves are low if you want to suppress sprouting (Kozlowski et al 1991). Also the creation of the appropriate light conditions in relation to species requirements is a way to promote or to suppress sprouting.

More research is needed in south Europe regarding species sprouting ability and sprouting under different site and shade conditions. For example, beech can sprout under rather closed canopies in low elevation in south-eastern Greece (personal observation), while sprouting functions as a mechanism of maintenance of beech stands in medium productivity sites (see Papalexandris and Milios 2010). This must be checked in various environments and for many species. In addition, practices that use sprouting in silvicultural systems or restoration activities must be checked in both silvicultural practice and research trials.

FACILITATION

Even though competition is one of the main forces influencing distribution and abundance of plant species (Bartelheimer et al. 2006), facilitation is an important ecological procedure for the maintenance and function of many ecosystems. According to Cheng et al. (2006) facilitation appears when one species facilitates the survival, growth or abundance of another. Facilitation among plants is related to the a) reduction of soil surface temperatures (Franco and Nobel 1989), b) protection from direct sunlight (Smit et al. 2008), c) increase of soil moisture (Zou et al. 2005), d) increase of soil fertility (Callaway et al. 1991) and e) reduction of the possibility of frost damage to tissues (Gomez-Aparicio et al. 2008). Moreover, facilitation is related to the protection from grazing (Milios et al. 2009). In many cases, facilitation is related to a combination of the above procedures (Milios et al. 2007; Gomez-Aparicio et al. 2008).

Facilitation plays an important role in Mediterranean forests and shrublands (Rousset and Lepart 2000). In warm and water – stressed environments protection against environmental stress through facilitation enables the establishment of plants. Moreover, in some cases, even light demanding species are established under nurse plants in severe for them abiotic conditions. Castro et al. (2004a) argue that *Pinus sylvestris* exhibited maximum survival under the canopy of shrubs compared to that under pines or in bare soil, in marginal southern distribution areas of the species, in mountains of Spain. One of the facilitating influences was that shrubs buffered summer drought, without reducing the radiation to levels critical for growth (Castro et al. 2004a).

As the climate changes new areas will become warm and water – stressed. In the future, in the degraded ecosystems, forest practice has to incorporate facilitation in restoration treatments. In reforestations in areas of sparse vegetation, in severe regarding aridity environments, the seedlings must be planted under the protection of nurse plants. Moreover, there can be a combination of cutting and subsequent sprouting of existing plants while afterwards these can be used as nurse plants in reforestations. After the establishment of planted species the young plants can be released from competition through the gradual cutting of competitive trees (or sprouts). Castro et al. (2004b) using as nurse plant the shrub *Salvia lavandulifolia* in reforestations with *Pinus sylvestris* and *Pinus nigra* found that the survival of pines was remarkably higher when planted under nurse plants as compared to open areas.

This approach can possibly be used even in species adapted in harsh climatic conditions such as *Pinus halepensis* and *Pinus brutia*, in ecosystems where the conditions regarding aridity and temperatures will become severe.

The importance of facilitation in regeneration procedure of shelterwood systems might increase. In many species the intensity of regeneration fellings will probably be reduced. Additionally, the intensity, the number and the intervals between the secondary fellings will be adapted to the new conditions. The basic criterion that will determine the diversifications in the procedure of regeneration will be the balance between facilitation (from heat, drought, other risks) and competition (light, water, etc.) of canopy trees upon new regeneration. In this frame, facilitation during the stand regeneration may be used in more cases and in more species than at present.

More research is needed regarding the usage of treatments based on facilitation in different species and site conditions. These treatments must be checked in both silvicultural practice and research trials.

CONCLUSIONS

The incorporation of sprouts and facilitation in the establishment and regeneration procedures of many species in various environments are indicated as silvicultural means (tools) in order to achieve various goals in the new conditions created by global climate change. These tools can be useful for the treatment of forest ecosystems in many parts of Europe which will be warmer and seasonally dry in the future.

All or a part of the abovementioned silvicultural approaches may be used, combined or even diversified in the different sites and species according to the specific ecological conditions, since in silviculture the general usage of simplistic rules and prescriptions always leads to problems and failures in all ecosystems and stands.

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FOREST MANAGEMENT AND CLIMATE CHANGES

PLENARY LECTURES

GROWTH ELEMENTS AND QUALITY OF AUSTRIAN PINE PLANTATIONS IN THE AREA OF RAŠKA

Miloš KOPRIVICA[1]

Abstract: *The present state of Austrian pine plantations in the area of Raška was researched in the aim of management planning and prediction of future development. The plantation age was 35-55 years, site class I-V. Permanent sample plots were established in 1998 by the Institute of Forestry, Belgrade. The plantations were surveyed three times: in 1998, 2004, and 2009. The data of sample plots and formed yield classes were processed using the classical dendrometric and statistical methods. It was assessed that Austrian pine plantations were in good health condition and that they were characterised by good productivity and quality. At the age of about 55 years, depending on the site class, the plantations were characterised by: stand quadratic mean diameter 17.4-21.6 cm, mean height 15.5-19.4 m, number of trees 1349-1088 trees/ha, basal area 32.1-39.8 m^2/ha, volume 281.1-398.1 m^3/ha, volume increment 5.16-7.28 m^3/ha, and volume increment percentage 1.83-2.11%. The plantation quality was good, but there were some adverse effects resulting from the absence of well-timed thinning. Based on the analysis of growth elements and plantation quality, the planned thinning methods were mixed thinning and crown thinning. Thinning weight by tree number was 25-35%, and by volume 20-25%. It was concluded that the prospect of further development of Austrian pine plantations in the area of Raška was good.*

Key words: Raška, Austrian pine, plantations, growth elements, increment, plantation quality, thinning

1. INTRODUCTION

Coniferous plantations occupy a significant position in the growing stock of Serbia. The dominant plantations are Austrian pine, Scots pine and spruce (Koprivica, M. *et al.* 2000). In the middle of the 20th century, large areas of bare land in the surroundings of Raška were afforested predominantly with Austrian pine. This was followed in the eighties of the 20th century by mass afforestation of the other part of Ibarska Klisura (Šmit, S. *et al.* 1997, Koprivica, M. *et al.* 1996). In the area of Serbia in general, Austrian pine plantations were established mostly on poorer site classes (Vučković, M. 1989, Koprivica, M., Ratknić, M. 1996, 1999, Koprivica, M. *et al.* 2000, 2002, Miletić, Z. *et al.* 2002, Rakonjac, Lj. *et al.* 2003).

The study of forest plantation development, productivity, stability and quality is always topical, especially in cases of changed site conditions resulting from the change in climate and other factors (Koprivica, M., Matović, B. 2004, Koprivica, M. *et al.* 2009). The adverse effects of climate and all other abiotic and biotic factors can be mitigated by preventive professional actions, i.e. by increasing forest vitality, stability and resistance. In plantations, it is best achieved by thinning (Vučković, M., Stajić, B. 2003, 2004).

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20052 „Changes in forest ecosystems affected by global warming"

This study was targeted at a more in-depth research of growth elements and quality of middle-aged Austrian pine plantations in the area of Raška, in the aim of a more precise definition of their actual state, planning of adequate management measures, and predicting the future development.

2. STUDY AREA

Austrian pine plantations were studied at several sites in the surroundings of Raška, at the age of 35-55 years, site class I-V. In 1998, the Institute of Forestry, Belgrade, established twenty permanent sample plots, which were measured in 1998 and 2003. However, in 2007 there was a major forest fire which destroyed about 75 hectares of forest plantations, i.e. two sample plots. Also, another two sample plots were destroyed by the construction of forest roads. Consequently, this study was performed on sixteen sample plots.

The sample plot size was selected so that 25-30 trees should remain after the end of the production period of 120-140 years. They are mostly at the altitude of 450-680 m, slope 8-33 degrees, predominantly north aspect. Most sample plots are located on eutric rankers over ultrabasites. The site on which Austrian pine plantations are established belong mainly to natural sites of oaks: *Quercetum deleschampii sepentinicum* and *Quercetum montanum poetosum nemoralis*. Only one study plantation grows on beech site: *Fagetum mesiacae montanum* (Koprivica, M. *et al.* 2002).

3. METHOD

The third measurement of sample plots was performed in September 2009. The diameter at breast height was measured on all trees and tree quality was evaluated using the Oxford classification. Tree height and diameter increment were measured on every second tree. Height was measured using altimeter Vertex III, and diameter increment was measured using Presser's borer. The data were collected and processed by an especially designed method (Koprivica, M. *et al.* 2008).

The data on tree diameter increment were measured precisely and processed at the Institute of Forestry Laboratory. The analysis included 248 trees. Height curves and curves of diameter increment were computed by analytical fitting of measured data, i.e. by Mihailov's function for height, and by second-order parable for diameter increment. Tree volume was estimated by regression equations (1) and (2) calculated in previous studies of these plantations and also Austrian pine plantations on the Pešter Plateau (Koprivica, M. *et al.* 2002, Rakonjac, Lj. *et al.* 2003). Current volume increment was estimated by diameter increment method, based on tree diameter increment over the past six years (2003-2009). The trees planned for thinning were marked according to the principles of mixed thinning and crown thinning.

After data processing, the sample plots were grouped in four yield classes formed in previous investigations (Koprivica, M. *et al.* 2002, Koprivica, M., Matović, B. 2004), taking into account plantation age and site class. Still, the loss of some sample plots resulted in minor changes, so the classification of plots per yield classes was as follows:

Yield class	Sample plot	Age	Site class
1	1, 3, 8, 12, 16	57, 53, 55, 55, 55	2, 2, 2, 2, 1
2	5, 15, 18, 19	57, 57, 49, 52	3, 3, 3, 3
3	2, 17	54, 52	3, 4
4	7, 10, 11	37, 37, 36	4, 5, 5

4. RESULTS AND DISCUSSION

The study results refer to the actual state of Austrian pine plantations, as the result of their previous development and tending measures. They present the size and structure of the most significant growth elements, as the indicators of plantation structure and preliminary productivity. An especially significant component is the analysis of plantation quality.

4.1 Tree height

Tree heights were precisely measured and the data were used for the construction of height curves, necessary for the calculation of tree volume on sample plots. The sample sizes of measured trees per yield classes was: 100 (1), 67 (2), 33 (3) and 48 (4). The data were fitted by Mihailov's function:

$$h = a\, e^{-b/d} + 1.30 \qquad (1)$$

The results of analytical fitting of tree heights are presented in Table 1.

Table 1. *Regression indicators for height curves of Austrian pine yield classes*

Yield class	Age	Site class	Regression parameters		S_e	R^2
			a	b	(m)	(%)
1	55	I/II	27.0304	8.65177	1.59	52.92
2	54	II/III	17.8710	2.95402	1.24	12.04
3	54	III/IV	18.8089	4.89929	0.70	55.13
4	37	IV/V	12.2389	5.54045	1.20	44.43

Height curves are presented in Diagram 1.

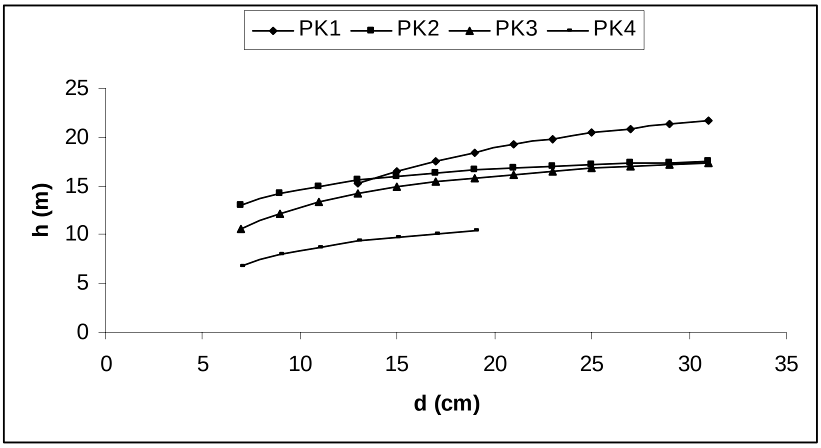

Diagram 1. *Height curves of Austrian pine yield classes*

Diagram 1 shows that yield classes 2 and 3 have almost the same height curve shape and position. Still, tree heights in all diameter classes are greater in yield class 2, as the consequence of a better site class. Height curve for yield class 1 is considerably steeper, and the difference in tree heights increases with the diameter increase. For example, the heights for tree diameter of 15 cm are: 16.5 m (1), 16.0 m (2) and 14.9 m (3), and the heights for tree diameter of 30 cm are: 7 m, 17.5 m and 17.4 m. The shape of height curve for yield class 4 is similar to height curves of yield classes 2 and 3, but its position is much lower because it is the case of younger Austrian pine plantations on the poorest site classes.

4.2 Diameter increment

Diameter increment was precisely measured and the data were used for the determination of current annual volume increment of trees on sample plots. The size of the sample of bored trees per yield classes was: 100 (1), 67 (2), 33 (3) and 48 (4). The measured data were fitted using the second-order parable,

$$id = a + bd + cd^2 \qquad (2)$$

The results of analytical fitting of tree diameter increment are presented in Table 2.

Table 2. *Regression indicators for diameter increment of Austrian pine yield classes*

Yield class	Age	Site class	Regression parameters			S_e (mm)	R^2 (%)
			a	b	c		
1	55	I/II	-2.73301	0.285323	-0.002988	0.78	48.06
2	54	II/III	-5.33843	0.621197	-0.011474	0.85	34.30
3	54	III/IV	-3.44750	0.434418	-0.007469	0.70	37.88
4	37	IV/V	0.23896	0.021962	0.009020	0.58	62.24

The curves of diameter increment are presented in Diagram 2.

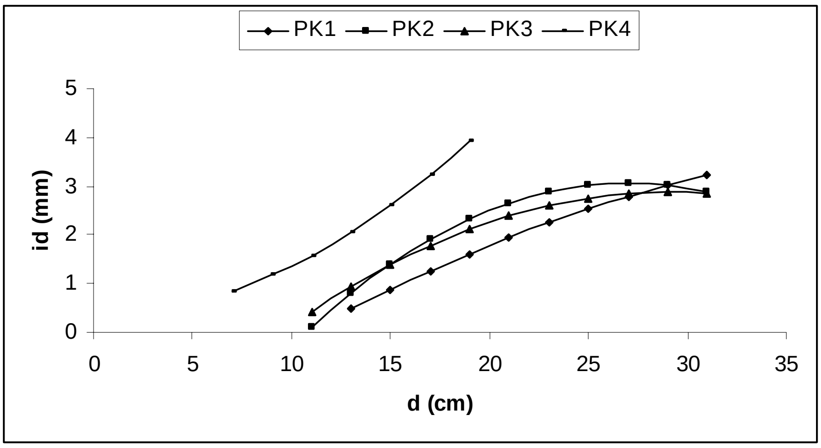

Diagram 2. *Curves of diameter increment of Austrian pine yield classes*

Diagram 2 shows that yield classes 2 and 3 have similar shapes and positions. Current diameter increment culminated when tree diameters were 27 cm (2) and 29 cm (3). Under the same tree diameters, tree increment was greater in yield class 2, which is the consequence of a better site class, and the result of thinning. However, in yield class 1, diameter increment did not culminate, and the line shape is most similar to straight line. It is interesting that in all diameter classes below 28 cm, tree increment in this yield class was lower, although it is the case of the plantations of the same age on the best site classes. This is probably the consequence of different stocking density of Austrian pine plantations and the late thinning.

The curve of diameter increment for yield class 4 deviates significantly from the curves for other yield classes both by shape and by position. The trees in this yield class have much greater diameter increments for the diameters between 7 and 20 cm, with a further increasing trend. This is primarily the consequence of considerably younger Austrian pine plantations in this yield class, and also probably the site class effects, because on poorer site classes, the trees force their diameter growth on the account of the retarded height growth.

4.3 Plantation state

The state of Austrian pine plantations was estimated based on the complete inventory of all trees on sample plots. Actually, three states were separately assessed: the state at the time of the inventory, the state of the planned thinning and the state immediately after the planned thinning. To increase the review and preciseness of the growth elements, the results are given per yield classes (Table 3).

Table 3. *State of growth elements of Austrian pine yield classes*

Yield class	Age	Site class	Density	Growth elements of yield classes per hectare						
				d_g	h_g	N	G	V	I_v	P_{iv}
				cm	m	trees	m^2	m^3	m^3	%
State before thinning										
1	55	I/II	0.8728	21.6	19.4	1088	39.8	398.1	7.28	1.83
2	54	II/III	0.8636	20.2	16.6	1061	34.2	303.5	6.42	2.11
3	54	III/IV	0.9582	17.4	15.5	1349	32.1	281.1	5.16	1.83
4	37	IV/V	1.1148	12.3	8.9	1987	23.3	93.2	2.52	2.70
State at the time of thinning										
1	55	I/II	-	18.2	18.2	383	10.0	98.0	1.42	1.45
2	54	II/III	-	17.1	15.0	282	6.5	59.5	1.04	1.75
3	54	III/IV	-	14.9	14.5	476	8.3	74.2	1.20	1.62
4	37	IV/V	-	8.8	7.6	376	2.3	10.2	0.18	1.76
State after thinning										
1	55	I/II	0.6535	23.2	19.9	705	29.8	300.1	5.86	1.95
2	54	II/III	0.6995	21.3	16.7	779	27.7	244.0	5.38	2.20
3	54	III/IV	0.7104	18.6	15.8	873	23.8	206.9	3.96	1.91
4	37	IV/V	1.0047	12.9	9.1	1611	21.0	83.0	2.34	2.82

Table 3 shows clearly the differences between yield classes in all growth elements. However, due to different plantation ages, only yield classes 1, 2 and 3 can be compared. The difference in stand quadratic mean diameter is 4.2 cm, mean height 3.9 m, number of trees 261 trees/ha, basal area 7.7 m^2/ha, volume 117 m^3/ha, and volume increment 2.12 m^3/ha.

The significance of differences between yield classes was tested using the analysis of variance. The differences between: diameter, height, stem length, and diameter increment of trees in plantations were classified in yield classes 1, 2 and 3. Altogether 200 trees were analysed, and the number of measured trees per yield classes was as follows: 100 (1) 67 (2) and 33 (3). The results are given in Table 4.

Table 4. *Results of the analysis of variance of Austrian pine yield classes*

Growth element	F ratio	Significance of differences	Yield class	Arithmetical mean	Difference between classes	Significance of differences
Diameter	9.12	significant	1	21.4	1 - 2	random
			2	20.1	1 - 3	significant
			3	17.7	2 - 3	significant
Height	62.09	significant	1	19.0	1 - 2	significant
			2	16.7	1 - 3	significant
			3	15.4	2 - 3	significant
Stem	62.15	significant	1	11.1	1 - 2	significant
			2	9.3	1 - 3	significant
			3	8.6	2 - 3	significant
Increment	4.58	significant	1	1.93	1 - 2	significant
			2	2.35	1 - 3	random
			3	1.80	2 - 3	significant

F - test shows that the differences between tested Austrian pine yield classes were statistically significant per all growth elements, at the probability level 95%. Therefore, the designation of yield classes was good. Sample plots within the same yield class are very similar and they are different between yield classes. Also, t - test shows the statistically significant difference between two compared means of growth elements in yield classes, at the probability level 95%. Only two comparisons are statistically random: between mean diameters in yield classes 1 and 2, and between mean diameter increments in yield classes 1 and 3.

As site class of even-aged stands is most often assessed based on stand age and mean height, an especially significant result of the analysis of variance is the mean height per yield classes. In yield classes 1, 2 and 3, plantation age is the same and mean heights are about 19, 17 and 15 metres respectively. The difference between mean heights is statistically significant at the probability level 99%, and it is the consequence of different site classes. This conclusion is proved by the following: "The stand site class ultimately refers to the yield. The yield denotes the produced quantity of wood volume reduced to year and hectare" (Matić, V. 1980).

4.4 Plantation structure

The structure of Austrian pine plantations per yield classes and growth elements was determined first by 2 cm diameter classes, and then grouped per 6 cm diameter classes (Table 5).

Certainly, the most significant structures are the structure of the number of trees and the volume structure per diameter classes. The diameter structure is used for the estimation of the size and structure of basal area, plantation volume and volume increment, and the volume diameter structure is a significant indicator of plantation quality. Under similar tree quality, economically more valuable and better quality Austrian pine plantations are the plantations with a higher percentage of larger-diameter trees in the volume.

Table 5. *Structure of growth elements of Austrian pine yield classes*

Yield class	Age	Site class	Diameter (cm)	Growth element of yield class			
				N	G	V	I_v
				Structure (%)			
1	55	I/II	4.1-10.0	-	-	-	-
			10.1-16.0	14.07	6.27	6.33	2.68
			16.1-22.0	45.23	35.55	34.94	29.71
			22.1-28.0	35.18	46.43	46.66	53.59
			28.1-34.0	5.53	11.76	12.07	14.02
			Sum	100.00	100.00	100.00	100.00
2	54	II/III	4.1-10.0	4.20	0.77	0.97	0.04
			10.1-16.0	13.29	6.63	7.21	4.01
			16.1-22.0	55.24	50.29	50.48	51.38
			22.1-28.0	23.08	33.09	32.52	37.80
			28.1-34.0	4.20	9.21	8.83	6.78
			Sum	100.00	100.00	100.00	100.00
3	54	III/IV	4.1-10.0	2.94	0.48	0.98	0.01
			10.1-16.0	41.18	26.62	27.12	19.83
			16.1-22.0	47.06	54.95	54.09	59.34
			22.1-28.0	7.35	13.29	13.12	15.83
			28.1-34.0	1.47	4.66	4.70	5.00
			Sum	100.00	100.00	100.00	100.00
4	37	IV/V	4.1-10.0	29.47	12.91	14.62	8.14
			10.1-16.0	55.79	56.99	57.00	52.80
			16.1-22.0	14.74	30.10	28.38	39.06
			22.1-28.0	-	-	-	-
			28.1-34.0	-	-	-	-
			Sum	100.00	100.00	100.00	100.00

The tree number structure and volume structure of yield classes per diameter classes is presented in Diagrams 3 and 4.

Percent distribution of the number of trees per diameter classes in all yield classes is similar to normal distribution. The number of larger-diameter trees is higher in Austrian pine plantations on better site classes: it is the highest in yield class 1, followed by yield class 2, and it is the lowest in yield class 3. Plantation age is about 55 years. Here also, yield class 4 shows a significant deviation per position because of the considerably younger plantations and the poorest site class.

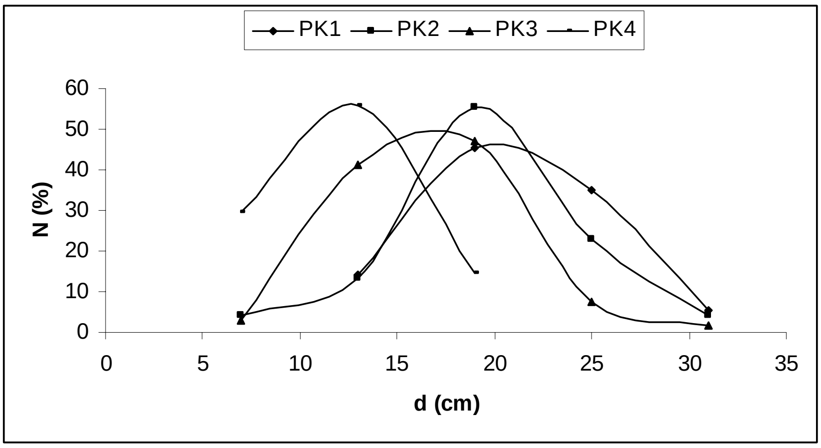

Diagram 3. *Distribution of tree number in Austrian pine yield classes per tree diameter*

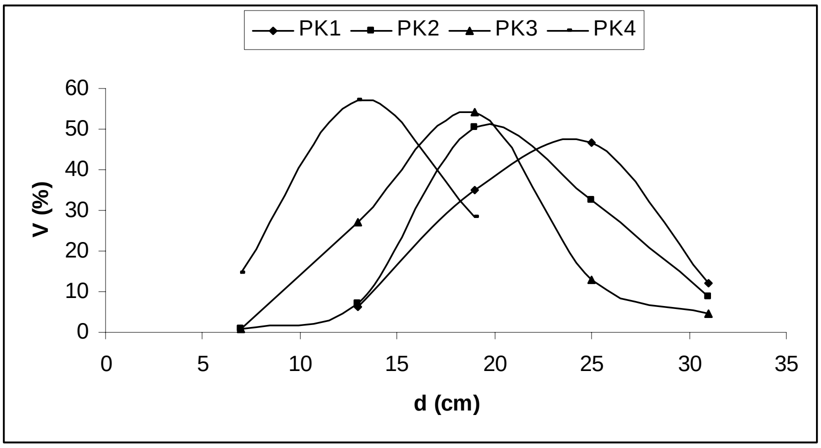

Diagram 4. *Distribution of volume in Austrian pine yield classes per tree diameter*

Percent distribution of volume per diameter classes in all yield classes is similar to the percent distribution of the number of trees, i.e. to normal distribution. Still, all volume distributions are moved to the right, because larger-diameter trees individually have a greater volume than the smaller-diameter trees.

If it is taken that saw logs can be produced from trees with diameters at breast height above 28 cm, outside bark, it is evident that the percentage of such trees in the volume depends on the yield class: 12.0% (1), 8.8% (2) and 4.7% (3).

4.5 Plantation development

As the data on the state of the study Austrian pine plantations are not available for all periods, it is impossible to analyse their entire development. The available data on the plantation state per yield classes were determined based on three surveys carried out in the past eleven years using the same method (Table 6).

Table 6. *State of Austrian pine yield classes based on three successive surveys*

Yield class	Age	Site class	Density	Growth elements in yield classes per hectare						
				d_g	h_g	N	G	V	I_v	P_{iv}
				cm	m	trees	m^2	m^3	m^3	%
Survey 1998										
1	44	I/II	0.8915	17.9	15.7	1436	37.0	326.0	5.40	1.66
2	43	II/III	0.8977	17.3	13.2	1321	31.6	242.0	5.60	2.31
3	43	III/IV	1.1346	14.0	11.7	2075	33.3	245.0	4.20	1.71
4	26	IV/V	1.3407	9.1	5.7	2829	19.4	68.0	4.10	6.03
Survey 2003										
1	49	I/II	0.8378	20.2	18.3	1150	36.7	333.0	6.05	1.82
2	48	II/III	0.7945	20.0	15.5	947	29.7	231.3	6.15	2.65
3	48	III/IV	1.1083	16.3	14.7	1665	34.8	286.8	5.53	1.93
4	31	IV/V	1.2424	11.4	8.7	2212	22.5	89.1	3.54	3.97
Survey 2009										
1	55	I/II	0.8728	21.6	19.4	1088	39.8	398.1	7.28	1.83
2	54	II/III	0.8636	20.2	16.6	1061	34.2	303.5	6.42	2.11
3	54	III/IV	0.9582	17.4	15.5	1349	32.1	281.1	5.16	1.83
4	37	IV/V	1.1148	12.3	8.9	1987	23.3	93.2	2.52	2.70

Note: as a result of different periods of thinning and minor changes in sample plot composition per yield classes, the direct comparison in this Table has an approximate character.

4.6 Plantation quality

The state of Austrian pine plantation quality was assessed by IUFRO or Oxford classification of trees (Mlinšek, D. 1968). It was applied according to the description presented in the reported research method (Koprivica, M. *et al.* 2008) and includes the analysis of biological and management aspects of tree quality. The analysed biological aspects were: tree position in the stand, tree vitality, and tree development tendency. Management aspects were: silvicultural role of the tree in the stand, stem quality, crown length, and tree health.

The Austrian pine plantation quality was analysed per yield classes used for the analysis of growth elements. Here also, yield class 4 has to be analysed separately from yield classes 1, 2 and 3.

Tree position in the stand was assessed based on the stand upper height (20% of the highest trees). There are three cases: *trees of the upper layer* (100), *trees of the medium layer* (200) and *trees of the lower layer* (300).

Diagram 5 shows that trees of the upper layer prevail in plantations of all yield classes. Their percentage is approximately proportional to site class. The exception is yield class 2, which has more trees in the upper layer (77.6%) than yield class 1 (67.9%), although it is a poorer site class. This can be explained by the previous thinning in the plantations of yield classes 2 which had a favourable effect on tree differentiation per height. In yield class 4, the upper layer has the lowest percentage of trees (50.5%), and the percentages in the medium and lower layers are 27.4% and 22.1% respectively, because this yield class consists of younger Austrian pine plantations in which the differentiation of trees by height is still to be more intense.

Tree vitality was estimated based on the tree ability to react to thinning. There are three cases: *trees of high vitality* (10), *trees of normal vitality* (20) and *trees of poor vitality* (30).

Diagram 6 shows that trees of normal vitality prevail in all yield classes. Simultaneously, all yield classes include a small number of trees of poor vitality, which are unable to react adequately to thinning. The lowest percentage of such trees is found in yield class 2 (4.2%), thanks to previous thinning. The lowest percentage of trees of high vitality is found in yield class 4 (27.4%), because it is on the poorest site class.

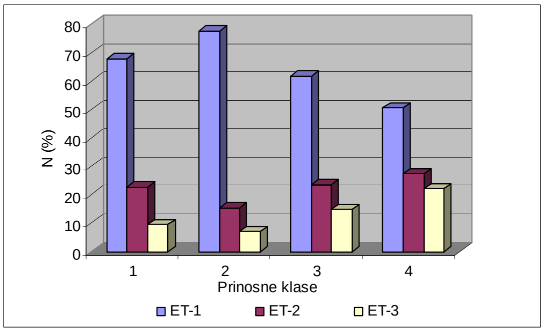

Diagram 5. *Distribution per position*

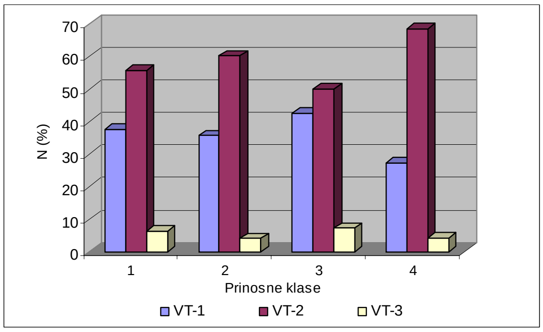

Diagram 6. *Distribution per vitality*

The tendency of tree development is estimated based on growth speed, i.e. height increment compared to neighbouring trees. There are three cases: *trees with progressive tendency of height growth* (1), *trees with intermediate tendency of height growth* (2) and *trees with retarded tendency of height growth* (3).

Diagram 7 shows the known fact that site class has the greatest effect on height growth. Still, the highest number of trees with progressive tendency of height growth (60.1%) occurred in yield class 2. This is the consequence of previous thinning, which removed most of the trees with a poorer development tendency. A high percentage of trees with poor tendency of height growth is present in yield classes 3 and 4 (35.3% and 37.9%), where the appropriate thinning was not done on time.

Silvicultural role of trees in the stand was estimated based on its significance for future production. There are three cases: *selected trees* (400), *exploitable trees* (500), and *harmful trees* (600).

Diagram 8 shows that the highest number of selected trees occurs in yield class 2 (35.7%), which was subject to thinning. This yield class compared to yield classes 1 and 3 also has the lowest number of harmful trees (26.6%). Yield classes 1 and 3 have similar structures of the number of trees by silvicultural role, but the structure is somewhat more favourable in yield class 1. In yield class 4, exploitable trees account for the highest percentage (56.9%). This can be explained by the fact that it is the case of younger plantations, and some exploitable trees can be expected to turn into the category of selected trees in future.

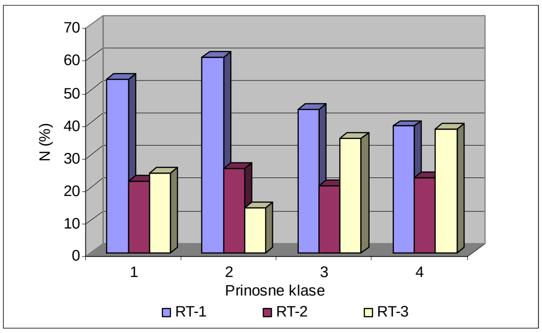

Diagram 7. *Distribution per tendency*

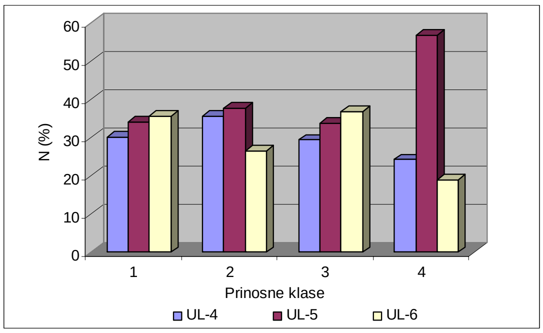

Diagram 8. *Distribution per silvicultural role*

Stem quality was estimated based on the tree potential for the production of specified assortments. The evaluation is based on the lower third of tree height, because it contains about 50% of the total volume of large trees. There are three cases: *excellent stem quality* (40), *normal stem quality* (50) and *poor stem quality* (60).

Diagram 9 shows that yield class 2 supports the highest percentage of trees of excellent stem quality (55.2%) and the lowest percentage of trees of poor stem quality (8.4%). Again, this is the direct consequence of the previous thinning, i.e. tending of Austrian pine plantations. Yield class 1 has a higher percentage of trees of excellent stem quality (49.2%) than yield class 3 (41.2%). The highest percentage of normal and poor stem quality occurs in yield class 4 (74.8% and 14.7%, respectively). This can be explained by the poorest site class and by young Austrian pine plantations in which there was no extensive natural pruning or removal of lateral branches.

Crown length was evaluated relative to tree height. There are three cases: *trees with long crown* (4), *trees with less long crown* (5) and *trees with short crown* (6).

Diagram 10 shows the high prevalence of trees with averagely long crown in yield classes 1, 2 and 3. The most favourable tree structure is in yield class 2, because the trees with insufficiently developed crown account for only 4.9%. Namely, primarily the trees with too large crowns and insufficiently developed crowns were removed by thinning. The highest percentage of trees with long crown (54.7%) is found in yield class 4, thanks to the above mentioned reasons.

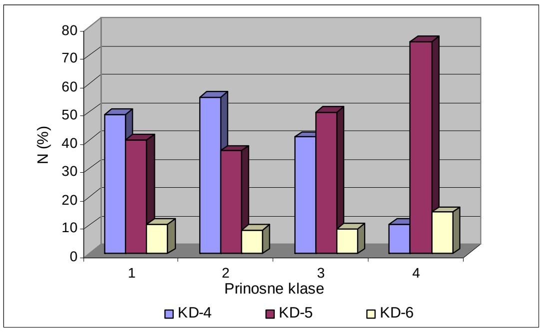

Diagram 9. *Distribution per stem quality*

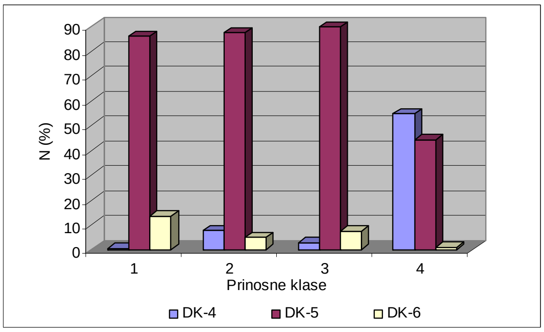

Diagram 10. *Distribution per crown length*

Tree health was estimated based on external tree characteristics, with special reference to root collar, crown and stem. There are three cases: *healthy trees* (7), *trees of doubtful health* (8) and *diseased trees* (9).

Diagram 11 shows that in all yield classes practically there are no diseased trees. The percentage of doubtful health is the highest in yield class 4 (61.1%). Actually, it was an attack of the phyto-pathogenic fungi *Lophodermium pinastri* and *Lophodermium seditiosum* which caused the acute needle browning and needle cast. As it is the case of pathogens which occur regularly in pine plantations, and which do not have a crucial effect on plantation health, the infested trees were not marked for felling.

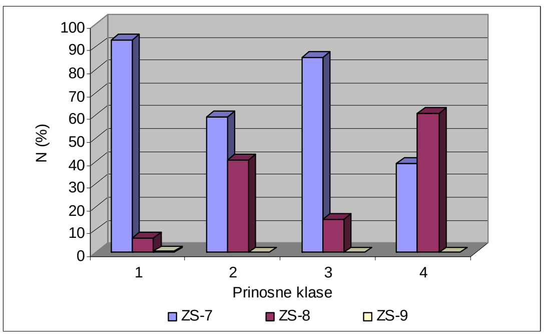

Diagram 11. *Distribution per tree health*

In general, it can be concluded that the health and quality of Austrian pine plantations in the area of Raška is good. This was also concluded in previous researches (Šmit, S. *et al.* 1997, Koprivica, M. *et al.* 2000). The previous thinning had a favourable effect on the quality of the study Austrian pine plantations.

4.7 Planned thinning

The trees which should be removed by mixed thinning or crown thinning were marked during the survey on all sample plots. In the aim of comparison with the state of Austrian pine plantations before thinning, the state of planned thinning and the state immediately after thinning per yield classes was presented in Table 3.

The data on tinning weight of planned thinning are presented in Table 7.

Table 7. *Thinning weight of planned thinning in Austrian pine yield classes*

Yield class	Age	Site class	Density	Growth elements per yield classes			
				N	G	V	I_v
				Thinning weight (%)			
1	55	I/II	0.8728	35.2	25.0	24.6	19.5
2	54	II/III	0.8636	26.5	19.1	19.6	16.2
3	54	III/IV	0.9582	35.3	26.0	26.4	23.3
4	37	IV/V	1.1148	18.9	10.0	10.9	7.1

The lowest thinning weight is planned in yield class 2, as these plantations were already thinned two times, i.e. about 25% of tree number and about 20% of volume. The planned thinning weight in yield classes 1 and 3 is higher, because there was only one previous thinning, about 35% of tree number and about 25% of volume Thinning weight per basal area is almost the same as per volume, and it is lower per volume increment. Taking into account the plantation age and the poorest site conditions, the planned thinning weight in yield class 4 is the lowest.

5. CONCLUSION

The main factors for the classification of Austrian pine plantations into four yield classes were plantation age and site class. The age of yield classes 1, 2 and 3 was about 55 years, and the age of yield class 4 was about 35 years. Growth elements and plantation quality were analysed per the above factors.

a) Actual state of growth elements in Austrian pine plantations is as follows:

- in yield classes 1, 2 and 3, plantation age is 54-55 years, site class I/II-III/IV, stocking 0.86-0.96, stand quadratic mean diameter 17.4-21.6 cm, mean height 15.5-19.4 m, number of trees 1061-1349 trees/ha, basal area 32.1-39.8 m^2/ha, volume 281.1-398.1 m^3/ha, volume increment 5,16-7,28 m^3/ha and increment percentage 1.83-2.11%.
- in yield class 4, plantation age is 37 years, site class IV/V, stocking 1,11, stand quadratic mean diameter 12.3 cm, mean height 8.9 m, number of trees 1987 trees/ha, basal area 23.3 m^2/ha, volume 93.2 m^3/ha, volume increment 2.52 m^3/ha and increment percentage 2.70%.

b) State of a part of Austrian pine plantations per thinning elements is as follows:

- in yield classes 1, 2 and 3, stand quadratic mean diameter is 14.9-18.2 cm, mean height 14.5-18.2 m, number of trees 282-476 trees/ha, basal area 6.5-10.0 m^2/ha, volume 59.5-98.0 m^3/ha, volume increment 1.04-1.42 m^3/ha and increment percentage 1.45-1.75%. Thinning weight per tree number is 26.5-35.3%, per basal area 19.1-26.0%, per volume 19.6-26,4% and per volume increment 16.2-23.3% .
- in yield class 4, stand quadratic mean diameter is 8,8 cm, mean height 7,6 m, number of trees 376 trees/ha, basal area 2.3 m^2/ha, volume 10.2 m^3/ha, volume increment 0.18 m^3/ha and

increment percentage 1.76%. Thinning weight per tree number is 18.9%, per basal area 10.0%, per volume 10.9% and per volume increment 7.1%

c) State of growth elements in Austrian pine plantations after thinning is as follows:

- in yield classes 1, 2 and 3, plantation age is 54-55 years, site class I/II-III/IV, stocking 0.65-0.71, stand quadratic mean diameter 18.6-23.2 cm, mean height 15,8-19,9 m, number of trees 705-873 trees/ha, basal area 23.8-29.8 m^2/ha, volume 206.9-300.1 m^3/ha, volume increment 3.96-5.86 m^3/ha and percentage increment 1.91-2.20%.
- in yield class 4, plantation age is 37 years, site class IV/V, stocking 1.00, stand quadratic mean diameter 12.9 cm, mean height 9.1 m, number of trees 1611 trees/ha, basal area 21.0 m^2/ha, volume 83.2 m^3/ha, volume increment 2.34 m^3/ha and increment percentage 2.82%.

d) Actual state of quality of Austrian pine plantations is as follows:

- in yield classes 1, 2 and 3, the highest percentage of trees is in the upper layer 61.8-77.6%, trees of normal vitality 50.0-60.1%, trees with progressive tendency of height growth 44.1-60.1%, percentage of exploitable and selected trees is almost the same 33.8-37.7% and 29.4-35.7%, trees with excellent stem quality 41.2-55.2%, trees with averagely long crown 85.9-89.7% and healthy trees 59.4-93.0%.
- in yield class 4, the highest percentage of trees is in the upper layer 50.5%, trees of normal vitality 68.4%, trees with progressive tendency of height growth 38.9%, exploitable trees 56.9%, trees with normal stem quality 74.8%, trees with long crown 54.7% and trees of doubtful health 61.1%.

In general, it can be concluded that Austrian pine plantations in the area of Raška are characterised by good production potential, excellent health and good quality. The periodic thinning should be continued with the intensified plantation protection against potential forest fires. The prospect of further development of Austrian pine plantations in the area of Raška is good.

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FOREST PROTECTION AND CLIMATE CHANGES

PLENARY LECTURES

THE CLIMATE CHANGE AND ITS IMPACT ON THE VITALITY OF FOREST ECOSYSTEMS

Mara TABAKOVIC-TOŠIĆ[1], Vesna GOLUBOVIĆ-ĆURGUZ[1], Snežana RAJKOVIĆ[1]

1. INTRODUCTION

Forests, by their structure, as well as by connections and relations among some members, belong to the category of the most complex ecosystems on the Planet. As natural resources, the forests are the significant productive-natural and ecological potentials of every country. Simultaneously with the investments in the establishment of forest plantations, the increased requirements in regard to the safety of the production were more and more transparent. The preservation of the vitality of plant species from seedlings to trees of the different age classes is a long process. In contrast to the agricultural plants, mainly annual plant species, where the yields are obtained during one growing season, in forestry the yield is obtained after the period ranging from ten to over 150 years.

The stability of the forest ecosystems to a great extent depends on the impact, i.e. presence of the different harmful abiotic and biotic factors at the global and local levels. At the local level, it refers to the plant diseases, economically harmful living organisms, climate factors (unfavourable air temperatures, precipitation, winds), local environment pollution (air pollution, presence of the harmful pollutants and heavy metals the concentration of which exceeds the critical limit in the soil and vegetative plant parts, damages caused by the pesticides...), whereas at the global level it refers to the climate change, reflected in the global warming which is the result of the ozone layer depletion.

The climate is regarded as the main ecological abiotic factor and it is inextricably bound to some ecosystems, i.e. their presence depends upon climate, and, therefore, it is of special importance to their development and stability. The climate parameters influence the soil fertility, vitality of plants, aggressiveness and pathogenicity of fungi which inhabit certain tissues of host plant, and population dynamics of so-called "useful and harmful" forest insects.

2. CLIMATE CHANGE

It was proved by the scientists that the human activities cause the global warming on the Earth. The carbon combustion is fast-paced, and, in general opinion it is practically unstoppable. The consequence of it is the occurrence of carbon dioxide in the atmosphere. The highest quantities

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project TR-20202 „Development of biotechnological methods in establishing and improving of forest ecosystems“

of carbon dioxide are released during the combustion of fossil fuels, coal, oil and natural gas, in the furnace chambers of thermal power plants, in the engines of airplanes, automobiles and other types of engines, in the households, and particularly in the wildfires.

Carbon dioxide is completely harmless gas and from the distant past it has been presented in the air, and the concentration of it ranged from 0.02 to 0.03%. However, at the beginning of the last century the concentration of it exceeded the limit (0.03%, i.e. 300 ppm) and started the exponential growth by about 1.5 ppm per a year, and at the end of 2000 reached the value of about 416 ppm, which along with the increase of the concentration of methane, nitrogen oxides, and chlorofluorocarbons, and caused the glass house effect, with vast consequences to the environment (Chakraborty et al., 2008). According to Norby et al. (2005), current free air CO_2 enrichment facilities have observed multi-year growth increases of 23 percent with 175 ppm enrichment above a 375 ppm ambient CO_2 concentration. The atmospheric principle of the glass house is simple and implies the easy penetration of the ultraviolet rays through the atmosphere, which causes the warming of the ground, and the so-called "glass house gases" which partly retain the infrared radiation, which is reflected in the atmosphere warming (Kukrika, 2002).

In addition to the above facts, there is a general agreement worldwide that the industry revolution, which was followed by the dirty technologies, caused the warming on the Earth. It regards to the numerous chemicals made by man, with the common characteristics of the high durability in the lower parts of atmosphere, water insolubility, and permanence. Also, all these chemicals contain chlorine or bromine, and when they reach the higher layers of the atmosphere, by the influence of the sun radiation they decompose and the chlorine or bromine atoms, which destruct the main protector of the Earth's surface from the UV radiation – ozone, are released. Paul Crutzen, winner of the Nobel Prize in chemistry in 1995, once said that the abrupt climate change would have occurred in the mid-1970s, if the chemicals for the cooling used in the industry of refrigeration facilities the chemicals for the cooling have contained bromine instead of chlorine.

In the elaboration of the topic Impacts of air pollution and climate change on forest ecosystems**,** IUFRO DIVISION 7: FOREST HEALTH, it is stated that there is an increasing awareness in both the science and policy communities of the importance of addressing the linkages between the traditional air pollutants and greenhouse gases. Many air pollutants and greenhouse gases have not only common sources, but also their emissions interact in the atmosphere, and may join to cause a variety of environmental impacts on the local, regional and global scales. Many air pollutants contribute to the Earth's radiative forcing. Examples are nitrogen oxides, carbon monoxide and non-methane volatile organic compounds which are precursors to tropospheric ozone. Tropospheric ozone is particularly relevant for the linkages between climate change and air pollution. Climate change, on the one hand, influences ozone concentrations through dynamical and chemical changes in the atmosphere. On the other hand, increasing background ozone concentrations affect climate change because ozone is a potent greenhouse gas and indirectly influences the lifecycle of other greenhouse gases such as methane. Other examples of linkages between air pollution and climate change are:

- SO_2 contributes to acidification and also plays a role in climate change, partly off-setting the greenhouse effect due to increased amounts of sulphate aerosols in the atmosphere;
- acidification and nitrogen deposition affect emissions of CH_4 and N_2O in some ecosystems;
- increased temperatures affect nitrate leaching;
- climate change may alter atmospheric transport patterns of air pollutants and the sensitivity of ecosystems for acidifying deposition;
- CO_2 emissions are almost entirely produced by burning fossil fuels, which is also an important source of several air pollutants;
- climate change induced stratospheric cooling is likely to delay the recovery of the stratospheric O_3 layer by approximately 20 years. In turn stratospheric O_3 determines tropospheric OH levels,

important for air pollution, and the amount of detrimental UV radiation arriving at the earth's surface.

The academician Georgi Bliznakov (1992) states that the mean annual air temperature on the Earth in 1866 was about 14.5°C, and in 1995 it was 15.4°C, i.e. over about 130 years it increased by one degree Celsius.

The Intergovernmental Panel on Climate Change (IPCC, 1995) has concluded that "the observed increase in global mean temperature over the last century (0.3–0.6°C) is unlikely to be entirely due to natural causes, and that a pattern of climate response to human activities is identifiable in the climatological record". It is expected that the global temperature by 2025 will increase by 1.5°C, i.e. by 3°C by the end of this century (Rosenzweig et al., 2001)

The effects of climate change can already be observed in Europe, and further changes in climate are projected to take place in the future. During the 20th century, Europe experienced an increase in average annual surface temperature of 0.8°C, with an increased rate of warming over time. The 1990s were the warmest on record. Warming has been stronger in most regions in winter than in summer. An increase in warm extremes has been observed rather than a decrease in cold extremes (IPCC, 2007).

The Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report, developed a number of emission scenarios with a projection period covering the 21st century. Modelling results show that annual mean temperature in Europe is likely to increase more than the global mean temperature. Until the end of this century the average annual temperature in Europe is projected to increase by 2.5-5.5°C for the A_2 scenario, and 1-4°C for the B_2 scenario. Some regions may experience lower or higher temperature increases than average. For the A_2 scenario, temperature increase in some regions in Europe may be as low as 2°C or even higher than 7°C in the scenarios. Southern Europe will be most affected, with consistent temperature increases between 3°C and more than 7°C, with warming even greater in the summer. Northern Europe will experience temperature increases by less than 2°C and up to 4°C, depending on the scenario and the region, with mainly winters getting less cold. Temperature extremes will decrease in the winter, but increase in the summer (IPCC, 2007).

It is estimated that the air temperature in South Europe will increase by 2°C in the winter period, and by 2-3°C in the summer, with the decrease of precipitation by 5-15% and of moisture by 15-25%. The Balkan Peninsula is one of the regions which are most endangered by the drought.

The similar climate change was reported in Serbia as well (Popovic et al., 2008). By analysing the period from 1931 to 2004 it is noticed that the increase of the average annual temperature has begun in 1982, and that it is has been a continuous process. It is estimated that by the end of the century the average temperatures will increase by 2.6-4°C. The warming will not be uniformly distributed over a year. In the winter the temperature will increase by about 2°C, whereas in the summer it will increase by more than 2°C. The anticipated increase of temperatures is similar to the increase in the whole of Europe, whereas the changes of the precipitation are more complex as there are oscillations with the frequent deficits. The annual sum of precipitation in Serbia has the tendency to decrease. The time of the year when the high temperatures occur simultenously with the decreased quantity of precipitation is particularly significant. In some regions of Serbia the precipitation rate will decrease by as much as 20% in the summer, whereas the slight increase of the quantity of precipitation is anticipated in the winter. Radicevic et al. (2008) report that the extreme coldness is less frequent, in contrast to the extreme heat, which will be more frequent. In Serbia the droughts are more frequent, intensive and durable, which is the result of the increased temperatures, of the decreased summer precipitation, as well as of the more dry periods, which last for a longer time. This trend will be particularly visible in the southeastern and eastern Serbia.

During the 20th century, the changes of the annual quantities of precipitation in Europe ranged from the slight increase on the north to the decrease on the south. Annual average precipitation will increase in northern and north central Europe, while it will decrease in southern

Europe. Annual precipitation patterns will also change. Southern Europe will experience lower rainfalls all year round. There will be less precipitation during summer time in Atlantic and continental Europe, but more winter precipitation. Decreases in annual average precipitation in southern and central Europe can be as high as 30-45%, and as high as 70% in the summer in some regions (IPCC, 2007). As a result of this, and warmer summer temperatures, the risk of summer drought is likely to increase in central Europe and in the Mediterranean area (Kelemen et al., 2009).

The dry years occur more frequently, which directly and indirectly distrubs the stability of the forest ecosystems. It is known that the drought during the development of the buds decreases the growth rate of the shoots in the next year as well. The more frequent occurrence of the dry periods causes the decrease of the height increment of all tree species, particularly of the hydrophilic species, such as beech and spruce. Berki et al. (1998) state that the sessile oak desiccation in the northern Hungarian mountains reached catastrophic proportions, and as the main reason the significant decrease in the content of the soil moisture is emphasized, caused by the increase of the air temperature and decrease of precipitation since the early 1970s.

Numerous General Circulation Models (GCMs) project a global mean temperature increase of 0.8–3.5°C by 2100 AD, a change much more rapid than any experienced in the past 10,000 years. Most significant temperature changes are projected at higher latitudes and over land. In addition, greatest warming is expected to occur in winter and spring, similar to the trends measured recently, although warming is projected for all seasons. While GCM projections vary, in general winter temperatures are expected to rise 6–10°C and summer temperatures 4–6°C over much of Canada and Russia with a doubling of atmospheric carbon dioxide. Global precipitation forecasts under a 2 CO_2 climate are more variable among GCMs, but indications are that large increases in evaporation over land due to rising air temperatures will more than offset minor increases in precipitation amounts. In addition, changes in the regional and temporal patterns and intensity of precipitation are expected, increasing the tendency for extreme droughts and floods (Stocks et al, 1998).

3. IMPACT ON THE VITALITY OF FOREST ECOSYSTEMS

About 90% of all natural disasters, which occurred since 1980 have been directly or indirectly attributed to the weather and climate. About 95% of the economic losses caused by the catastrophical events are the result of the climate-related disasters. The annual number of the disasters caused by the weather and climate in Europe increased by about 65 % over the period 1998-2007 in the comparison with the annual average value for 1980. It is estimated that in the next decades the losses caused by the natural disasters will be dominant, and that in the second half of the next century the effects of the climate change on the economy will be more expressed (Rosenzweig et al., 2001).

Climate change, in particular increased temperatures and levels of atmospheric carbon dioxide as well as changes in precipitation and in the frequency and severity of extreme climatic events, is having notable impact on the world's forests and the forest sector.

Forest productivity and species diversity typically increase with increasing temperature, precipitation and nutrient availability, although species may differ in terms of their tolerance (Das, 2004). As a key factor that regulates many terrestrial biogeochemical processes, such as soil respiration, litter decomposition, nitrogen mineralization and nitrification, denitrification, methane emission, fine root dynamics, plant productivity and nutrient uptake, temperature changes are likely to drastically alter forests and ecosystem dynamics in many ways (Norby *et al.*, 2007). The impacts of elevated temperatures on trees and plants will vary throughout the year since warming may relieve plant stress during colder periods but increase it during hotter periods (Garrett *et al.*, 2006).

Moisture availability in forests will be strongly influenced by changes in both temperature and precipitation. Warmer temperatures lead to increased water losses from evaporation and evapotranspiration and can also result in reduced water use efficiency of plants (Mortsch, 2006). Longer, warmer growing seasons can intensify these effects resulting in severe moisture stress and drought. Such conditions can lead to reductions in the growth and health of trees although the severity of the impacts depends on the forest characteristics, age-class structure and soil depth and type (Mortsch, 2006). Young plants such as seedlings and saplings are particularly susceptible whereas large trees with a more developed rooting system and greater stores of nutrients and carbohydrates tend to be less sensitive to drought, though they are affected by more severe conditions. Shallow-rooted trees and plants as well as species growing in shallow soils are more susceptible to water deficits. Deep-rooted trees can absorb water from greater depths and therefore are not as prone to water stress. Moisture stress and drought can also impact forest health by enhancing susceptibility to disturbances such as insect pests and pathogens and forest fires.

Higher atmospheric CO_2 levels result in increased growth rates and water use efficiency of plants and trees, so long as other factors such as water and nutrients (e.g. nitrogen, phosphorus, sulphur, some micronutrients) do not become limiting. It has been suggested however that this positive effect declines with increasing concentrations (Stone, Bhatti and Lal, 2006).

The impact of the climate change on the ecosystems, which mainly refers to the warming caused by the anthropogenic increase of the glass house gases (C, CH_4, N_2O, O_3, HCFCs, CFCs), which will initiate the numerous adverse effects on the forest ecosystems, has been elaborated in the domestic and foreign literature. For instance, Willmott and Legates (1991) report that the increase of temperature ensured the sufficient energy for the increased transpiration and evaporation, and owning to the limited capacity of the atmosphere to absorb the moisture, all these phenomena have been globally reflected in the increase of the precipitation (Quoted by Liovic and Zupanic, 2005). The increased precipitation are not uniformly distributed, so in some regions the floods and soil erosion can be expected, whereas the decrease in precipitation and accelerated forest desiccation (Bradley et al., 1987).

The growing season in Serbia is increasingly extended, warmer and drier, and although there is a positive trend of the potential evapotranspiration and sum of precipitation, the trend of sums of evaporation is high. The spring comes earlier and the vegetation occurs more and more earlier. It is clearly visible that the past decades have been warmest, based on the data obtained by the instrumental observations since 1890.

It will also imply the decrease of vitality and gradual forest decay, due to the following reasons: decrease of the soil moisture, occurrence of the climate extremes, shortening of the growing season, difficulties in the regeneration, reduced resistance to the harmful biotic factors (the occurrence of the epiphytototics of the pathogene fungi, or the outbreak of the economic harmful insects), and all these factors will lead to the large scale forest desiccation (Medarevic, 2005).

Among the numerous hypotheses on the endangerment and decay of the forest ecosystems, over the past decades, the hypotheses on the air pollution as the cause of these phenomena have become more visible. The study on the deposition of the alien admixtures from the atmosphere and their effects on the ecosystems, refer to the source and emission of the pollutants, their transport and transformations, deposition and influence on the different receptors. The influence of pollutants on forest ecosystems have not been researched so far, although there are numerous proofs that the simultaneous occurrence of the dry periods and high temperatures, as well as the presence of pollutants, lead to the vitality of trees, which creates the optimal conditions for the development of numerous pathogene organisms, and due attention will be paid to this problem in the next period. Also, it should be emphasized that the Mediterranean pluviometric precipitation regime, which is unfavourable to the forest due to the spring and autumn maximum, is ideal for the development of the parasite fungi. Therefore, there are great possibilities for the occurrence of the fungal diseases, which will be multiplied every year.

It is known that the air pollution and acid rains affect the natural ecosystems. In the past decades the numerous harmful effects of the air pollution, particularly of the acid rains, on all aspects of nature, have been registered. The acid deposition refers to all acid products which are deposed from the air in the solution of raindrops. However, the role of the acid rains is still unclear, although they probably influence the change of the natural ecosystems in different ways. Namely, it is very hard to prove the influence of the acid rains on the occurrence of the diseases and their influence mainly refers to the presence of the phytopathogene organisms on the plants.

If their doses are high enough, the pollutants directly cause the visible damages on the forest trees. The accumulation of the individual pollutants, or the mixtures of the harmful gas substances on the foliage, results in their penetration by the stomes in the leaf tissues, the damages of which are reflected as the specific symptoms. The activity of each pollutant is characterized by the typical symptom on the foliage, physiologically-chemical mechanism of toxicity, toxicity threshold, as well as the sensitivity of some plant species. These characteristics can be accepted generally, since in the different ecosystems and site conditions, the symptoms of damages and sensitivity are variable to a certain extent. The different sensitivity rates of plants was determined based on the carbon dioxide, fluorides, photochemical pollutant ozone, peroxy acetyl nitrate, chlorine, hydrogen chloride, nitrogen oxides, deposition powder, increased soil concentration, etc. However, the facts that the combinations of pollutants are always present in the soil and that the harmful effect of them is peculiar, should be taken into account.

The continuous forest pollutation by the emissions of the harmful substances is phytotoxic, but it also predisposes the plants to the increased influence of some environmental biotic factors, which in succession continue the desiccation process to the complete decay (death) of forests.

The epidemic forest desiccation as the modern phenomenon, to a greater or lesser extent, has been reported in many countries in Europe, North America and Central Asia. The scope of the forest desiccation in the Central Europe is unprecented in the world literature. The intensity of the desiccation and economic consequences often vary greatly, in dependence on the climate and edaphic conditions, tree type, etc. The scientists of the different profile started the detailed researches in the second half of the last century, and drew the public attention to this phenomenon, as the sign of the ecological catastrophy. There are several hypotheses on the possible cause of this phenomenon. In Germany and some other countries the view that the air pollution is the primary factor of forest desiccation is well-expressed. The pollutants often have an adverse effect on the vegetation by the assimilative organs and rhizosphere in the form of gases, solid particles, or acids, causing certain pathogene changes and death of all organs, or the whole plant. This phenomenon is clearly visible in the vicinity of the great industrial centers (Fuhrer, J. et Fuhrer F., 1982; Ulrich, 1980; Solar, 1986).

Sobocký and Mankovská (1987) state that the influence of the industrial smoke mitigates the resistance of the forest stands and increases their predisposition towards the harmful biotic factors. The trend of the mass oak desiccation in the regions polluted by the industrial smoke is directly proportional to the intensity of air pollution.

There are also some other hypotheses and theories, which explain the forest desiccation by the change of the climate and edaphic conditions. These changes serve as the primary factors, causing the physiological decay of the plants. The plants of the decreased vitality become more suspectible to the parasites which cause weakeness, and to the secondary pests, which in the last instance cause the plant desiccation in great areas.

The one-sided interpretation of the complex process of the dying of forests does not provide the answer to the problem solving. The desiccation of forests is the result of the unfavourable influence of the complex of abiotic and biotic factors, which can act stimultaneously, or alternate successively.

4. CONCLUSION

Forests are subjected to a variety of disturbances that are themselves strongly influenced byclimate. Disturbances such as fire, drought, landslides, species invasions, insect and disease outbreaks, and storms such as hurricanes, windstorms and ice storms influence the composition, structure and function of forests. Climate change is expected to impact the susceptibility of forests to disturbances and also affect the frequency, intensity, duration, and timing of such disturbances.

A changing climate will also alter the disturbance dynamics of native forest insect pests and pathogens, as well as facilitating the establishment and spread of non indigenous species. Such changes in disturbance dynamics, in addition to the direct impacts of climate change on trees and forest ecosystems, can have devastating impacts particularly because of the complex relationships between climate, disturbance agents and forests. Any of these disturbances can increase forest susceptibility to other disturbances.

Forests are particularly sensitive to climate change, because the long life-span of trees does not allow for rapid adaptation to environmental changes. Unlike in agriculture, adaptation measures for forestry need to be planned well in advance of expected changes in growing conditions because the forests regenerated today will have to cope with the future climate conditions for at least several decades, often even more than 100 years (EFI, 2010).

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PESTICIDE USE AND CLIMATE CHANGE

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Adaptation in forestry is sustainable forest management that includes a climate change focus. Climate change over the next 100 years is expected to have significant impacts on forest ecosystems. The forestry community needs to evaluate the long-term effects of climate change on forests and determine what the community might do now and in the future to respond to this threat. Management can influence the timing and direction of forest adaptation at selected locations, but in many situations society will have to adjust to however forests adapt. Adapting to climate change in the face of the uncertain timing of impacts means we must have a suite of readily available options. A high priority will be coping with and adapting to forest disturbance while maintaining the genetic diversity and resilience of forest ecosystems [25].

The impacts of climate change in forest can be positive, negative or neutral, since these changes can decrease, increase or have no impact on diseases, pest and weeds, depending on each region or period. Climate change alters the average and posibility of pesticide treatment.

Trans-boundary movement of toxic substances through natural and man-made pathways and their worldwide use and escalation of industrial activities to countries with cheaper labor, pose a threat to human beings and environment of the countries of this region which are hardly prepared to tackle their adverse consequences. Trans-boundary transport of chemicals is known since long back. Once applied pesticides disperse from the point of application and become redistributed, some on global scale.

Because of that, Forest Stewardship Council revised policy on pesticides (*FSC-POL-30-001 FSC Pesticides Policy (2005)*). The policy is designed to implement the relevant requirements of the FSC Principles and Criteria for Forest Stewardship and has three main elements:

- The identification and avoidance of ‘highly hazardous’ pesticides;
- Promotion of ‘non-chemical’ methods of pest management as an element of an integrated pest and vegetation management strategy;
- Appropriate use of the pesticides that are used.

The policy requires the establishment of indicators and thresholds for the identification of pesticides recognised by FSC as being particularly hazardous, based on their active ingredients. These indicators and thresholds and the resulting list of pesticides recognised by FSC as being ‘highly hazardous’ are listed in this FSC Guidance document.

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project TR-20202 „Development of biotechnological methods in establishing and improving of forest ecosystems“

The FSC Pesticides policy prohibits the use of these ‘highly hazardous’ pesticides in FSC-certified forest management units unless such use has been explicitly justified on specified grounds (including stakeholder consultation), adequate provisions to preferably prevent, otherwise minimize or mitigate their negative impacts and a program in place to identify alternatives. In these circumstances the FSC Board of Directors may approve a 'temporary derogation' for the specified use in a defined geographical area (usually national or sub-national). This Guidance document provides further information of FSC’s approach to pesticides and establishes the criteria for identifying ‘highly hazardous’ pesticides. Annex I of this guidance document specifies the complete set of indicators and thresholds used for the identification of 'highly hazardous' pesticides. Annex II lists the active ingredients which exceed these thresholds and which are therefore identified by FSC as being 'highly hazardous'.

Finally, this Guidance document recognises that further work is required in relation to general requirements for minimising pesticide use in FSC-certified forests, and for the appropriate measures to minimise risk when pesticides are used. This document will be revised and updated as and when this work is completed.

Pesticide are defines as “any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest”. A pesticide may be a chemical substance or biological agent (such as a virus or bacteria) used against pests. Farmers in the hot spots are over burdened with increasing costs of cultivation, a deleterious credit system, and declining productivity, increased incidences of pests and diseases, and spurious pesticides. The sole reliance on chemical pesticides for plant protection has created serious problems. In addition, problems of pest outbreaks, resistance and resurgence of pests demand more pesticides [20,22].

Pesticides are associated with risks to human health and/or to the environment. On the other hand, society accepts these risks within certain limits as there are also benefits linked to the use of pesticides, in particular in forestry production. Overuse of pesticides has brought about a decline in the bio-diversity of non-target organisms in the hot spots. Pesticides are necessary but should only be part of a total pest control program, not like entire program. Sustainable farming is a management-intensive method of growing crops at a profit while concurrently minimizing negative impact on the environment, improving soil health, increasing biological diversity, and controlling pests. Sustainable forestry is dependent on a whole-system approach, having as its focus on the long term health of the land [19,23].

There is necessary to established a regulatory infrastructure for the management of pesticides. Pesticide management involves the regulatory control, proper handling, supply, transport, storage, application, use and waste management, and disposal of pesticides to minimize adverse environmental effects and human exposure. The problem of pesticide misuse is a well-known and widely-held concern for many officials, researchers, trainers' journalists and environmentalists. Once released into the environment, pesticides tend to build up in the fat tissues of living organism, causing serious harm to the health and a potential loss of bio-diversity. Until now, costs of environmental problems and farmer's health impairments have not yet been included in the total cost of productions in the forest and agriculture sectors. The environmental costs of pesticide misuse are potentially huge.

Over the last two decades significant effort has been dedicated to understanding the fate and transport of pesticides in surface water and groundwater and to use this understanding in the development of environmental policy and regulation. However, there have been few studies that have investigated the relationships between pesticides and climate change, and where this work has been undertaken it has principally been in relation to the impacts of climate change on forest production rather than in the context of environmental protection. The main climate drivers for changing pesticide fate and behaviour are thought to be changes in rainfall seasonality and intensity and increased temperatures, but the effect of climate change on pesticide fate and transport is likely to be very variable and difficult to predict. In the long-term, indirect impacts, such as land-use change driven by changes in climate, may have a more significant effect on pesticides in surface and groundwaters than the direct impacts of climate change on pesticide fate and transport [2].

The climate change have many impacts on the fate and behaviour of pesticides in the environment. It is interesting to look individually at the sources of pesticides, the movement of pesticides through the subsurface (pathways) and the receptors, specifically the groundwater resources used for water supply and the rivers fed by groundwater. In the long term, land-use change driven by changes in climate may have a more significant effect on pesticides in the environment than the direct impacts on pesticide fate and transport.

Sources

- Changes to cropping patterns mean that changes in pesticide use will be limited to a shift in the amount of certain classes of already approved pesticide. Thus there is likely to be little change to the range of active ingredients as a result of climate-induced change in cropping patterns
- Increased prevalence of existing pests, diseases and weed species is predicted under climate change, implying wider and more frequent applications of existing pesticides or the introduction of products that are new.
- The tolerance of crops to pesticides may reduce under higher levels of ozone. If this is the case, increased pesticide applications may start to reduce crop yield and this may lead to the manufacture of new active ingredients.
- Higher temperatures would mean a greater proportion of pesticides in the gas phase, and consequently longer potential atmospheric transport distances from sources, however, degradation processes will also be accelerated, so the overall effect of higher temperatures is not clear.
- The rate of atmospheric degradation of vapour-phase pesticides may increase due to higher concentrations of tropospheric ozone.
- Changes in seasonal rainfall may lead to changes in the spatial and temporal distribution of wet deposition of airborne pesticides and their degradation products.

Pathways

- Higher temperatures will give rise to increased volatilization and faster degradation of pesticide residues in the soil and surface waters.
- Increased winter rainfall will lead to wetter soils and so pesticide-rich water will move more rapidly from the surface through the soil matrix.
- More by-pass flow due to more intense rainfall events will increase the likelihood of rapid pesticide movement to drains, surface waters and vertically to below the soil layer.
- Surface runoff may become more significant leading to increased erosion of pesticide-rich soil particles from fields to drains and surface waters
- Shorter recharge periods could allow less opportunity for pesticide transport and more time for degradation
- Higher soil water contents will increase degradation rates in soils re-enforcing temperature effects while warmer dryer summers may lead to increased cracking of shrink-swell clay soils and may increase the potential for by-pass flow in autumn and winter. The net effect may be to increase the speed at which pesticides are moved by by-pass transport routes in the winter
- Dry soils have a lower biodegradation potential than wet soils and pesticide residues from spring application could persist through the summer to the autumn
- More frequent and intense storm events will affect groundwater recharge. Periodic flushing into aquifers of pesticides sorbed onto colloids and sediments may be enhanced.

- High groundwater levels may occur more frequently due to increased winter rainfall. Periodic high groundwater levels can intercept pesticides and other diffuse agricultural pollutants in the unsaturated zone and soil zone, reducing the time for pesticide degradation and leading to seasonal increases in the concentration of pesticides in groundwater
- More frequent localised groundwater flooding of agricultural land may mobilise pesticides sorbed onto colloids and sediments.

Receptors

- In summer, mean river flows may decrease significantly contributing to a reduction in the dilution potential of surface water bodies potentially increasing pesticide concentrations if runoff or spray drift events occur
- Reduction in annual minimum groundwater levels by the 2080s are expected (e.g. up to about 2 m in the Chalk) but the implications for source yields and pesticide exposure at receptors is uncertain
- The impact of climate change on baseflow to groundwater-dominated rivers has not been systematically studied, and the implications for changes in pesticide exposure is very uncertain.

Conditions are more favorable for the proliferation of insect pests in warmer climates. Longer growing seasons will enable insects such as grasshoppers to complete a greater number of reproductive cycles during the spring, summer, and autumn. Warmer winter temperatures may also allow larvae to winter-over in areas where they are now limited by cold, thus causing greater infestation during the following crop season. Altered wind patterns may change the spread of both wind-borne pests and of the bacteria and fungi that are the agents of crop disease. Crop-pest interactions may shift as the timing of development stages in both hosts and pests is altered. The possible increases in pest infestations may bring about greater use of chemical pesticides to control them, a situation that will require the further development and application of integrated pest management techniques and biopreparates.

There is a fine balance between pests and disease-causing organisms (known as pathogens) and their host plants. It is possible however to make two generalizations: stressed trees are more susceptible to insect pests and diseases, and the majority of insect pests that currently affect are likely to benefit from climate change as a result of increased summer activity and reduced winter mortality. Some insect pests that are currently present at low levels, or that are not considered a threat at this time, may become more prevalent.

The use (and abuse) of pesticides has increased to combat insect-pests and diseases. However, the major causes concern of are the undesirable side effects of these chemicals on biodiversity, environment, food quality and human health. Climate change will have important implications for insect conservation and pest status [1].

Climate and weather can substantially influence the development and distribution of insects [24]. Most of the warming over the last 50 years is likely to have been due to man-made activities. Anthropogenically induced climatic change arising from increasing levels of atmospheric greenhouse gases would, therefore, be likely to have a significant effect on insect pests. Current best estimates of changes in climate indicate an increase in global mean annual temperatures of 1[o]C by 2025 and 3[o]C by the end of the next century. Such increases in temperature have a number of implications for temperature-dependent insect pests. To protect ourselves, our economy, and our land from the adverse effects of climate change, we must ultimately dramatically reduce emissions of carbon dioxide and other greenhouse gases. The causes of anthropogenic climate change are broad and often difficult to address. There is no single solution to this complex problem, but numerous opportunities exist for reducing problems of climate change. The issue of climate change is one of the most profound challenges of our time, and we believe it is a challenge that can be met [12,13,14,15,16].

Global warming will increase pest populations, including weeds, invasive species, insects, and insect-borne diseases, which will likely lead to large increases in the use of pesticides. The effects of climate change are already beginning to be seen, and will continue to be seen for years to come. Without drastic actions to curb global warming, the current course we are heading on will lead to booms in pest populations and pesticide use.

Climate change is likely to alter the balance between insect pests, their natural enemies and their hosts**.** One of the most important effects of climate change will be to alter the synchrony between host and insect pest development, particularly in spring, but also in autumn; the predicted rise in temperature will also generally favor insect development and winter survival, although there will be some exceptions. Changes have already been observed in the distribution of native butterfly populations.

Disease management strategies depend on climate conditions. Climate change will cause alterations in the disease geographical and temporal distributions and consequently the control methods will have to be adapted to this new reality. There are few discussions on how chemical control will be affected by climate change, despite the importance of this subject. Changes in temperature and precipitation can alter fungicide residue dynamics in the foliage, and the degradation of products can be modified. Alterations in plant morphology or physiology, resulting from growth in a CO_2-enriched atmosphere or from different temperature and precipitation conditions, can affect the penetration, translocation and mode of action of systemic fungicides.

Besides, that changes in plant growth can alter the period of higher susceptibility to pathogens which can determine a new fungicide application calendar [8,3,4,6]. The fungicide market will certainly change. Chen & McCarl (2001) [7]. performed a regression analysis between pesticide usage and climate variations in many locations. The per acre pesticide usage average cost for corn, cotton, potatoes, soybeans and wheat were found to increase as precipitation increases. Similarly, the pesticide usage average cost for corn, cotton, soybean and potatoes also increase as temperature increases, while the pesticide usage cost for wheat decreases.

However, the main impact of climate change on chemical control will be in the plant protection realm. The fact that the entire humanity is suffering the consequences of anthropogenic activity in the process of exploiting the resources of the planet will raise an awareness that this activity must be conducted in a sustainable way. Society will certainly exert pressure for the use of nonchemical methods to control plant diseases [21].

The impact on pathogens whose reproduction or dispersal is clearly affected by temperature is relatively predictable. Warmer summers may in particular favor certain thermophilic rust fungi. Warmer winters may increase the activity of some weak pathogens. An increased incidence of summer drought would probably favor diseases caused by fungi whose activity is dependent on host stress, particularly root pathogens.

One of the direct consequences of climate change in the pathogen-host relationship is the genetic resistance of plants to diseases. Many changes in plant physiology can alter the resistance mechanisms of cultivars obtained by both traditional and genetic engineering methods. Several studies provide evidences of these alterations, such as significant increases in photosynthetic rates, papillae production, silicon accumulation in appressorial penetration sites, higher carbohydrate accumulation in leaves, more wax, additional epidermal cell layers, increased fiber content, reduction in nutrient concentration and alteration in the production of resistance-related enzymes [17, 5, 9,18].

There is practically no information on the impacts of climate change on plant disease biological control. The few results obtained focus on climate change impacts on the composition and dynamics of the microbial community of the phyllosphere and the soil, which can be very important for plant health. Key soil aspects for microbial activity will be modified, such as soil nutrient availability, soil temperature, and soil water content.

The authors suggest the abundance of these fungi species can indicate an increase in the soil suppressiveness to phytopathogenic fungi and other pests [26]. conducted one of the few detailed studies on the effect of climate conditions on biological control efficiency, demonstrating the effects of the rainfall regime and time of application of *Acremonium vittelinum* and *A. persicinum* for the control of the tar spot of coconut caused by *Catacauma torrendiella* and *C. palmicola.* However, there is no information on most antagonists. Studies on this subject will be important for maintaining the efficiency of biological control. Additionally, it is necessary to know the responses of the diseases to these changes.

These answers will allow conclusions on what might happen to biocontrol, both natural and through the introduction of bioagents. The prediction of the effects of climate change on plant disease biological control is complex and currently based on indirect observations. Nevertheless, the vulnerability of biocontrol agents will surely be higher with climate change, since this is one of the problems when applying antagonists [10]. The adaptability of some agricultural systems can help to minimize the negative impacts of climate change with the adoption of new cultivars and other practices.

Developing countries, though, will have more difficulties in adapting to climate change, due to the lower technological development and to the scarce resources available for the adoption of measures [11]. argued that in general the climate change will be beneficial for biological control, both natural and introduced, since the awareness of the society towards environmental problems will demand measures that minimize pollutant emissions. Therefore, the biological equilibrium of agricultural systems will be benefited, leading to an increase in the complexity of the system, and consequently, to biological control. To achieve this, specialists from different agriculture-related areas need to go beyond disciplinary boundaries and position the global climate change impacts in a broader context, including the whole agroecosystem.

Objectives

- To assess and understand the relationship between pesticide usage and climate
- change (commonly called global warming) for crops
- To make aware on the impact of pesticides on the biodiversity and productivity
- To raise awareness and seek solutions of agriculture related environmental issues for ensuring a safe (minimizing the use of environment prone chemicals, pesticides, etc) and sustainable agricultural development.

The wide uncertainties in climate scenarios, regional variation in climate effects, and interactions of environment, economics, and farm policy suggest that there are no simple and widely applicable adaptation prescriptions. Farmers will need to adapt broadly to changing conditions in agriculture, of which changing climate is one factor. It is difficult to predict accurately what adaptations people will make. This is particularly challenge since adaptations are influenced by many factors, including government policy, technology research and development, and agricultural extension services.

Policy Issues

- Increasing concern over the environmental impacts of pesticide use, as evidenced by multilateral environmental agreements such as the Stockholm Convention on POPs, denotes the urgent need for management of pesticides.
- While confronting the challenge of climate change will ultimately require comprehensive national policy and international agreements, the states and regions have a valuable role to play.

- Educate key policy makers and the public about the causes and potential consequences of climate change and assist the domestic and international communities in developing practical and effective solutions to this important environmental challenge.

Consequences of Climate Change

Climate change is a unique, global, long-term problem, involving complex interactions. Regional changes in climate, particularly increases in temperature, have already affected some physical and biological systems. Both natural and human systems are vulnerable to climate change because of their limited adaptive capacity. This vulnerability varies with geographic location, time, and social, economic and environmental conditions In what way could Climate Change affect us in the future and how serious could the consequences be? Climate change was real and the consequences could not be ignored. Negative consequences of climate change include effects on pesticide use, run-off of nutrients and potential regional conflicts for some groundwater sources. Pesticides are toxic to many forms of life. Beneficial insects such as ladybugs and honeybees can be killed by pesticides which can lead to worse insect problems in the future.

Man will have to adapt to and cope with the climate change consequences that are not prevented by mitigation. Economic losses can be expected, especially in poorest regions; the higher the warming, the greater the losses. Some other important changes include precipitation, cloud cover and extreme temperatures. Promoting adaptation, sustainable development and equity can be mutually reinforcing.

Table 1. *Regression Results for Effects of Climate on Per Acre Pesticide Treatment Cost*

Crop	Precipitation	Temperature	Time	Constant
Corn	0.6540	0.8200	-2.3465	-11.966
	(25.22*)	(18.38*)	(-30.01*)	(-4.88*)
Cotton	0.0242	0.9783	0.1253	1.6406
	(1.82*)	(6.12*)	(9.53*)	(1.76*)
Potatoes	1.3034	2.4479	9.8340	-109.34
	(24.17*)	(13.26*)	(34.26*)	(-10.82*)
Soybeans	0.0471	0.5719	-0.2080	32.647
	(2.81*)	(14.33*)	(-3.54*)	(15.94*)
Wheat	0.6813	-1.5058	0.3793	4.6158
	(24.14*)	(-15.63*)	(31.35*)	(12.51*)

Notes: Temperature is measured in degrees Fahrenheit and rainfall is measured in inches. t-ratios are presented in parentheses and a * sign indicates 95% significance. Cotton and Wheat functions are log-linear [8].

Your comments imply that the results are small and thus not important. Actually they are on the order of 5-10% of the total climate change impact on agriculture so that must also be small.

Mitigation of Climate Change

- A strong need to reduce grower input cost with concomitant increase in yield and quality with reduced environmental impact is the need.
- Minimize the hazards and risks from the use of pesticides.
- Improved controls on the use and distribution of pesticides.
- Application of the substitution principle.
- Encouraging low-input or pesticide free crop farming.
- Implementing Rotterdam Convention on Prior Informed Consent (PIC) and Stockholm Convention on Persistent Organic Pollutants (POPS)
- Consider fully gender and environment issues in all aspects of development and management in agriculture.

– Better not to use/consume ODS according to the time schedule of the Montreal Protocol. Alternative, affordable chemicals exist for all the ozone- damaging chemicals, and these substitutes don't harm the ozone layer.
– These Codes do not have a legal basis, but serve to establish acceptable standards of conduct for the users as well as the public and private sectors. Codes have been adopted for a range of topics including the Safe Handling of Pesticides, Safe Disposal of Surplus Pesticides, the Application of Fumigants, etc. Codes of practice suggest to follow Pesticide Use Rules, Sale Rules and Layout rules for the storage, loading and unloading of pesticides.
– Organic farming methods combine scientific knowledge and modern technology with traditional farming practices based on thousands of years of agriculture. In general, organic methods rely on naturally.

Conclusion and Recommendation

– Government and Non-government Organizations (NGOs) need to promote programs on education about basic pesticide use, concept of eco-friendly farming and also global warming, which will ensure long-term food security and environmental safety.
– Create increased awareness of change in the context of agricultural, environmental and health policies.
– Pesticide reduction based on FSC politic, developing of regular monitoring systems with objectively verifiable indicators and research capacity to deal with the problems of chemical pesticides and climate change.
– Our goal should be directed towards healthy communities and ecosystems and
– Greatly enhanced efforts should be implemented to understand the relationship between pesticide use and climate for crops in the tune of protecting, sustaining or restoring the health of people, communities and ecosystems using integrated and comprehensive approaches and partnerships.
– In effective transfer of technologies bilateral, regional multinational and global networking of activities is an essential part that is often given less attention. The international agencies can play an effective role in this aspect.
– The valuation of externalities should be expressed in monetary terms whenever the available data and methodology considerations allow.

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CLIMATE CHANGE EFFECTS ON PATHOGENS AND HARMFUL INSECTS

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1. INTRODUCTION

Climate change over the next 100 years is expected to have significant impact on forest ecosystems, particularly on their vitality and health condition. The forestry community needs to evaluate the long-term effects of climate change on forests and determine what the community might do now and in the future to respond to this threat. During the past decade, our understanding of the potential risks that climate change poses to forest ecosystem function and their protection has increased. Simulation studies of expected changes in species ranges and changes in ecosystem dynamics have indicated that rapidly changing climatic conditions could significantly thwart forest protection efforts at a global scale. We need more knowledge about the interaction between climate variables (mean annual precipitation, degree days greater than 5 degrees and less than 0 degrees, hours of leaf wetness, consecutive days without precipitation during the growing season, very dry periods, daily minimum and maximum temperature, relative humidity, lightning strikes, fall precipitation …) and insects or pathogens. We need answers to questions such as:

- Does temperature affect the number of harmful insect generations, emergence time, and survival?
- How will changes in precipitation affect tree pathogens?
- In which ways are other insects affected by temperature and precipitation?
- Will the global warming cause the changes in the type and frequency of the outbreaks of the harmful insects and epiphytotics, i.e. whether they will transform from the acute to chronic?
- Will the climate change, together with the increase in the population size of the harmful insect species imply the increase in the population size of their enemies, predators and parasites?
- How long does it take for an insect or pathogen to kill a tree?

The increased air temperatures and the level of the atmospheric carbon - dioxide, as well as the changes in the quantity and distribution of the precipitation, as well as the frequency and value of the climate extremes, whether it refers to the temperature or humidity, have the important impact on the vitality and the health condition of the forest ecosystems, which is particularly reflected in the influence on the abiotic and biotic factors, which contribute to it.

A deeper understanding of the complex relations among the climate change, forests and harmful biotic factors, is of vital importance to the application of the suitable measures aimed at the

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project TR-20202 „Development of biotechnological methods in establishing and improving of forest ecosystems“

health protection of the forest tree species, at the prevention, or hindrance of the introduction and spread of the autochthonous and allochtonous economically harmful and invasive species.

By the future climate change scenarios, adaptation of both tree species and their disturbance agents becomes important. Trees adapt slowly, with selection operating over the multi-decade reproductive time frame. Changes in fitness – either through selection or through the migration of more fit types – is slow compared to the life cycles of many of their pests. Disturbance agents such as insects and some fungal diseases can change very quickly, on an annual basis. The underlying genetic knowledge about the trees and their disturbance agents is important, and not always well known.

Changes in the patterns of disturbance by forest pests (insects, pathogens and other pests) are expected owning to the climate change as a result of higher temperatures, changes in precipitation, increased drought frequency and higher carbon dioxide concentrations. These changes will play a major role in shaping the world forests and forest sector. There is evidence in the fossil record that previous episodes of rapid global warming were accompanied by increased levels of insect herbivory (Currano et al., 2008). This evidence, as well as observations from the birch forests of North Europe (Kozlov, 2008; Wolf, Kozlov and Callaghan, 2008), confirm predictions that current herbivory trends will amplify (DeLucia et al., 2008).

Insects and pathogens have been noted to respond to warming in all the expected ways, from changes in phenology and distribution to influencing community dynamics and composition (Menéndez, 2007). While some impacts of climate change may be beneficial in terms of protecting forest health (e.g. increase winter mortality of some insect pests due to thin snow cover; slower larval development and increased mortality during droughts), many impacts will be quite detrimental (e.g. accelerated insect development rate; range expansions of pests) (Ayres and Lombardero, 2000).

Climate change can affect forest pests and the damage they cause by: directly impacting their development, survival, reproduction, distribution and spread; altering host physiology and defense; and impacting the relationships between pests, their environment and other species such as natural enemies, competitors and mutualists.

Temperature and precipitation in particular, have a very strong influence on the development, reproduction and survival of insect pests and pathogens and as a result it is likely that these organisms will be affected by any changes in climate. Forest insects and pathogens can respond rapidly to their climate environment, affecting directly their development, survival, reproduction and spread. With their short generation times, high mobility and high reproductive rates it is also likely that they will respond more quickly to climate change than long-lived organisms, such as higher plants and mammals (Menéndez, 2007) and thereby may be the first predictors of climate change. The impact of climate change on the frequency and intensity of insect outbreaks is less clear, mainly because there is insufficient long-term data for analysis.

2. THE INFLUENCE OF THE CLIMATE CHANGE ON THE PATHOGENS AND PLANT DISEASES

The climate change has capacity for influencing the changes of the physiology and resistance of the plant hosts, as well as the developmental phase of pathogens, thereby influencing the interaction host-pathogen, by increasing the risk of infections, or by inducing the defense, which implies the increase of the resistance (Coakley et al., 1999, Garrett et al., 2006). Two most important climate factors, which are significant because of their influence, are temperature and humidity (Agrios, 1997), whereas the content of the nutrients in the soil, soil pH, the presence of the light and pesticides, also can influence the occurrence and course of some diseases. These factors indirectly influence the development of the disease, by affecting the growth and sensitivity of the hosts, the multiplication and activity of pathogens, or by the intereactions between host and pathogens.

If the infection occurs, there are three phases of the development of the plant diseases: survival of the primary inoculum of pathogens, the level (degree) of the development of disease during the growing season and annual duration of the epidemic in the relation with the plant host (Boland et al., 2004). The effects of the climate change on each of these components are peculiar to each plant disease. Within the pathogenic fungal species there are several types of the primary inoculum (Agrios, 1997, Lucas, 1998, Trigiano, et al. 2004). The soil fungal species (*Botrytis, Fusarium, Phytophtora, Pythium, Rhizoctonia, Verticillium*, etc.) survive by forming the different structures, such as sclerotia, or thick-walled spores (chlamydospores or oospores), which are almost resistant to the lack of moisture, or other types of climate change. The climate change has significantly greater impact on the survival of the pathogenic fungi, which during the winter produce the primary inoculum in the infected plant tissue (*Alternaria, Cercospora, Erysiphe, Phomopsis, Venturia,* etc.).

The changes of temperature can influence the relations among the plant host, pathogen and biocontrol organism (Agrios, 1997). The plants and pathogens have the different minimal temperatures when their activities stop, as well as the different temperatures which are optimal for their growth and development. Some species need the minimal temperature in the early spring in order to start their activities (*Nectria, Leucostoma (Cytospora), Phytophthora*).

In the regions with moderate climate the most frequent plant pathogens decrease their activity during the winter and in the early spring due to the low temperatures. Although there are some diseases which have been favoured over the cold period, many species favour the higher temperatures. The increase of temperature causes the change of the physiology of plant host, which can be reflected in the increase of the sensitivity or the resistance to the plant pathogens. The resistance to the pathogens becomes effective due to the increased defence of plants, which are the results of the changes in physiology, nutrition status and water ability. The duration of the resistance depends on the number of the infection cycles in the growing season. During the development of all plants two interruptions can occur over the year. The first interruption occurs in the winter when the temperatures are low, and the second one occurs over the short summer period when the plants reached the maximum growth rate. Owning to the adequate moisture and optimal temperature, the polycycle fungi complete their life cycle at a fast rate, frequently in a few days. By the increase of the temperature and disappearance of the dry summer, the plant diseases caused by fungi decrease, as a result of the reduction of the number of cycles in the polycycle diseases and of the deceleration of some monocycle diseases. In this way the primary inoculum reduces in the next season.

The effects of the increase of temperature on the plants vary depending on the time of year. Some species favour the warm, dry conditions for development *Sphaerotheca, Uncinula, Ustilago,* etc.). These conditions are favourable for the development of disease on the root, particularly of *Heterobasidion annosum*, whereas under the colder climate conditions it is reduced. Over the dry period the attacks of *Armillariela* spp, which in the normal conditions is not strongly pathogenic, increase. However, in these conditions the following types of diseases *Cronartium ribicola* i *Gremmeniella abietina-Scleroderris lagerbergii* (Lagerb.) reduce, since the cold and wet conditions are the preconditions for the occurrence of infection.

It was proved by the researches that numerous plants become more sensitive to the development of diseases when the temperature increases, but some plants become more resistant to the diseases by the increase of temperature (Coakley et al. 1999).

The unfavourable environmental conditions had the important role in the oak desiccation process, which was intensive in the second half of the 20th century (Brasier, 1996). The presence of the stressful conditions (the effects of the global warming) initiated the increase of the occurrence of *Phytophthora cinnamomi* fungus, which directly infuenced the beginning of the oak desiccation.

Due to the warming the period of the inoculum production and infection was extended, as well as the possibility of the spread of the fungus in the host plant, which made the great potential of the inoculum. Owning to their long-lasting influence the chronic desiccation occurred, followed by the attacks of the bark beetles and invasion of the fungi, the agents of the root and branches diseases. Due to all these factors the desiccation and dying of plants increased.

Some pathogens, as well as plants either react to the climate change by migrations, or adapt to the change at a fast rate. Nevertheless, numerous pathogens are not able to do it, owning to the short period of the sporulation, or due to the inability of the spores to spread. The interaction between pathogens can be altered due to the influence of climate change (Garrett et al. 2006).

There are many interrelative effects of the moisture on the beginning and development of the infectious disease, which are similar to the effects of temperature (Agrios, 1997). The moisture is necessary for the germination of the fungal spores and penetration in the tissues of the plant, for the translocation of the pathogens through the plant, as well as for the transportation from one plant to the other. The extention or the repetition of the conditions characterized by the high humidity enable the occurrence of the epidemic. However, the humidity also influence the plants by increasing the succulence and their sensitivity to the different pathogens. The dense plantations of the plants enables the increase of the humidity on the foliage, which is favourable for the development of the foliar pathogens.

Although some pathogenic species are indepependent from the atmospheric humidity, since they are able to use the water and nutrients of the host, there are also pathogens which require the cover of the plant tissue by the water layer, as it is the necessary precondition for the release of spores. The number of the infectious phases in the development of the disease over the season for some species are influenced only by the precipitation, and the occurrence of the new infections are related to the rain periods. For some species the presence of the humidity in the host, as well as the relative atmospheric humidity, are needed for the germination and spread of spores, which is typical for *Plasmopara viticola*, since it cannot develop without the high relative humidity or the unbound humidity in its environment. The presence of the humidity is necessary for these fungal species during the formation of the spores, whereas the dry and warm weather is the precondition for its growth and sporulation. All these activities restart when it rains, or after the recurrence of the humid weather conditions.

The spores of the powdery mildew can germinate, penetrate or cause the infection only when there is high relative humidity in the vicinity of plants. During many diseases, which attack the underground parts of the plants (root decay or seed rot), and are caused by the species from *Pythium., Phytophthora, Rhizoctonia, Sclerothinia gena*, their activity is proportional to the quantity of the soil humidity, and is greater in the vicinity of the saturation point. The increase of the humidity enables the easier multiplication and mobility of the spores in the wet soil, and can also decrease the ability of the host to defend itself by the reduction of the available oxygen in the soil and decrease of the temperature of these soils.

The extreme quantities of humidity which are continuously present have the influence on the diseases. The intensive rains, frost and hail can have an adverse effect on the young plants and cause the soil erosion (Rosenzweig et al., 2001). The alternation of the drought and intensive rains is favourable for the fungal infections on the leaves and root. The stress caused by the drought, in combination the stress caused by the poplars, often alternate, and are most frequently accompanied with the high radiation and winds. Due to the stress caused by the drought, the stomes close by reducing the transpiration, the consequence of which is the increase of the plant temperature. Over the dry periods the sporulation of fungi is reduced, but the development of the plant hosts is also decelerated. In the tissue of the host the carbohydrates accumulate, as a result of the stress caused by the drought, which can be beneficial for the pathogens, such as *Macrophomina phaseolina* and *Septoria musiva*, the agent of the poplar canker wounds, which can survive in the extreme dry soils as well (Garrett et al., 2006).

During some diseases the level of the precipitation in the certain period of year causes the fast spread of the fungi (Woods et al., 2005). The long-lasting precipitation in the summer is favourable for the fast spread of the pathogenic fungi *Dothistroma septosporum* and *Dothistroma pini*.

The results obtained by Boland et al. (2004) show that the CO_2 level increased by 30% in the comparison with the mid 19th century. By the combustion of the fossil fuels, the increase of the areas subjected to deforestation, or by some other activities, man caused the global warming by increasing the atmospheric concentration of the radioactive CO_2, methane, nitrogen oxides and chlorofluorocarbons.

The increase of the leaf mass, the extented survival of the leaves on plants, branching and the root lenght, are only some of the numerous factors of the CO_2 impact on the plants. All these factors also enable the easier survival of pathogens, which implies the increase of inoculum, as well as the possibility of infection of many tree species.

The changes in the intensity and quality in the UV radiation are the result of the ozone layer depletion. The ultraviolet rays stimulate the sporogenesis in the fungi, but can also reduce the spread of the spores and the occurrence of the early phase of infection (Chakraborty et al., 2008).

3. THE INFLUENCE OF THE CLIMATE CHANGE ON THE HARMFUL ENTOMOFAUNA OF THE FOREST ECOSYSTEMS

The magnitude of the impacts of temperature on forest pests will differ among species depending on their environment, life history, and ability to adapt. Flexible species that are *Polyphagous*, occupy different habitat types across a range of latitudes and altitudes, and show high phenotypic and genotypic plasticity are less likely to be adversely affected by climate change than specialist species occupying narrow niches in extreme environments (Bale et al., 2002; Thomas et al., 2004).

The increase of temperature in the summer months will accelerate the development and increase the reproduction ability of some harmful insect species, whereas the warming over the winter period, in the combination with the lack of the temperature minimal extremes, will cause the increase in the survival rate. It should be emphasized that the impact of the temperature of the poikilothermic organisms, such as insects, will vary depending on the climate region. Also, it is anticipated that owning to the global warming the species will migrate and the altitudinal ranges will move to the higher altitudes and latitudes, since the climate has the main role in the defining of the limits of distribution of the insect species and their geographical sub-units.

Parmesan and Yohe (2003) reported that more than 1,700 Northern Hemisphere species have exhibited significant range shifts averaging 6.1 km per decade towards the poles (or 6.1 m per decade upward).

Some examples of forest pest species from Serbia that have responded or are predicted to respond to climate change by altering distribution include the following.

Neodiprion sertifer Geoffr. (*Diprionidae*) is an important pest species on pines in Europe, Northern Asia, Japan and North America where it was introduced. It is one of the most serious defoliators of Scots pine (*Pinus sylvestris*) forests in Northern Europe. Virtanen et al. (1996) suggested that outbreaks of the sawfly on Scots pine in Eastern and Northern Finland are prevented by low winter temperatures which kill eggs, and predicted that outbreaks would become more common owning to the winter warming.

Since 1989, when the European pine sawfly was registered after a long pause, and it is supposed that the climate change was one of the crucial factors, the focuses of the infection have been discovered in the pine plantations across Serbia. As a result of the applied methods of control, this phenomenon has not reached calamitious dimensions (Tabakovic-Tosic, 2002).

Geometridae: In Serbia, there have been several recent outbreaks of species, which are thought to be relatively innocuous. These outbreaks are associated with warm late autumn and warmer winter temperatures. Outbreaks are possibly a direct temperature impact on the insect life cycle, but the actual cause and effect is unknown. The host condition and interactions with other organisms may also be important factors.

Coleophora laricella (Hübne, 1817) Natural control factors, such as weather, needle diseases, and native predators and parasites, contribute to the reduction of the population. In all probability, in all places where larch grow, prolonged cold, wet weather in the spring, and the frost occurring after hibernation of the larvae, can cause considerable mortality. In suitable places it has a permanent fluctuation, and in artificial stands the outbreak can last for as long as 10-12 years. In the common larch cultures at the waste disposal sites of the waste-rock of energetic-industrial complex Kolubara, it lasted 15 years, and one of factor of that prolonged outbreak was climate change (Tabakovic-Tosic et al, 2009).

The gypsy moth *Lymantria dispar* Line, 1758, is one of the major pests of broadleaf forests and orchards. It is characterised by a high reproductive capacity, considerable ecological plasticity and polyphagia. It occurs periodically in high numbers (outbreak). Although it is found on four continents (North Africa, Asia, Europe, North America), the greatest damage is caused to the forests of the Balkan Peninsula, which have all the favourable environmental conditions for the gypsy moth development.

Over the 150-year period in Serbia there were 17 outbreaks, and the eighteenth outbreak started this year. The outbreaks do not occur at regular time intervals. Acute and chronic outbreaks are differentiated based on the increase of the number of egg masses per unit area and the attained amplitudes in the stages of eruption and culmination. During the last seventy years in Serbia gypsy moth had six outbreaks of acute type: 1945-1950, 1952-1957, 1961-1966, 1995-1999, 2003-2007, and 2009(2010)-. (Tabakovic-Tosic, Jovanovic, 2006). The frequence of the gypsy moth outbreaks, i.e. the shortening of the latent period over the past 15 years, was to a large extent caused by the climate change, in regard to the creation of the optimal site conditions for the complete activity of this defoliating species.

The eight-toothed spruce bark beetle (*Ips typographus*) is the most important insect pest in Central European forests. About 85% of beetle infested stands are killed by this species. In the region of mountain “Stara planina” in the south of Serbia, extreme meteorological events like storms, droughts and *Ips typographus* and *Pityogenes chalcographus* infestations killed thousands cubic meters of standing trees during the period 2000-2007. It shows that storms and extended drought and heat periods are much more important key factors for Ips typographus and *Pityogenes chalcographus* outbreaks than the rise of the average temperature.

The ability of a species to respond to global warming and expand its range will depend on a number of life history characteristics, making the possible responses quite variable among species. Bale et al. (2002) suggested that fast-growing, non-diapausing insect species or those not dependent on low temperature to induce diapause, will respond to warming by expanding their distribution whereas slow-growing species that need low temperatures to induce diapause (i.e. boreal and mountain species in the northern hemisphere) will suffer range contractions.

Range shifts may be limited by factors such as day length or the presence of competitors, predators or parasitoids (Walther et al., 2002). For example, the range expansion of insects which are very host-specific (specialists) may be limited by the slower rate of spread of their host plant species (Harrington, Fleming and Woiwod, 2001).

Phenology can be expected to be influenced by climate change. Where insect life cycle events are temperature-dependent, they may be expected to occur earlier and increased temperatures are likely to facilitate extended periods of activity at both ends of the season, provided there are no other constraints (Harrington, Fleming and Woiwod, 2001). With increased temperatures, it is expected that insects will pass through their larval stages faster and become adults earlier.

Therefore, expected responses of insects could include an advance in the timing of larval and adult emergence and an increase in the length of the flight period (Menéndez, 2007). Members of the order Lepidoptera again provide the best examples of such phenological changes.

Salama, Knowler and Adams (2007) reported an increase in numbers and diversity of moths in traps of the Rothamstead survey and their altered phenology suggests that climate change is partly responsible. First appearance of 17 species in Spain has advanced by 1 to 7 weeks in just 15 years (Stefanescu et al., 2003). Seventy percent of 23 butterfly species in California, USA have seen an advancement of first flight date of approximately eight days per decade (Forister and Shapiro, 2003). Changes in phenology (early adult emergence and an early arrival of migratory species) have also been noted for aphids in the UK (Zhou et al., 1995; Harrington et al., 2007). Gordo and Sanz (2005) investigated climate impacts on four Mediterranean insect species (a butterfly, a bee, a fly and a beetle) and noted that all species exhibited changes in their first appearance date over the last 50 years which was correlated with increases in spring temperature. Parmesan and Yohe (2003) estimated that more than half (59 percent) of 1598 species investigated exhibited measurable changes in their phenologies and/or distributions over the past 20 to 140 years. They also estimated a mean advancement of spring events by 2.3 days/decade based on the quantitative analyses of phenological responses for these species. Root et al. (2003), in a similar quantitative study, estimated an advancement of 5.1 days per decade.

There is increasing evidence in the literature that insect species are changing their genetic makeup in response to climate change. The physiological makeup of populations can also be altered. In species of butterflies with facultative (photoperiod induced) diapause, Burke et al. (2005) reported the conversion of a thermal gradient (elevation) into a gradual shift in the prevalence of discrete univoltine or bivoltine life strategies involving changes in critical photoperiod and development times, with corollary consequences on reproductive rates.

Changes in temperature, precipitation, atmospheric CO_2 concentrations and other climatic factors can alter tree physiology in ways that affect their resistance to herbivores (Ayres and Lombardero, 2000).

Long-term drought can result in reduced tree growth and health thereby increasing their susceptibility to insect pests. A number of insect pests are associated with stressed trees, such as *Agrilus* beetles which have been linked to oak decline. Others are limited by host defences in healthy trees, such as the European spruce bark beetle (*Ips typographus*) (Evans, 2008). Drought can also elicit changes in plant and tree physiology which will impact pest disturbance dynamics. Leaves may change colour or become thicker or waxier, which could affect their palatability to insects. The concentration of a variety of secondary plant compounds tends to increase under drought stress which would also lead to changes in the attraction of plants to insect pests. Moderate drought however may actually increase production of defense compounds in plants and trees possibly providing increased protection against pests. Sugar concentrations in foliage can increase under drought conditions making it more palatable to herbivores and therefore resulting in increased levels of damage (Harrington, Fleming and Woiwod, 2001). Another advantage for forest pests is the increased temperature of drought-stressed trees, which can be 2 to 4 °C warmer, which can benefit the fecundity and survival of insects for example (Mortsch, 2006). The impacts of such changes to host tree physiology and susceptibility provoke different responses from pest species.

Higher atmospheric CO_2 levels result in improved growth rates and water use efficiency of plants and trees. This increased productivity leads to lower nitrogen concentrations in trees and plants as carbon-nitrogen (C:N) ratios rise and thus reduces the nutritional value of vegetation to insects (Kopper and Lindroth, 2003; Mortsch, 2006). In response insects may increase their feeding (and consequently tree damage) in an attempt to compensate for the reduced quality and gain the necessary nitrogen (Ayres and Lombardero, 2000). For example, under increased CO_2 levels the winter moth (*Operophtera brumata*) consumes more oak (*Quercus robur*) leaves due to a reduction in leaf toughness, while the gypsy moth (*Lymantria dispar*) exhibits normal pupation weight but requires a longer time to develop as a result of an increase in tannin concentrations (van Asch and Visser, 2007).

4. SUMMARY AND CONCLUSIONS

Due to their shorter generation time, insects and pathogens may be able to adapt to climate change more quickly than their hosts. There will be more insect activity. Increasing temperatures will help insects to have more generations per year. There will likely be more pathogen-related mortality. It is thought that temperatures influence pathogens, and that increasing temperatures will increase pathogen activity. Changes in climate will bring surprises and may destabilize some existing relations.

One way to think about the overall changes in insect behaviour is to track the data in the insect surveys. If summarized over time, these are likely to show that the endemic levels of insects are rising significantly, and becoming close to the current epidemic levels.

In many areas there will be more stressed trees, increased insect and pathogen activity, more native and non-native invasive species (plants, insects, pathogens), and an increase in fires. Trees adapt slowly, while insects and pathogens can adapt more quickly. During this extended period of adjustment, future endemic levels of insects and diseases resemble current epidemic disturbances. Given the anticipated rate of change, it is unlikely that existing systems will just migrate from one place to another.

Further detailed studies of important forest pests would allow the development of pest management strategies for the future and assist forest managers and policy-makers to better prepare for the challenge of dealing with climate change and provide insights into future pest adaptations to climate change.

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FOREST POLITICS AND CLIMATE CHANGES

PLENARY LECTURES

CLIMATE CHANGE, ENVIRONMENT AND FORESTS IN FOREST POLICY STATEMENTS

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Abstract: *The international policy context for forestry is changing rapidly, and in the past five years the role of forests in climate change has climbed right up the global policy agenda. The fact that 20% of all global emissions are estimated to come from deforestation is a big issue for the planet, and the protection of forests is going to have to be a key part of climate change policy.*

Environment and Forests programme seeks to inform the processes of policy change in forestry in ways which improve the livelihoods and well-being of the forest-depending, whilst also securing the long-term future of forest resources. During the past years it is becoming clearer that human beings have a great influence on the earth´s climate machine as supposed for a long time. Today, the change in climate can no longer be excluded from public discussion. In doing this, it is frequently overlooked that science has been engaged with this subject even longer and has to some extent given warnings at an early stage but never found a listener within the public or in the world of politics.

The potential role of forestry in the related policy debate, both as a tool for mitigation and as an impacted resource requiring substantial effort at adaptation, should be more addressed. Forestry in general has not been adequately incorporated into current mitigation efforts in EU legislatives – neither in terms of fossil fuel substitution nor in terms of the carbon sequestration potential for forests.

Due to preserve the viability of forestry public opinion needs the precise leeds, besides the integral role of forests and the forest sector in mitigation and adaptation to climate change, but also to have developed further strategies for the meaningful use of forest-based resources.

Key words: Forest Policy, Environment, climate change, forests, resource

1. INTRODUCTION

„We have less than 10 years to halt the global rise in greenhouse gas emissions if we are to avoid catastrophic consequences for people and the planet. It is, simply, the greatest collective challenge we face as a human family," Ban Ki-Moon said during his keynote speech to the World Federation of U.N. Associations"[2].

Defining what is dangerous interference with the climate system is a complex task that can only be partially supported by science, as it inherently involves normative judgements. There are different approaches to defining danger, and an interpretation of science is likely to rely on scientific, ethical, cultural, political and/or legal judgements. As such, the agreement(s) reached among the Parties in terms of what may constitute unacceptable impacts on the climate system, food production, forest ecosystems or sustainable economic development will represent a synthesis of

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[2] United Nations Secretary General Ban Ki-Moon spoke of the challenges facing the world and singled out climate change as the greatest. www. mongabay.com by Jeremy Hance, August 10, 2009

these different perspectives. Over the past two decades several expert groups have sought to define levels of climate change that could be tolerable or intolerable, or which could be characterized by different levels of risk. Based on the available knowledge at the time a 2ºC increase was determined to be 'an upper limit beyond which the risks of grave damage to ecosystems, and of nonlinear responses, are expected to increase rapidly'. This early work also identified the rate of change to be of importance to determining the level of risk, a conclusion that has subsequently been confirmed qualitatively.

More recently, others in the scientific community have reached conclusions that point in a similar direction 'that global warming of more than 1°C, relative to 2000, will constitute "dangerous" climate change as judged from likely effects on sea level and extermination of species' (Hansen *et al.,* 2006).

Probabilistic assessments have also been made that demonstrate how scientific uncertainties, different normative judgments on acceptable risks to different systems and/or interference with the climate system affect the levels of change or interference set as goals for policy emissions would be costly and dangerous.

The Heads of State, Heads of Government, Ministers, and other heads of delegation present at the United Nations Climate Change Conference 2009 in Copenhagen, have agreed on Copenhagen Accord[1] which is operational immediately: „We underline that climate change is one of the greatest challenges of our time. We emphasise our strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities. To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change. We recognize the critical impacts of climate change and the potential impacts of response measures on countries particularly vulnerable to its adverse effects and stress the need to establish a comprehensive adaptation programme including international support".

2. OBJECTIVE OF THE UNFCCC

United Nations Framework Convention on Climate Change (UNFCCC[2]) was adopted in May 1992 in New York and opened for signature at the 'Rio Earth Summit' in Rio de Janeiro a month later. It entered into force in March 1994 and has achieved near universal ratification with ratification by 189 countries of the 194 UN member states (December 2006) . Article 2 of the UNFCCC specifies the ultimate objective of the Convention and states: 'The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner' (UN, 1992). The criterion that relates to enabling economic development to proceed in a sustainable manner is a double-edged sword. Projected anthropogenic climate change appears likely to adversely affect sustainable development, with adverse effects tending to increase with higher levels of climate change. Conversely, costly mitigation measures could have adverse effects on economic development. This dilemma facing policymakers results in (a varying degree of) tension that is

[1] CONFERENCE OF THE PARTIES, Fifteenth session, Copenhagen, 7-18 December 2009, Agenda item 9 - Copenhagen Accord
[2] http://unfccc.int/essential_background/convention/items/2627.php. 190 ratifications - one from the European Union.

manifested in the debate over the scale of the interventions and the balance to be adopted between climate policy (mitigation and adaptation) and economic development. The assessment of impacts, vulnerability and adaptation potentials is likely to be important for determinating the levels and rates of climate change which would result in ecosystems, food production or economic development being threatened to a level sufficient to be defined as dangerous. Vulnerabilities to anthropogenic climate change are strongly regionally differentiated, with often those in the weakest economic and political position being the most susceptible to damages.

Sustainable development has environmental, economic and social dimensions. Properly designed climate change responses can be part and parcel of sustainable development, and the two can be mutually reinforcing. Mitigation, by limiting climate change, can conserve or enhance natural capital (ecosystems, the environment as sources and sinks for economic activities) and prevent or avoid damage to human systems and, thereby, contribute to the overall productivity of capital needed for socio-economic development, including mitigative and adaptive capacity.

Sustainable development paths can reduce vulnerability to climate change and reduce GHG emissions[1]. The projected climate changes can exacerbate poverty and thereby undermine sustainable development especially in developing countries, which are the most dependent on natural capital and lack financial resources. Hence global mitigation efforts can enhance sustainable development prospects in part by reducing the risk of adverse impacts of climate change.

Climate change adaptation and mitigation can also be the focus of policy interventions can be considered as an issue that is indirectly influenced. Such climate policies can tend to focus on sectoral policies, projects and policy instruments, which meet the adaptation and mitigation goals, but are not necessarily strongly linked to all the economic, social, and environmental dimensions of sustainable development. In this case climate change policy implementation in practice can encounter some conflicts between general development goals and the goal of protecting the global environment, climate policies that do not take economic and social considerations into account might not be sustainable in the long run. It might then be distinguish between climate change policies that emerge as an integrated element of general sustainable development policies, and more specific adaptation and mitigation policies that are selected and assessed primarily in their capacity to address climate change. Examples of the first category of policies can be energy efficiency measures, energy access and affordability, water management systems, and food security options, while examples of more specific adaptation and mitigation policies can be flood control, climate information systems, and the introduction of carbon taxes. It is worth noticing that the impacts on sustainable development and climate change adaptation and mitigation of all these policy examples are very context specific, so it cannot in general be concluded whether a policy supports sustainable development and climate change jointly or if there are serious tradeoffs between economic and social perspectives and climate change.

2. THE SUSTAINABLE DEVELOPMENT CONCEPT

Sustainable development (SD) has been discussed extensively in the theoretical literature since the concept was adopted as an overarching goal of economic and social development by UN agencies, by the Agenda 21 nations, and by many local governments and private-sector actors. The SD literature largely emerged as a reaction to a growing interest in considering the interactions and potential conflicts between economic development and the environment. SD was defined by the

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[1] Greenhouse Gas Emissions: Gases that trap heat in the atmosphere are often called greenhouse gases. Some greenhouse gases such as carbon dioxide occur naturally and are emitted to the atmosphere through natural processes and human activities. Other greenhouse gases (e.g., fluorinated gases) are created and emitted solely through human activities. The principal greenhouse gases that enter the atmosphere because of human activities are**:** Carbon Dioxide (CO_2)**,** Methane (CH_4)**,** Nitrous Oxide (N_2O)**,** Fluorinated Gases, etc.

World Commission on Environment and Development in the report Our Common Future as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987)[1]. The literature includes many alternative theoretical and applied definitions of sustainable development. The theoretical work spans hundreds of studies that are based on economic theory, complex systems approaches, ecological science and other approaches that derive conditions for how development paths can meet SD criteria. Furthermore, the SD literature emphasizes a number of key social justice issues including inter- and intra-generational equity. The debate on sustainability has generated a great deal of research and policy discussion on the meaning, measurability and feasibility of sustainable development. Despite the intrinsic ambiguity in the concept of sustainability, it is now perceived as an irreducible holistic concept where economic, social, and environmental issues are interdependent dimensions that must be approached within a unified framework (Dresner, 2002). However, the interpretation and valuation of these dimensions have given rise to a diversity of approaches.

A growing body of concepts and models, which explores reality from different angles and in a variety of contexts, has emerged in recent years in response to the inability of normal disciplinary science to deal with complexity and systems – the challenges of sustainability. An international group of ecologists, economists, social scientists and mathematicians has laid the principles and basis of an integrative theory of systems change. This new theory is based on the idea that systems of nature and human systems, as well as combined human and nature systems and social-ecological systems, are interlinked in never-ending adaptive cycles of growth, accumulation, restructuring, and renewal within hierarchical structures (Holling *et al.*, 2002). A core element in the economic literature on SD is the focus on growth and the use of man-made, natural, and social capital. The fact that there are three different types of capital hat can contribute to economic growth has led to a distinction between weak and strong sustainability, as discussed by (Pearce and Turner, 1990). Weak sustainability describes a situation where it is assumed that the total capital is maintained and that the three different elements of the capital stock can, to some extent, be used to substitute each other in a sustainable solution. On the other hand, strong sustainability requires each of the three types of capital to be maintained in its own right, at least at some minimum level. An example of an application of the strong sustainability concept is Herman Daly's criteria, which state that renewable resources must be harvested at (or below) some predetermined stock level, and renewable substitutes must be developed to offset the use of exhaustible resources (Daly, 1990). Furthermore, pollution emissions should be limited to the assimilative capacity of the environment.

There is a controversy between economists and ecologists by saying that ecologists have deemed current consumption patterns to be excessive or deficient in relation to sustainable development, while economists have focused more on the ability of the economy to maintain living standards (Arrow *et al.,* 2004).

It is concluded here that the sustainability criterion implies that inter-temporal welfare should be optimized in order to ensure that current consumption is not excessive. However, the optimal level of current consumption cannot be determined (i.e. due to various uncertainties). Theoretical considerations therefore focus instead on factors that make current consumption more or less sustainable. These factors include the relationship between market rates of return on investments and social discount rates, and the relationship between market prices of consumption goods (including capital goods) and the social costs of these commodities. Some basic principles are therefore emerging from the international sustainability literature, which helps to establish commonly held principles of sustainable development. These include, for instance, the welfare of future generations, the maintenance of essential biophysical life support systems, more universal participation in development processes and decisionmaking, and the achievement of an acceptable standard of human well-being (Swart *et al.*, 2003).

[1] World Commission on Environment and Development. The term 'sustainable development' was popularised by the World Commission on Environment and Development (WCED) in its 1987 report entitled Our Common Future.

Relationship between climate change and Sustainable Development

There is a dual relationship between sustainable development and climate change. On the one hand, climate change influences key natural and human living conditions and thereby also the basis for social and economic development, while on the other hand, society's priorities on sustainable development influence both the GHG emissions that are causing climate change and the vulnerability. Climate policies can be more effective when consistently embedded within broader strategies designed to make national and regional development paths more sustainable. This occurs because the impact of climate variability and change, climate policy responses, and associated socio-economic development will affect the ability of countries to achieve sustainable development goals. Conversely, the pursuit of those goals will in turn affect the opportunities for, and success of, climate policies.

Implementation of Sustainable Development and climate change policies:

Sustainable development and climate change are influenced by a number of key policy decisions related to economic, social and environmental issues, as well as by business-sector initiatives, private households and many other stakeholders, and these decisions are again framed by government policies, markets, information sharing, culture, and a number of other factors. Some of the decisions that are critically important in this context are investments, use of natural resources, energy consumption, land use, technology choice, and consumption and lifestyle, all of which can lead to both increasing and decreasing GHG emission intensities, which again will have implications for the scope of the mitigation challenge. Seen in a longerterm perspective these decisions are critical determinants for development pathways. There has been an evolution in understanding of how SD and climate change mitigation decisions are taken by societies. In particular, this includes a shift from governments that are defined by the nation/state to a more inclusive concept of governance, which recognizes various levels of government (global, transnational/regional, and local), as well as the roles of the private sector, non-governmental actors and civil society.

3. CLIMATE CHANGE MITIGATION POLICIES

Decision-making about climate change policies is a very complex and demanding task since there is no single decisionmaker and different stakeholders assign different values to climate change impacts and to the costs and benefits of policy actions. However, many new initiatives emerge from governmental cooperation efforts, the business sector and NGOs (non governmental organizations), so various coalitions presently play an increasing role. A large number of analytical approaches can be used to support decision-making, and progress has been made both in integrated assessment models, policy dialogues and other decision support tools. Like most policy-making, climate policy involves trading off risks and uncertainties. Risks and uncertainties have not only natural but also human and social dimensions. They arise from missing, incomplete and imperfect evidence, from voluntary or involuntary limits to information management, from difficulties in incorporating some variables into formal analysis, as well as from the inherently unpredictable elements of complex systems. An increasing international literature considers how the limits of the evidence basis and other sources of uncertainties can be estimated.

Costs and benefits of climate change mitigation policies can be assessed at project, firm, technology, sectoral, community, regional, national or multinational levels. Inputs can include financial, economic, ecological and social factors. In formal cost-benefit analyses, the discount rate is one major determinant of the present value of costs and benefits, since climate change, and mitigation/ adaptation measures all involve impacts spread over very long time periods. The potential linkages between climate change mitigation and adaptation policies have been explored in an emerging literature. It is concluded that there is a number of factors that condition societies' or individual stakeholders' capacity to implement climate change mitigation and adaptation policies including social, economic, and environmental costs, access to resources, credit, and the decision-making capacity in itself. Climate change has considerable implications for intragenerational and inter-generational equity, and the application of different equity approaches has major implications for policy recommendations, as well as for the implied distribution of costs and benefits of climate policies. Different approaches to social justice can be applied when evaluating equity consequences of climate change policies. They span traditional economic approaches where equity appears in terms of the aggregated welfare consequences of adaptation and mitigation policies, and rights-based approaches that argue that social actions are to be judged in relation to the defined rights of individuals. The cost and pace of any response to climate change concerns will critically depend on the social context, as well as the cost, performance, and availability of technologies. Technological change is particularly important over the long-term time scales that are characteristic of climate change. Decade (or longer) time scales are typical for the gaps involved between technological innovation and widespread diffusion, and of the capital turnover rates characteristic for long-term energy capital stock and infrastructures. The development and deployment of technology is a dynamic process that arises through the actions of human beings, and different social and economic systems have different proclivities to induce technological change, involving a different set of actors and institutions in each step. The state of technology and technology change, as well as human capital and other resources, can differ significantly from country to country and sector to sector, depending on the starting point of infrastructure, technical capacity, the readiness of markets to provide commercial opportunities and policy frameworks. The climate change mitigation framing issues in general are characterized by high agreement/much evidence relating to the range of theoretical and methodological issues that are relevant in assessing mitigation options.

Adaptation and mitigation: Adaptation and mitigation can be complementary, substitutable or independent of each other. If complementary, adaptation reduces the costs of climate change impacts and thus reduces the benefits of mitigation. Although adaptation and mitigation may be substitutable up to a certain point, they are never perfect substitutes for each other since mitigation will always be required to avoid 'dangerous' and irreversible changes to the climate system. Irrespective of the scale of the mitigation measures that are implemented in the next 10–20 years, adaptation measures will still be required due to the inertia in the climate system.

As was mentioned (IPCC, 2007), changes in the climate are already causing setbacks to economic and social development in some developing countries with temperature increases of less than 1°C. Unabated climate change would increase the risks and costs very substantially. Both adaptation and mitigation depend on capital assets, including social capital, and both affect capital vulnerability and GHG emissions. Through this mutual dependence, both are tied to sustainable development. The stabilization of GHG concentrations and, in particular, of the main greenhouse gas, CO2, requires substantial emission reductions, well beyond those built into existing agreements such as the Kyoto Protocol[1]. The timing and rate of these reductions depend on the level of the climate goal chosen.

[1] The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions. The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and entered into force on 16 February 2005. 184 Parties of the Convention have ratified its Protocol to date. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh in 2001, and are called the "Marrakesh Accords." The major distinction between the Protocol and the Convention is that while the Convention encouraged industrialised countries to stabilize GHG emissions, the Protocol commits them to do so. Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of "common but differentiated responsibilities."

Mitigative capacity here is seen as a critical component of a country's ability to respond to the mitigation challenge, and the capacity, as in the case of adaptation, largely reflects manmade and natural capital and institutions. It is concluded that development, equity and sustainability objectives, as well as past and future development trajectories, play critical roles in determining the capacity for specific mitigation options. Following that, it can be expected that policies designed to pursue development, equity and/or sustainability objectives might be very benign framework conditions for implementing cost-effective climate change mitigation policies. The final conclusion is that, due to the inherent uncertainties involved in climate change policies, enhancing mitigative capacity can be a policy objective in itself.

It is important to recognize here that the institutional aspects of the adaptive and mitigative capacities refer to a number of elements that have a 'public-good character' as well as general social resources. These elements will be common framework conditions for implementing a broad range of policies, including climate change and more general development issues.

This means that the basis for a nation's policy-implementing capacity exhibits many similarities across different sectors, and that capacity-enhancing efforts in this area will have many joint benefits. There may be major differences in the character of the adaptive and mitigative capacity in relation to sectoral focus and to the range of technical options and policy instruments that apply to adaptation and mitigation respectively. Furthermore, assessing the efficiency and implementability of specific policy options depends on local institutions, including markets and human and social capital, where it can be expected that some main strengths and weaknesses will be similar for different sectors of an economy. As previously mentioned, the responses to climate change depend on the adaptive and mitigative capacities and on the specific mitigation and adaptation policies adopted. Policies that enhance adaptive and mitigative capacities can include a wide range of general development policies, such as market reforms, education and training, improving governance, health services, infrastructure investments etc. The actual outcome of implementing specific mitigation and adaptation policies is influenced by the adaptive and mitigative capacity, and the outcome of adaptation and mitigation policies also depends on a number of key characteristics of the socioeconomic system, such as economic growth patterns, technology, population, governance, and environmental policies.

4. AGROFORESTRY AS ATTAMPT FOR CLIMATE CHANGE RESPONSE

Over the past decade, several models have been developed to predict the impact of climate change on biodiversity. Results from these models have suggested some alarming consequences of climate change for biodiversity, predicting, for example, that in the next century many plants and animals will go extinct (Willis, Bhagwat 2009).

With the world facing a variety of crises: climate change, food shortages, extreme poverty, and biodiversity loss, researchers are looking at ways to address more than one issue at once by revolutionizing sectors of society. One of the ideas is a transformation of agricultural practices from intensive chemical-dependent crops to mixing agriculture and forest, while relying on organic methods. The latter is known as agroforestry or land sharing – balancing the crop yields with biodiversity.

Agroforestry – intentional management of shade trees with agricultural crops – has the potential for providing habitats outside formally protected land, connecting nature reserves and alleviating resource-use pressure on conservation areas. Here we examine the role of agroforestry systems in maintaining species diversity and conclude that these systems can play an important role in biodiversity conservation in human-dominated landscapes (Bhagwat, at.al. 2008).

As Bhagwat underlined: „Admittedly, we might not be able to grow rice under shade trees, but the principle of agroforestry has several implications for biodiversity management in highly human-dominated landscapes. Studies have suggested that forested landscapes are pretty good at maintaining biodiversity if the tree cover is above 30%. In other words, if rice fields were surrounded by hedgerows, woodlots and forest patches, then there will be much more biodiversity in the landscape". He believes that such a system of agriculture would also help mitigate climate change („agricultural land partly covered in trees will fix more carbon than land without trees"), alleviate poverty, and prevent future food shortages.

Further more: „Once these changes are in place, growing food locally, using fewer agrochemicals, and caring for the wildlife on farmland will all make sense. If these changes do not happen, and we carry on with the business-as-usual, then we are likely to face severe food shortages in the future, particularly in poorer countries."

Priorities need to get right – to much attantion have paid to economic concerns and less so to social and environmental concerns. Food has to be distributed better to address the huge gulf between the haves and have nots. Finally, food trade has to be sort out, make sure that we give importance to growing food locally rather than transporting it thousands of miles, half way across the globe.

The difference between „land sparing" and „land sharin": Land sparing is what we do in over 100,000 protected areas around the world. We allocate this land for conservation in the hope that the spared land will harbour world's biodiversity. What we also do in the process is that we intensively cultivate the non-spared land in the hope to produce as much food out of it as possible. Land sharing – as in sharing the earth with millions of other species – is a different approach to managing human-dominated landscapes.

How many of the hundreds of millions of hectares that farmers can spare will revert to trees? The amount depends on where cropland is abandoned and how people choose to use it.
Yet still the world's forest estate dwindles because the forces of the great restoration have not spread rapidly or widely enough. What must be done to expand and accelerate the Great Restoration worldwide? To answer that question and build a vision of the potential for the "Great Restoration" we focus on agriculture and logging -- the two main threats to natural forests. We argue that these two industries must continue their transformation into modern, ultra-efficient industries (Victor, 2003).

5. CONCLUSION

The forestry community is committed to helping design and implement new mechanisms to mobilize forests for climate mitigation and adaptation, while exploiting synergies with sustainable development objectives and managing associated risks. We recognize the significance of forest-based emissions and the cost-effectiveness of early action to reduce them. The most important drivers of deforestation originate from outside the forestry sector, including agriculture. There are also significant opportunities to correct current market and governance failures that lead to perverse outcomes for climate change and food security. Forest- and agriculture-based adaptation strategies are available but are not yet fully appreciated by policymakers and the general public.

Significant financial resources and political will are needed to better address food security, slow deforestation and forest degradation, and reach emission reduction targets. Investments must be transparent and additional to support for global food security and rural development. These resources must be accessible to all stakeholders, including researchers, civil society and especially forest communities, stakeholders and their associations. Resources must also be devoted to the research necessary to underpin needed advances in the effectiveness, efficiency, and equity of agriculture- and forestry-based approaches to mitigation and adaptation.

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ECOLOGICAL ETHICS FOR NEW AGE

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Abstract: *Ecological crisis causes many new challenges to the modern society, for which it is necessary to define ethic attitudes related to the essence of nature, knowledge on its laws, current events and possible consequences. This paper defines the characteristics of anthropocentrism, anthropo-biocentrism and biocentrism. The characteristics of "Deep ecology" and "Hypothesis on Gaia", as well as a number of ideologies based on these concepts, are presented. Climate change is only the top of the iceberg of the increasing ecological problems, which inevitably leads to the ecological revolution in the near future. The aggressive, but wise education of the population with the help of gnostic mediators is necessary.*

Key words: Ecological ethics, Deep ecology, hypothesis on Gaia, anthropocentrism, biocentrism

INTRODUCTION

Ecological crisis causes many new challenges to the modern society, for which it is necessary to define ethic attitudes related to the essence of nature, knowledge on its laws, current events and possible consequences.

In the last few decades there have been great activities aimed at construction of the philosophical bases for environmental protection. In the aim of better understanding of nature and man's place in it, the answer is nowadays mainly searched in the Eastern philosophical tradition (India, China, Japan), but in the Western philosophy as well there is a search for the roots from which the appropriate relation to nature would be developed.

During the development of civilizations the different attitude on nature, which depended on the public, social, economic and other factors were expressed.

In the early stage of the development of the human society the attitude towards nature was conditioned by the sense of the dependency on nature. Later, by the development of knowledge on nature processes the attitude that man is only one of the countless and various forms of the manifestation of the "creative power of nature" was developed.

In the supplement to the Report of the Roman Club "Limits of Growth: 30 years later" (Meadows, et al, 2004) the authors connect the accelerating industrialization, uncontrolled growth of the number of population, widely distributed malnutrition and use of the renewable and non-renewable nature resources in the process of environmental pollution. Inextricably bound elements will limit the "Limits of Growth" on the planet, which will result in a great decrease of the industrial

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Acknowledgement: The study was partly financed by the Minstry of Science and Technological Development of the Republic of Serbia, the Project – TR 20056 „High-resolution satellite images in the collection and processing of spatial information on forests and forest ecosystems"

production and reduction of the number of population. According to this report, the catastrophe would happen as early as in 2020.

It is possible to avoid this black forecast by the establishment of economic and ecological stability, by which the world policy must accept the realizations of the concept of the sustainable development. The approach which in the 1980s appeared to be the real solution, regardless of the fact that the solutions are mainly motivated by the interests of the Western capital and desire to preserve the achieved "civilization comfort" as long as possible, is no longer achievable today. The processes which have been started have already gone a far way in the destruction of the environment. It imposes the need for the establishment of the "new ecological ethics" in the aim of the survival of not only civilization but nature in general.

The paper presents the characteristics of the ecological ethics of anthropocentrism and biocentrism (anthropo-biocentrism and radical biocentrism).

ANTHROPOCENTRISM

The contemporary use of nature and nature resources is based on the anthropocentric philosophy. Before Francis Bacon, the majority of the Western philosophers neglected the fact on the human belonging and the problems of this kind they mainly observed uninterestedly. After the publication of Francis Bacon's programme (The New Organon), the application of the empirical research began, in order to subdue the nature, which also implied the imrpovement of the human life. All major philosophical and social doctrines of the modern age (Liberalism, Marxism, Socialism, Anarchism, Feminism, etc.) used this view as a starting point. It was considered that man, by expansion of technique, built the artifical new world, without the ecological limits.

After the Second World War, anthropocentric arrogance, technocratia and loathing of the non-human was fully expressed. In the technological societies all human activities, from personal behaviour to social and economic activities, gained the forms of machines (Volponi, P., 1967).

Today the multinational companies function by the principles of economic growth and profit, which are devoid of ethics and moral. There is the boundless need in anthropocentrism of transforming nature world in the industrial processes and commercial products in the fastest and "most efficient way", and the values of the ecosystem are reduced to its commercial potentials (Drengson A., Duncan T., 1997). Nature (ecosystem) serves solely to man, regardless of the fact in which way it reflects on the very ecosystem and all other organisms which directly or indirectly depend on it.

The long-term objective of the antropocentrically-oriented (industrial) forestry is the transformation of nature forests in tree plantations. The areas are cleared by the clearcutting and the reforestation of the cleared places is performed, by which the species of the greater yield and completely satisfy the needs of the wood industry are favoured. The majority of the forest ecosystems, particularly in the riparian areas, as well as degraded and devastated nature forests, were turned into the plantations, which led to the simplification of ecosystems in which two or more species present biocoenosis. By the uncontrolled introduction of the foreign tree species into the forest ecosystems, solely because of economic reasons, the problem becomes more drastic. The use of mechanisation and construction of the forest roads are favoured, the end result of which is the weakening of biodiversity, surface erosion, soil degradation, disturbance of the hydrological regime, deterioration of water quality from river basins, as well as destruction of the habitats of wild animals and birds.

Anthropocentrism is the major cause of the global ecological crisis, which is reflected in the following:

● climate change caused by the human activities (phenomenon of the Glass house, destruction of the ozone layer, global melting, increase of sea level, frequent floods and hurricanes)

● water and soil degradation

● reduction of plant and animal world (about one thousanf animal and six hundred plant species are endangered, which disappear fifty to one hundred times faster than nature selection occur)

● huge energy consummation and the increasing risk production

● development of "modern" science (both nature and social) which enables the "robbing of the Planet" and destruction of nature ecosystems.

● The development of the modern science influenced the change of habits, desires, characteristics of the individuals and their interaction with nature.

● Culture and global spirit of Ecumena are in crisis. There is an increasing lack of moral, barren search for identity and blockade of the establishment of more quality and different systems of values.

Anthropocentrism was continuously developed, until it became the dominant view of the West, with the tendency to impose it on other civilizations. In the Christianity the Ortodox view dominates, which is based on the Bible, whereas man has the right to use all the nature goods without no limits (animals, birds, other organisms, and all non-organic components of nature). Today the views od "ecoteology" are the forced world view. The Christianity bears the considerable responsibility for it and is to be blamed for the destruction of nature by the science and technology of the Western civilization. The Christianity, particularly the Western form of it, is "the most anthropocentric religion in the world (Shabecoff P., 1993).

In the last few decades, owning to the increasingly visible ecological crisis, the anthropogenic view of the Roman-Catholic church on nature has been revised in philosophy, religion, literature, painting and music. By the Encyclical of Pope John Paul II from 1989 "Peace with the God Creator, peace with the all God creatures", the Roman-Catholic church accepted the fact that the anthropocentric attitude towards nature is unsustainable in its Ortodox form.

ANTHROPO-BIOCENTRISM (MODERATE BIOCENTRISM)

Anthropo-biocentrism (moderate biocentrism) objectively values the biological diversity, states the imposssibility of determination of meaning of life in collecting the facts on biological life and indirectly, establish critical attitude towards the possibilities of transferring determined facts in human experience.

In anthropo-biocentrism (moderate biocentrism) we included the concept of the sustainable use of the nature resources and management which is close to nature.

The development of concept of sustainable use of nature resources can be followed through five phases (groups) (Perman et al., 1996).

1. The first group defines the sustainable use as the condition in which usefulness or consummation does not decrease by time. Each generation must have the equal right to benefit from environment so the industrial development which enables it during the unlimited time period is considered to be sustainable (Solow, 1987). The final report of Brundstland's Commission (WCED 1987) defines the sustainable development as one which satisfies the current needs without disturbing the possibilities of the future generations to satisfy their needs. This definition is not accurate, since it does not define what is the acceptible standard for satisfying the human needs.

2. The second group of definitions views sustainable use as the condition in which the resources are used in the way that the future productive possibilities of humankind are preserved. Having in mind that the needs of the future generations are unknown to us, it is impossible to think about the usefulness which some nature resources will have to the future generations. The criterion of sustainability is the preservation of the productive possibilities of ecosystem (Solow, 1986, 1991). The industrial development has the chance to be sustainable if the reduction of the supplies

of resources is compensated by the increased quantity of “physical and intelectual capital“.

3. The third group of concepts views the sustainable use as the condition in which the supplies of nature capital do not decrease by time. The development does not decrease the supplies of some nature resources. The UNESCO insists on this concept in its documents.

4. The fourth group of concepts considers the sustainable to be the condition in which the resources are used in the way they bring the sustainable yield or increment. This concept responds to the exploitation of the renewable resources, but the generalization to all nature resources is impossible.

5. The fifth group of concepts is based on the concept of stability and harmonization of the ecological population by the time. The sustainable is considered to be the condition in which the minimum conditions of stability and harmonization of ecosystem are satisfied. The system is ecologically sustainable if it has the characteristic of harmonization, so each activity which reduces the harmonization of ecosystem is considered to be unsustainable. Unfortunately, only EX POST gets the knowledge whether the system is harmonized or not. Only after the disturbance it can be safely concluded whether the use is sustainable or not. If the criterion of ecological sustainability is the aim of the development policy, the successfulness is reflected in the avoidance of the accident situation which disturbs the harmony of the ecosystem.

“The management which is close to nature“ accepts the premise that the ecosystem is the complexity of the living organisms and has its value “per se“. These ecological paradigms analyse in another way the needs of people and their attitude towards nature. The way in which nature creates and maintains the ecosystems is accepted. In nature ecosystems there are no undesirable species, except the species introduced by man. In forestry, for example, during the removal, each tree or product are valued from the viewpoint of functioning of ecosystem. Nature itself continues the further development and stability of ecosystem, not people according to their notions about it. Ecosystem belongs to all the species which live there, including people. Therefore, man does not have the right to destroy it only because of his interests. The ecocentric concept protects, maintains and renews the functioning of nature ecosystems with the simultaneous use of all goods and services for the satisfying the needs of people on steady and permanent bases. The advantages are given to the ecological processes in ecosystems, in the way they satisfy the economic needs of society, but not in the way of the industrial use. The ecocentric concept insists on the protection of the remaining old nature forests as the last haven of the plant species, as well as of the other species of organisms. The integral part is the care of soil, water, biodiversity and biomass.

“The Certification of Forests“ is the tool of market aimed for achieving the permanent sustainable forest management, and thereby the “healthy and vital forest for the future generations“. The forest management from the viewpoint of the certification has to fulfil the international criteria of the permanent sustainable management. The base for Certification are the Paneuropean criteria and indicators of the sustainable forest management. The international certification of the sustainable forest management requires the standardization of the characteristical documents to the level of the mutual comparison. The forestry certification is defined by the process which results in the written document (certificate) made by the third independent organization by which the location and status of the management of forest from which the tree originates are determined (Jović, Đ., 2005). There are two components:

● Assessment of forest management (inspection in the field within the above standards and survey of the documents - plans of management, plans of use, etc.) Assesment can be conducted at the level of the management units of the forest owners, regions, or country;

● Assessment of the products (certification) should influence the selection of the customer during the buy. The process of assessment should follow the product through the whole productive process, from forest to shop. The certification applies the system of surveillance from the transports of stumps and primary procession, through the further transport to the final procession;

The certification should improve the management of forests as nature resources and enables the access to the market of the certificated timber.

RADICAL BIOCENTRISM

Radical biocentrism equalizes the life of plants, animals and man, finding the justification for this attitude in DNA, which is common to all living creatures. From these facts the ethic attitude that all living creatures in nature are equal is derived.

Deep ecology

Simultaneosly with the concept of the sustainable development the serious critical analysis among the activists (ethicists) of environmental protection - Deep ecologists appear. (The creator of “Deep ecology” is considered to be the Norwegian philosopher Arne Naess (“Shallowness and Depth of Long-Term Trends of Ecology”), but the book after which it was named “Deep Ecology" is written by Bill Devall and Georg Session, 1986).

“Deep ecologists“ criticize the idea of the sustainable development and are of the opinion that without the drastic consideration on the hypotheses of the modern civilization it is not possible to achieve progress in environmental protection. “Deep ecology“relies on some views in the Western philospohy, mainly on Spinosa, as well as on the rituals of the primary cultures, Buddhism, Taoism, and Hinduism. They consider that in the ecological ethics “something new“is unnecessary, but it is needed to awake the old - to accept the unity of people, plants, animals and Earth.

It is the philosophical concept which offers the theoretical justification for the view “first nature, then society“.

The primary societies had the rich ceremonial and ritual life. The Tucano Indians (from the Amazonian jungles) used the myths and rituals with their shamans in order to prevent the excessive hunting and fishery. They view the world as the circulation of energy in which the all Universe takes part. The basic circulation of energy consists of the limited quantity of creative energy which continuously flows between people and nature. The Kung Tribe which has been living in the Kalahari Desert for 11,000 has few material things which belong to them, and their ritual life is one of the most sophisticated in the comparison with any other ethnic group.

In Masdaism, originated under the influence of Zarathustra’s views on the world, the hymns dedicated to the domestic or semi-tame animals which live in the agrar households. Hinduism does not view the humankind, now at the top of the evoluative pyramid, separately from nature. The series of incarnations, starting from the fish, by the further development through the amphibian forms and mammals to the human incarnation, symbolise the evolution of the life on the planet. Therefore, man is not created in order to dominate the other life form, but is integrally included in the whole incarnation. Nature cannot be destroyed, without our destruction in the end as well. The rule of embryology is that “ontogenesis is the short summary of phylogenesis“, points to the correct view of Hinduism in the relation Nature – Man. In Lamaistic religion, originated in Tibet (which is the variant of Buddhism), the various spirits and forces are sleeping in the rivers, mountains, lakes, trees. Any harm done to them will result in the droughts, epidemics, and diseases of the humans, as well as the loss of the soil fertility. In Taoism man by his existence does not have the right to govern nature. The main characteristic of Gianism is Panpsyhism: everything which exist in the world (animals, plants, stones, water drops, etc.) has the soul. The avoidance of violence is the basic ethical principle, and causing no harm to nature refers to both biotic and abiotic components. Plants have the right to exist at the same level as man, and by the all important biological characteristics they are equal to man. The same attitude the followers of Gianism have towards the all animals, including the microorganisms. Following these principles, the followers of Gianism erected the shelters for animals which were endangered by the illness or injuries.

The attitude that it is ethically incorrect to cause harm to any component of nature (abiotic or biotic) - biotop or biocoenosis, raises the sanctity of ecosystem to the level of the basic ethical principle. This way of thought and living is based on the purest ecological ethics, and the all teaching is the product of the intellectual observations (there are no totemic or mythological remains).

"Deep ecology" is based on the above philosophical and religious postulates, offers the nature philosophy which with the nature spirituality justifies the eco-primitive perspective of the eco-activists, who advocate the significant reduction of population and reduction or abolishment of the industrial technology. It would reduce or eliminate the destruction of nature by the modern industrial countries. The development of eco-awareness implies the acceptance of life in small, ecologically harmonised communities which survive by practising the ecological agriculture ("Law on Ecological Agriculture", Official Gazette, Federal Republic of Yugoslavia number 28/2000) and other solutions which are mainly acceptible for nature as the way for overcoming the current ecological crisis.

Earth first!

EARTH FIRST! and primitive stream which developed from it advocates the direct action in the defence of "Mother Nature". It finds the sources for its activities in the native eco-anarchism by Edward Abbey and native radical environmental protection by David Foreman. The original Earth First! often supported the anti-immigration attitude (North-American wildnerness is preserved only for the citizens of the USA and Canada as the only access to the defence of the remaining wilderness from the increasing human pillage by mining, road construction, agricultural explotation and tourism, and in the service of the mass consummation society) without the development of the critical social theory. Among the followers of Earth First! are the liberal-refomist environmental protectionists,eco-leftist supporters, eco-syndicate supporters connected with the IWW, the Green, eco-anarchists. Earth First! is the movement which advocates the direct action in the defence of the virgin nature, and the attitude of "Deep ecology" "Nature first, society is only the second"- dominates.

Social ecology

Social ecology is the radical ideology which advocates the view that the ecological problems in the contemporary world are the consequences of the problem within the human societies. It is possible to protect nature by the creation of the new social structures which will take into account the relation between people and nature by which the fight for environmental protection will not be efficient as long as the societies solve all the economic, racial, etnhic, cultural, sex, and other conflicts.

Eco-socialism

Eco-socialism (Green socialism or Socialist ecology) is the radical ideology which considers the environmental protection to be the direct consequence of the capitalism in the same way as poverty and social alienation. The fight for protection and environmental protection are inextricably bound with the fight for complete or partial abolishment or reform of the capitalistic system. Eco-socialism is nowadays the important component of the antiglobalisation movement.

Green syndicalism

Green syndicalism is the movement which is related to the anarcho-syndicalism or eco-anarchism. It connects the organization of the traditional syndicate, with the methods of the direct action related to the Green movement. It is the professional program of the International Syndicate (IWW). It is related to the movements of the preservation of the traditional skills and knowledge, such as the construction of wooden ships, organic agriculture, etc. They are very active in the movements for return to Earth, as well as in some religious communities (Mennonites and Amish).

Green movement

The Green movement advocates the ecologism, sustainability, non-violence, and social justice. All the programs of the Green parties state **"Ecological wisdom"** as one of its key values. The "Ecological wisdom" originated from the "Deep ecology" and is related to the native religions and cultural customs.

Green anarchism

Green anarchism is the ideology which connects anarchism with the ecological contents, i.e. emphasizes the environmental protection by abolishment of the states and the replacement of them by the anarchistic communities which would be closer to nature. Among the Green anarchists the fraction of so-called "anarcho-primitive followers" think that the technology is the precondition is for the existence of state and environmental pollution, so the technology must be abandoned.

The fraction of so-called "technologically positive green anarchists", who are of the opinion that exactly the technology will enable the creation of anarchist communities in harmony with nature, differ from them. People should increase their distance from nature in order to keep the accessibility to the resources of non-human species. This concept condemn people to life in the urban megapolises in which, in all probability, the "eco-terrorism" will govern, imposed by the governing institutions in the aim of the protection of the remaining "nature oases" (Lewis, M., 1998).

Hypothesis "GAIA"

Within the holistic thought in the 1970s the hypothesis on Earth as the living creature appeared. According to this hypothesis "atmosphere, oceans, climate and Earth crust are adjusted to the condition suitable for life and this condition is the result of the behaviour of living organisms". Hypothesis on Gaia claimed that temperature, oxidation, acidity and certain characteristics of rocks and water are constant and that this homeostasis is preserved in the active processes (based on the feedback) by which biota authomatically governs.

Life and its environment are so closely connected that Gaia actually evolves, not the organisms or environment separately. In this system man is reduced to only one nature species which has no other task but the self-preservation, as other species. "Not only is the planet pulsating with the life, but it seems that it by itself is living creature. All living matter on Earth, together with the atmosphere, ocean, and land, is the complex content which has characteristical patterns of the self-organization. They are in the condition of the chemical and thermodynamic harmony and able to, by the number of processes, regulate the environment so that the optimal conditions for life are ensured. Therefore, Earth is the living composition, not only does it function as the organism, but is, judging from all facts, organism – Gaia, living planet creature" " (Lovelock J., 1972; 2002; 2006)**.**

"What if Mary is another name for Gaia? Then her capacity for virgin birth is no miracle, it is a role of Gaia since life began. She is of this Universe and, conceivably, a part of God. On Earth, she is the source of life everlasting and is alive now; she gave birth to humankind and we are part of her." – Lovelock J. (1972, 2002, 2006).

The new sphere, which is developing and strenghtening - "noosphere" or sphere of "thought" or mind, idea, usable pieces of information, which we call "global brain" (noosphere was terminologically analysed, according to the premises of Vladimir Vernadovski, by Teilhard de Chardin), is added to the Earth spheres. We are increasingly becoming the part of the global network which quickly integrates, as the neuron cells of the "global brain which is awakening" (Rasell, P., 1989).

"Genesis is the integral part of cosmogenesis, it not ends with "the spirit of Earth" or with the global awareness, but it continues to the "Omega point", to the basic super-modern and super-spatial centre of the world which was started and directed by the total evolutionary movement or cosmogenesis, which at the end finishes all the genesis by the unity of the God and the world“ (Rasell, P., 1989). This “Fifth level of evolution“ initiates “new“ ethical questions or brings us back to the “old“ dim memories and knowledge of the “global brain“ which is awakening again.

ECOLOGICAL ETHICS OF HUMAN ATTITUDE TOWARDS ANIMALS

"If the human pain can be expressed as sin, punishment, warning, temptation, atonement, award, these concepts can not be applied for the animals; they are normally not guilty, nor atoned, are not likely to live eternally, but, they still suffer. Why"? (Kolakovski L., 1987).

The ortodox Cartesinas insist that the "animals do not have soul...", which implies that they cannot have any feelings, and, therefore, cannot feel pain.

In the Indian wisdom, there is no sharp border line between man and other creatures.The same soul can subsequently inhabit both animal and human bodies.

The individual differences between animals of the same species have been proved, which makes them similar to man; some are kind and amiable, some selfish and secluded. It is proved that animals can be altruistic, elephants suffer from the syndrom of "broken heart"; young bears which are left alone can scream out of fear or be afraid of their own shadows, the dogs exposed to the electric shock become depressed, helpless, and lethargic. The chimpanzees feel loneliness and mental torture (Masson J., McCarthy S., 1992).

The news that the dog drag away other dog, which was hit by the car, from the road, risking its own life, made the headlines worldwide (December 16th, 2008).

The practical implications of these understandings or norms point to the fact that we should have mininal influence on other species in general (Naess A., 1973).

In many countries the laws on animal protection are adopted. For instance, the Law on Protection of Rights of Primates, was adopted in Spain, and in Serbia the law which treats any kind of animal tortures as the criminal act was adopted, etc.

FINAL DISCUSSIONS

The expectation that by the application of the Kyoto Protocol it is possible to stop or slow down the consequences of the human destruction of nature is not realistic. It is not possible to stop or prevent the ecological catastrophe which can be observed from the everyday metastasis of the climate change. It will be impossible to stop climate change even if all the industrial countries reduce the emission of the pollutants to the greater extent than it is required by the Kyoto Protocol. The return to the previous condition, or the conservation of the current one, is not realistic any longer, which faces us with the dark scenario of the future - destruction of all plant and animal species (including man). Climate change is just the top of the iceberg, and only the most visible manifestation of the human destruction of nature, and simplifies the complex circumstances by which the development of the civilization, has systematically destructed nature environment for centuries.

We witness the decadence of the modern (Western) civilization, but we also witness the birth of the new age - “early stage of the construction of the new model of the world society which will be different from the previous model, and to the extent to which the society originated by the Industrial Revolution differed from the agrarian society which preeceded it“ (King, A. et Schneider, B. , 1991).

The expectation that human awareness in the next ten years or so will evolve to such a great extent that we will due to moral reasons accept the birth control, ascetic way of life (which implies taking only the neccesary elements from nature and environment), moral sense for the needs of other people and other species (which is the basic precondition for the materialisation of the idea of living in the small, ecologically harmonised communities), is UNREAL.

The world is at the beginning of the first global ecological revolution. The ecological revolution will be the brutal clash with the previous social model and will represent the aggressive arrival of the new social model. The climate change, population explosion, reduction of nature resources, consummation (market) way of life, growth of the industrial production, globalisation, environmental pollution and moral indifference assure us that it will happen soon.

By the mottos of the type “what will we leave as the inheritance to our children“ we cannot influence the human conscience. As the solution of the ecological crisis or less painful transition to the new society, the “aggressive“ education of the population and familiarization with the ecological ethics of every individual.

In order to achieve (bring back) the harmony with nature it is needed to find the ways:

1. How to transmit the perennial wisdom to the post-modern society?
2. How to use the knowledge and technology of the post-modern society to the return of the tradition of co-existence with nature?
3. How to integrate the perennial wisdom and post-modern knowledge by creating the new understanding and the practical application of it?

One of the ideas for solution of the above questions is Jung’s concept of “gnostic mediators“ (Walsh, R.,). The gnostic mediators are the people who fill themselves by the wisdom so deeply that they can communicate directly from their experience in language and concepts of some other culture.

The world must avoid the retardation in the fight against the global warning and work of the **“ecological New Deal“** in order to simultaneosly overcome the climate and industrial crisis. We jointly face up with the two crises: in ecology and world economy. They also represent the great opportunity - to simultaneosly tackle with the both challenges“ (Secretary General od the United Nations Ban Ki-Moon – The UN Conference on Ecology, Poznan, Poland).

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ENVIRONMENTAL PROTECTION AND CLIMATE CHANGES

PLENARY LECTURES

MICROCLIMATE CONDITIONS – POSSIBLE LINK OF UNDERSTANDING VULNERABILITY OF FOREST ECOSYSTEMS UNDER CLIMATE CHANGE

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Abstract: *The human influence on the Earth's climate is becoming more and more obvious. Climate observations prove the existence of a global warming trend: global average temperature has increased by 0.8ºC since 1900 and the 12 hottest years observed globally since 1880 all occurred between 1990 and 2005.*

The European heat wave of 2003 was a drastic demonstration of the extent of impacts. Forests are particularly sensitive to climate change, because the long life-span of trees does not allow for rapid adaptation to environmental changes. Associated with climate change there are several factors affecting forest ecosystems, which can act independently or in combination.

Climate variability is particularly important in connection with changes in precipitation, because extreme events such as extended droughts have much more drastic consequences on tree growth and survival than gradual changes in average climate conditions. Because trees are obviously adapting to the local average water availability extreme events cause growth responses across site conditions.

In Serbia observed impacts of climate change is most obvious in increasing of temperature and decreasing of annual precipitation. Those two factors lead to drought which is quite often natural hazard in Serbia with serious damages to national economy, especially to agriculture, forestry and water resources. Dry years were particularly frequent in the last two decades of the 20th century. The annual air temperature trend over Serbia is following the global changes increasing. Effects of increases of temperature and decrease of precipitation will differ with location.

This paper presents the results of measurement of microclimate characteristics in different forest stands in order to collect information about potential vulnerability on climate change.

Key words: microclimate, climate change, forest ecosystems

1. INTRODUCTION

The human influence on the Earth's climate is becoming more and more obvious (Lindner *et al*. 2010). Climate observations prove the existence of a global warming trend: global average temperature has increased by 0.8˚C since 1900 and the 12 hottest years observed globally since 1880 all occurred between 1990 and 2005 (Lindner *et al.* 2010). The European heat wave of 2003 was a drastic demonstration of the extent of impacts (Schar and Jendritzky, 2004; Ciais *et al.*, 2005; Lindner 2010). Forests are particularly sensitive to climate change, because the long life-span of trees does not allow for rapid adaptation to environmental changes. Associated with climate change there are several factors affecting forest ecosystems, which can act independently or in combination.

Available observational evidence indicate that global climate change as a result of natural forcing and human activity are consistent in direction and coherent across diverse localities and

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regions with the expected effects of regional changes in air temperature (IPCC, 2001). Thus, from the observed climate data, there is high confidence that recent regional changes in temperature have had discernible impacts on precipitation, evaporation, streamflow, runoff and other elements of hydrologic cycle, as well as changes in the variability of climate, particularly in the frequency and intensity of some extreme climate phenomena.

Some recent studies have pointed out more frequent and severe drought in the territory of Serbia and in other parts of the Balkan peninsula (Bošnjak, 1997; Dragović, 1997; Jovanović and Popović, 1997; Palfai, 1992; Spasova *et al*., 1997; Spasova *et al.*, 1999; Spasov and Zelenhasić, 1990; Spasov, 1997; Spasov and Spasova, 2001; Stanescu *et al*.,1994, Stojšić and Škorić,1997, Tomov *et al*.,1997). The most severe drought in 2000 with extremely high air temperatures, and without snowcover during winter 2000/2001 were only some of the last in the series of climate extrems in the region of South Europe. In addition to natural climate changes, their basical statistical indicators give clear signals of the existence of human induced climate variations.

Extreme climate events such as spring temperature fluctuations and summer drought will increase in frequency and duration. In combination with a raised mean temperature, climate extremes will negatively affect trees and increase their susceptibility to secondary damage through pests and pathogens. Extreme events are likely to have a profound affect on Europe’s forests and natural resources, for example on boreal (Schlyter *et al.*, 2006), alpine (Fuhrer *et al.*, 2006) and lowland forests (Dorland *et al.*, 1999).

Previous studies have shown that spatial and temporal variations in temperature are significant in differentiating vegetation zones, species composition and populations at large spatial and temporal scales (Wilson 1970, Bergen 1974). Little attention has been paid to small scales, such as the stand and substand levels (Chen & Franklin 1997). Microclimate is the climate in a small space. Data obtained from the network stations can not be applied to the climatic conditions of plants. Observations of temporary or permanent microclimate stations indicate conditions in forest ecosystems. Because the spatial heterogeneity at various scales in ecological system often influences different ecological processes (Pickett & Cadenasso 1995) and because both biotic and abiotic elements of an ecosystem chahge almost countiounsly both in space and in time, we expect that temperature and its variabilty at small scales may be critical some ecological processes in ground flora and forest soil, though probably not to the overstory. Unfortunately, it is not clear how the spatial variation of temperature is related to some ecological phenomena and processes at the stand and substand levels (e.g. species distribution, composition and diversity, ground flora, microorganisms, soil animals and decomposition). We know little about temperature and its variation at these scales.

This paper presents the results of measurement of microclimate characteristics in different forest stands in order to collect information about potential vulnerability on climate change.

2. MATERIAL AND METHODS

Research was conducted in the plantation of *Populus x euramericana* (locality: Experimental field Institute of Lowland Forestry and Environment), in the associations *Fraxineto-Quercetum roboris* (locality: PE Vojvodinasume, Sremska Mitrovica, Morovic) and *Quercetum petrae* (locality: NP Fruska Gora). Data on microclimate indicators were collected by meteorological stations during a year 2009 (temperature, relative humidity), but only the data for August and for the warmest day in the vegetation period were presented.

Climatological data are analyzed on the basis of annual report of Republic Hydrometeorological Service of Serbia.

Analysis of the soil moisture was on the basis of data described by Galic *et al*. (2009).

3. RESULTS AND DISSCUSION

As climate change is a major driver of changes in forest stands, flora and fauna, it needs to be presented at first. Extremely high rising of annual air temperature is registered throughout the entire territory of Serbia (Spasov *et al.* 2001). In northern part of Serbia (Autonomous Province Vojvodina) in last 10 year is registered a higher temperature for 1˚C (table 1). This climate observation proved the existence of warming trend and correlation that the 12 hottest years observed globally since 1880 all occurred between 1990 and 2005 (Lindner et al. 2010).

Table 1. *Increase in monthly mean air temperature (1998-2008) compared to the normal 1960-1991*

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	IV -IX
Kikinda	2.1	0.9	0.8	1.1	1.2	1.6	1.7	1.8	0	1	0.7	-0.1	1.1
Palić	1.9	1.1	0.6	1.1	1.6	2.1	-0.4	2	-0.2	1.1	0.9	-0.2	1.2
Rimski Šančevi	1.6	0.7	0.7	0.9	1.2	1.6	1.5	1.7	0	0.1	0.7	-0.2	1
Sombor	1.9	1.2	0.9	1	1.2	1.7	1.4	1.6	-0.1	1	0.7	-0.1	1.1
Sr. Mitrovica	1.3	0.5	0.6	0.8	1.1	1.4	1.3	1.4	-0.3	1.1	0.6	-0.2	0.9
Zrenjanin	1.8	0.5	0.7	1.4	1.2	1.9	1.8	1.9	0	1.1	1.2	-0.2	1.2
Average	1.7	0.8	0.7	1.0	1.2	1.7	1.2	1.7	-0.1	0.9	0.8	-0.1	1.0

Table 2. *Differences in the amount of rainfall (1998-2008) compared to the normal 1960-1991*

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	IV -IX
Kikinda	-4.5	-3.3	-1.7	4.8	-3.9	-8	22.2	4.7	21.8	7.6	5.8	-5.8	41.6
Palić	-2.9	-5.1	7.8	6.8	7.6	15.7	6.7	1.3	16.9	14	-3.5	-10.5	55.0
RimskiŠančevi	-3.4	-8	-3.3	-0.1	6.1	10.8	11.6	2.4	26.2	17.9	9.3	-1.5	57.0
Sombor	36.1	28.5	39	48.3	52.8	80.4	86.1	60	60.1	48.1	57.1	42.9	387.7
Sr. Mitrovica	-2.8	-9.2	0.2	-3.7	-0.5	0.5	-0.7	3.9	17.6	20.2	4.2	-4.6	17.1
Zrenjanin	-0.7	-3.5	-1.7	-3.7	-11	-8.1	1	-3.2	26.5	7.1	12.8	6.7	1.5
Average	3.6	-0.1	6.7	8.7	8.5	15.2	21.1	11.5	28.1	19.1	14.2	4.5	559.9

The previous research of climatic conditions also showed severe drought (Bošnjak,1997; Dragović,1997; Jovanović and Popović, 1997; Palfai, 1992; Spasova *et al.*,1997; Spasova *et al.*, 1999; Spasov and Zelenhasić, 1990; Spasov, 1997; Spasov and Spasova; 2001; Stanescu *et al.*, 1994; Stojšić and Škorić, 1997; Tomov *et al.*, 1997).

Few aspects, very important for each drought analysis are: time period (duration of drought), possibility (expected frequency of drought phenomenon) and deficit of precipitations (drought intensity).

Only significant rising of summer rains could cover this deficit, which perhaps, regarding to mentioned assessments about precipitation regime in future, can't be expected (chart 1).

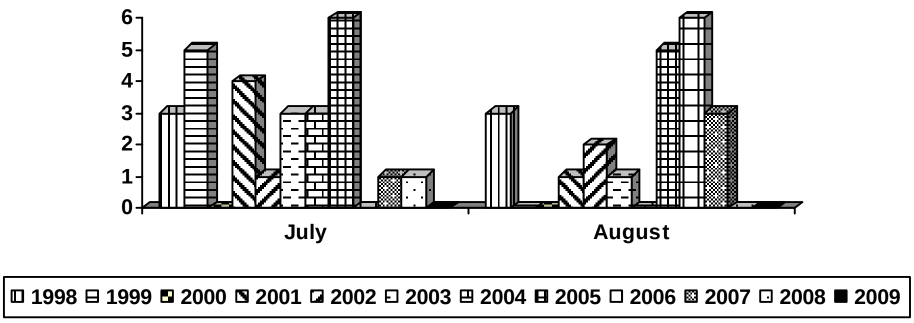


Chart 1. *Number of days with precipitation amounts greater than 10 mm in July and August in period 1998-2009*

Impacts on ecosystem dynamics and functioning do not include the effects of extreme events that are dealt with further. They concern vegetation phenology and distribution, fauna biology and distribution, and finally global productivity.

Air temperature in investigated forest stands during August (2009) are shown on chart 2, 3 and 4.

Chart 2. *Temperature in investigated forest stands during August (7 hours)*

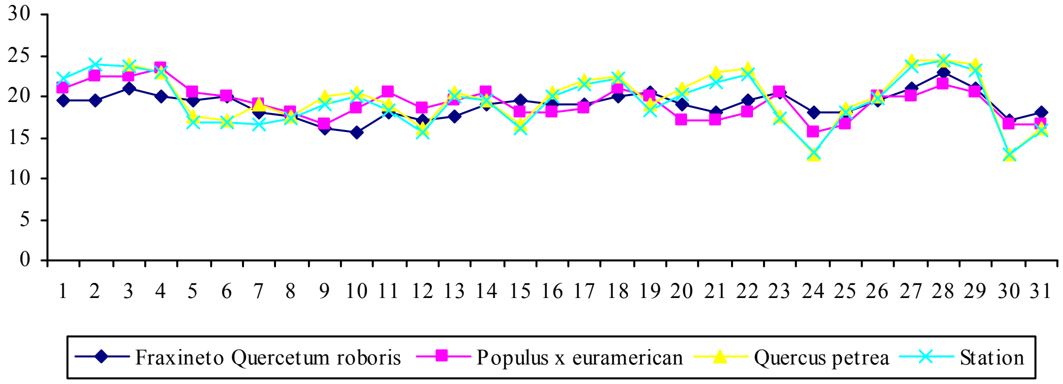


Chart 3. *Temperature in investigated forest stands during August (14 hours)*

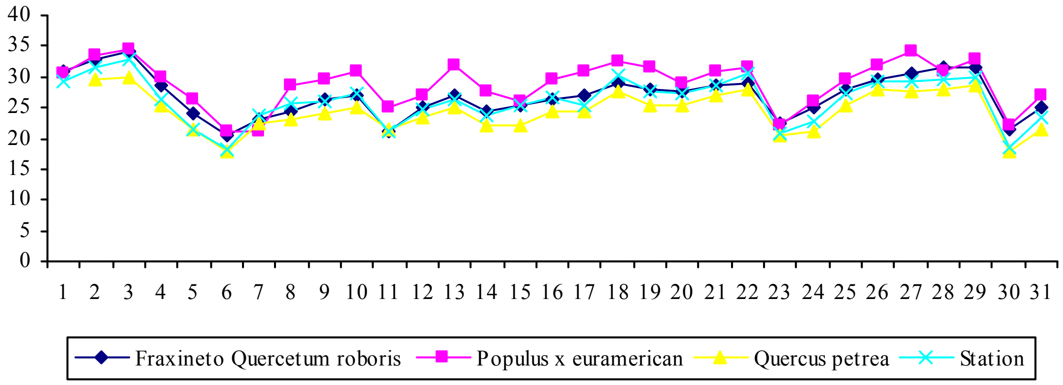
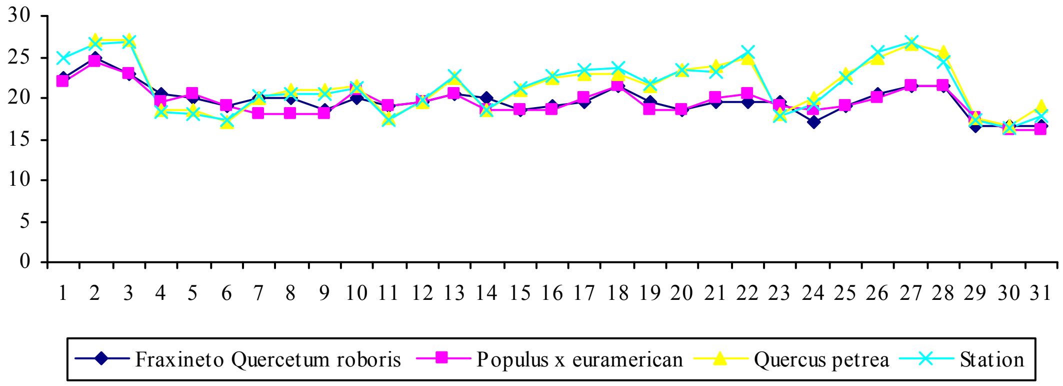
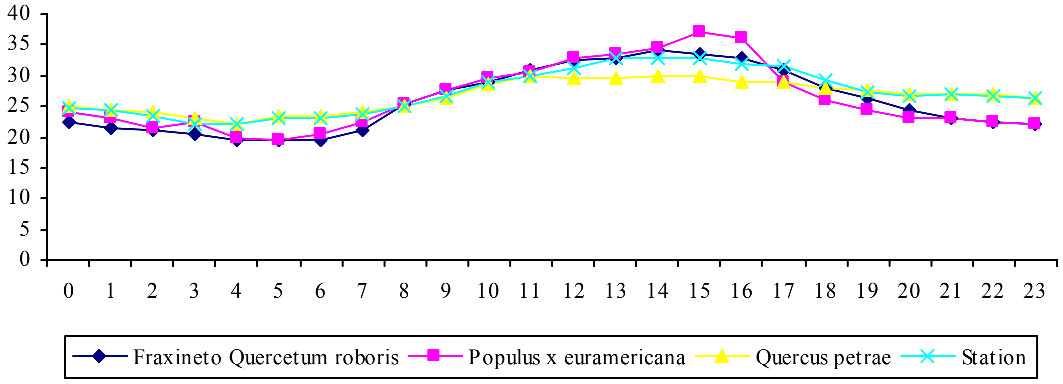


Chart 4. *Temperature in investigated forest stands during August (21 hours)*



Microclimatic conditions during the warmest day of the vegetation period 2009th are shown on chart 5.

Chart 5. *Microclimatic conditions – air temperature during the warmest day of the vegetation period 2009th*



The largest temperature difference was found in the plantation of *Populus x euramericana* of 16.5 ˚C. In the stands *Fraxineto-Quercetum roboris* was determined temperature difference of 14.5 ˚C. The minimum temperature difference is found in sessile oak stands.

Relative humidity in 14 hours during the month of August (Chart 6) and the warmest day of the vegetation period (Chart 7) is shown for stands *Fraxineto-Quercetum roboris*.

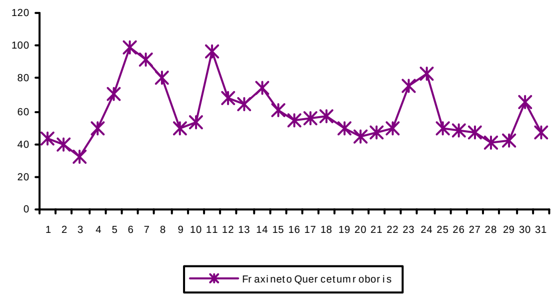


Chart 6. *Relative humidity in the stands Fraxineto Querceto roboris in 14 hours – August*

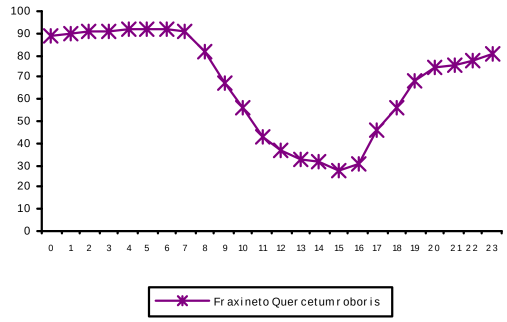
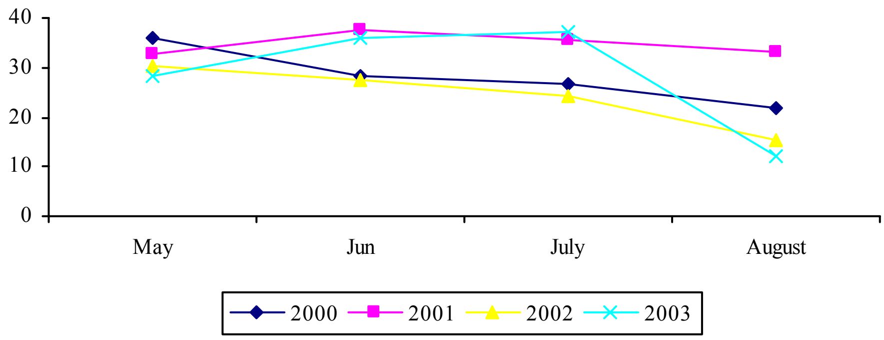


Chart 7. *Relative humidity in the stands Fraxineto Quercetum roboris the hottest day of the vegetation period 2009th*

The analyzed indicators explored in the stands showed different microclimatic regimes. Evident increase in air temperature in the future could possibly lead to even larger oscillations.

Heat waves, like in 2003, can significantly affect the associations, especially if we take into account the available water in the soil. From the above reasons the dynamics of soil moisture data at 70 cm during the four-year period was showed (Chart 8).

Chart 8. *The dynamics of soil moisture in Populus x euramericana the fluvisol f. sandy loam (Galić et al. 2009)*



In this diagram is clearly observed that the heat wave greatly influenced the moisture content in soil. Soil moisture is reduced compared to the period before the heat wave of 26% vol.

4. CONCLUSION

The paper presents data on the characteristics of the microclimate (air temperature and relative humidity of air) and soil moisture in August 2009 in one plantation *P. x euramericana* and two association *Fraxineto Querceto roboris* and *Quercetum petreae*. The deviations in air temperature up to 16.5˚ C has been found in plantation of *Populus x euramericana* to the warmest day in August 2009. The minimum temperature difference is found in sessile oak stands.

The above fact with increasing temperature and decreasing amount of rainfall is likely in the future affect the vulnerabilty of forest ecosystems.

Heat waves further threaten forest ecosystems. The amount of water in the soil can be a month down to 26% vol. (heat wave 2003).

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International Scientific Conference
FOREST ECOSYSTEMS AND CLIMATE CHANGES
March 9-10th, 2010., Institute of Forestry, Belgrade

THE COMPOSTING OF THE PLANT WASTE MATERIAL FOR THE PRODUCTION OF THE ORGANIC FERTILIZERS AND ENVIRONMENTAL PROTECTION

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INTRODUCTION

The disposal of the great quantities of the organic waste, which are created in the households, municipal utility services, industry, forestry and agriculture, is the increasing problem, along with the already known problems such as pollution of air, soil and ground waters.

The history of the creation of the urban waste materials and their regulation can be traced back to the dawn of civilisation and urbanization. In the Neolithic Age, humans started to live in the urban communities, which implied the change of their way of life. The grouping of people is inextricably bound to the waste materials in all forms, both inorganic and organic. Based on the current archaelogical sites, the first pits for the collection of waste materials were found in the Sumerian cities about 6,000 years ago. In addition, the ancient Romans may have been acquainted with the composting. The composting technique was first described by the Roman Markus Porcius Cato, more than 2,000 ago. In the work DE AGRICULTURE he gave recommendations to the farmers and even listed the selection of fertilizers which are good for the agriculture. The ancient civilizations in South America, India and China, where the intensive agriculture was practiced, are known to have been used the agricultural, animal and human waste materials as the fertilizers. These waste materials were disposed in the form of heaps, or placed in the pits, where it rot over a long period and in the end was used for the soil amelioration. In the 13th century the Knights Templar described the composting in a great detail. In the documents, which have been preserved, the techniques which the Knights Templar used to improve the fertility in the arid and the areas with the damaged soil, are described. It is interesting to mention that in these times the people did not have knowledge on the microbiology, or the soil chemistry, but there were detailed and accurate descriptions of the activities, which were aimed at the production of compost, as well as the ways in which it was used for the improvement of soil. During the researches conducted in 1950s, the significant scientific data, which were of great importance to the modern composting, were obtained. The reflections on these problems, or the introduction of changes at the national or global levels, contribute to the mitigation of the above problems.

The organic nutrients, which occur in the form of waste material can become the secondary raw material. As a result, the composting, as the form of the organic nutrient procession, was classified in the group of the research and developmental activities, such as energy, raw materials,

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Note: *This paper is the result of the researches within the project TR - 18201 which is financed by the Ministry of Science and Technological Development of the Republic of Serbia, with the participation of Mining basin "Kolubara".*

environment, and other industrial activities, in the aim of the incorporation of these activities in the program of the recycling of the organic waste materials. Composting was classified in the priority group of the reseaches in the EU member states.

Table 1. *The quantity of organic waste materials which is created in the EU member states, expressed in millions and tons per year*

The source of waste material	Quantity million tons/year
Waste materials originated from households	150
Agricultural and forest waste materials	950
Industrial waste materials	410
Municipal waste materials (leaves, street litter, etc..)	200
Sewage sludge	300

The results of the researches of all relevant aspects of composting in the world, led to the important effors aimed at the mechanisation of the composting processes, particularly in Europe. In almost all West European countries the mechanical methods of composting process were designed and patented. The researches in this area are still underway, and the EU is involved in the financing of the research projects.

Composting

Composting in the widest sense refers to the biological reduction of the organic nutrient in the humus. Whenever the plant ceased to exist in an organized way (living) residues are attacked by the soil microorganisms which are found in the environment. These tiny forms of plant and animal world feed on and digest the complex organic nutrients which are found in manure, agricultural and forest litter and other organic residues and over time form the relatively stable material which resembles humus and is called “compost“, the physical and chemical content of which is favourable for the normal development of plants. This process is a result of joint action of the environmental conditions.

There are three reasons for the the transformation of the fresh organic litter into the compost: in order to prevent the phytotoxicity of the fresh non-stabilizing organic litter; to reduce the presence of agents which are pathogenic to man, animals and plants to the level which do not poses the health risk, and, finally to produce the organic fertilizers or preparations for the soil amelioration, by recycling organic litter and biomass. In regard to the technology, the composting process stops in the phase in which the quantities of the organic nutrients are still relatively high. In other cases, the process will continue, if the environmental conditions permit, until the complete mineralization of the organic nutrients.

The main product – compost, which can be defined as the stabilizing chemical product of composting is useful for the growth of plants. Compost sustained the initial, fast-paced stage of decomposition; stage of stabilizing and the incomplete process of humification.

Materials which can be composed

Lignin – main structural element of plants which is difficult to decompose and decomposes at slowest pace.

Cellulose – the dominant components in the plants. Generally speaking, residues in which the plant remainders are dominant, there is the greatest percentage of cellulose.

Hemicellulose – xylan, pectin and starch are the main ingredients of hemicellulose.

Type and sources of the nutrients

The macronutrients for the microbes are carbon C, nitrogen N, phosphorous P and potassium K. The micronutrients are also present: cobalt Co, manganese Mn, magnesium Mg, copper Cu, and numerous other elements. Calcium Ca belongs to the group which is between macro and micro elements. However, the main role of Ca is its buffer characteristic, i.e. it resists to the change of pH value. Although the nutrient elements can be present in the sufficient concentrations in the waste materials, they are inavailable to the microbes unless they are not in form which be assimilated by the microbes and thereby become useful for them. Certain groups of microbes have the enzyme complex which enables them to attack, decompose and use the organic nutrient, which is present in the fresh litter, since the other groups can use only the productions of decomposition as the source of the nutrient elements. This fact is important since the decomposition, and thereby the composting is the result of the activity of the dynamic succession of different groups of microorganisms, in which one group prepares the ground for the forthcoming group. The other important aspect of the availability of the nutrient elements in the composting refers to the fact that some organic molecules are very resistant, i.e. they resist to the microbial attack, although the microbes have the sufficient enzyme complex. As a result, this material decomposes slowly, even when all other environmental conditions are preserved at the optimal level.

Technology of composting

The technology which is used in the composting has three phases: preparation of the material; the very process of composting and the improvement of the end product.

The *first phase* refers to the preparation of materials for composting which consists of mincing of material and extraction of the undesirable material.

The *second phase* refers to the very process of composting during which some processes are artificially accelerated or stimulating by aeration, turning and mixing, as well as by wetting, if possible.

The *third final phase* among other things refers to the mincing, equalization of product and mixing with other substances.

The duration of the composting process depends on numerous factors, including the material which is used, temperatures, moisture, frequency of aeration and demands of the users. The proper moisture content and C/N ratio, as well as the frequent aeration, are the preconditions for the shortest composting. The conditions which decelerate the process refer to the lack of moisture, high C/N ratio, low temperature, insuffucient aeration, big particles and high percentage of the resistant material (such as wood material). The duration of the process of composting also depends on the planned use of compost. It can be shortened if the fully ripened compost is not needed. For instance, if the compost should be used for the agricultural growing seasons since it will ripe in the fields after some time. On the other hand, if the dry or stabilized-ripe compost is needed, the process is frequently prolonged.

The process of decomposition and stabilization of the material can be completed for few weeks under the favourable conditions. However, this process most frequently lasts for more than two months. Since by the use of some highly mechanized controlled systems the really short periods of composting can be achieved, the period of ripening which lasts from four to eight months, before the compost can be used, is recommended. The Table 2 presents the data on the duration of composting in regard to the selected method and material.

Table 2. *Typical durations of composting for the selected methods and materials*

Method	Material	Active time of composting		Time of ripening
		Range	**Typically**	
Passive composting	Leaves Manure c	2 - 3 years From 6 months to 2 years	2 years 1 year	/ /
Heap- without the frequent turning	Leaves Manure + additives	From 6 months to 1 year 4-6 months	9 months 6 months	4 months 1-2 months
Heap- frequent turning	Manure + additives	1-4 months	2 months	1-2 months
Heap- passive aeration	Manure with layer	10-12 weeks	/	1-2 months
Static heap aerated	Sludge + wood splinters	3-5 weeks	4 weeks	1-2 months
Rotary drum	Sludge or solid residues	3-8 days	/	2 months

The quality of compost

It is hard to define the quality of compost, since the definition has to taken into account many different elements. Some of the most important elements are of the sanitary character and from the domain of environment, since the agronomic quality is neglected. This situation is the result of the fact that the compost is more regarded as the residues, than the quality product for the different and interesting purposes.

In regard to the soil amelioration by using compost, it can be considered as the tool which directly influences the physical, chemical and biological fertility of soil. The stability of compost has an important role in all aspects of the soil fertility. In order to become the subject of the commercial transaction, the compost should have peculiar and stable characteristics, which makes it the product which can be competent with the suitable fertilizers and products aimed at the soil amelioration. There are many barriers which influence the development of real market for the compost. These barriers refer to the negative attitudes towards the compost, the possible presence of the pollutants in the compost, legislation, the question of standard, as well as the questions which refer to the structure of market.

Having all these facts in mind, many world insitutions for the environmental protection, at both national and local levels, in the aim of tackling the problem of progressive decrease of the organic nutrients in the agricultural soil, promote the programs and additionally finance the farmers to start recycling organic nutrients. This attitude should, at least in theory, lead to the wide use of the compost and organic nutrients for the amelioration of agricultural soil. Such attempts give the guidelines to all countries on the ways in which the waste materials can be used, not only in order to reduce the litter and fill the waste disposal sites but to obtain product which is widely-used in agriculture.

FINAL DISCUSSION

The solving of the problem of the organic waste materials of plant origin by composting enables the valuation of the raw material which is the source of problem. In regard to agriculture, if the raw material (residues on the fields) is burnt, the great quantity of energy, which is wasted,is released, and the gases from the combustion have an adverse effect to the atmosphere. These gases are the most frequent source of wildfires, which causes the additional disturbances during the process of waste material disposal. If the biomass is disposed, it occupies the valuable space of the waste disposal sites and by its subsequent processes of decompostion poses the great problems. By the processes of recycling and composting of the biological waste materials, the waste disposal sites release by 40-60% in the volume. The technology of composting is well-developed and enables the dimensioning in regard to the sources of biomass, which is economically profitable.

The greatest advantage of the use of compost in agriculture and forestry refers to the sustainability of this practice. The concept of sustainability must be regarded in the wide sense: activity or system which cannot be viewed separately or in isolation from other activities and systems. The production of compost is the opportunity for the society as a whole to close the cycle of the nutrient elements: compost obtained in the agriculture and forestry must be returned to the soil, since it is the precondition for the sustainable and ecologically responsible management of this material.

The use of compost in agriculture and forestry can be regarded as the sustainable activity, since the following demands are met at the same time:

- should guarantee the environmental protection,
- to enable the preservation of productivity based on the sustainable use,
- prevent the disapperance of non-renewable resources.

The compost is very frequently treated more like the material which should be put away than the resource. Nevertheless, this product should be treated as the good and cheap fertilizer and the tool for the improvement of the soil quality.

The key to the use of compost is the full understanding of the main characteristics, as well as the agronomically assessment of the organic nutrients of the different origin for the improvement of the soil fertility.

By adding the compost to the soil, the physical, chemical and microbial fertility of soil is improved. Many research scientists pointed to the improvement of the structure, water retention and permeability. On the steep terrains it prevents the soil erosion, in the sandy soils it increase the water retention, whereas in the clay soils it prevents the creation of bogs and compaction. At the same time, it prevents the creation of crust on the soil after the rain.

It is more difficult to assess the value of compost than of the mineral fertilizer. Since the release of the nutrient elements is slow, the increase of yield occurs in the subsequent years, so it is hard to estimate the real value of the use of compost.

Due to the physical-chemical characteristics, the compost is the ideal nutritive media for the development of many different microbial groups. The microbial process of composting is very complex since it is characterized by the succession of the microbial associations which alternate as a result of the environmental changes, which are determined by the previous activity. Bacteria, actinomyces and fungi are particularly active during the process of composting.

In spite of the numerous research projects on the compost upressiveness, the general principles of the suppression of the diseases by the use of compost in regard to their quality, are insufficiently studied. Undoubtedly, the adding of the microorganisms to the compost is promising, but the further researches are the preconditions for making the safe assumption that this technology is successful. According to the previous results, the ripened compost with the inoculated anthagonistic microflora gives the best results. No matter whether you have the industrial facility, or the small garden, no matter whether the process of composting takes place in the warm conditions and is fast-paced, or in the cold conditions and at slow rate, the obtaining of the compost always implies the same biological principles. There are different methods of composting, depending on the different conditions or economic possibilities. During the selection of methods of composting the basic conditions of composting must be provided, in order to achieve the efficient and economically justified process of composting, no matter whether the traditional, well-known process of composting is used, or some other method is created.

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BIOMASS – POTENTIAL FOR FUTURE

PLENARY LECTURES

OPPORTUNITIES FOR FOSSIL FUELS AS ENERGY SOURCE PARTIAL SUBSTITUTION BY BIOMASS IN SERBIA – A CONTRIBUTION TO THE GLOBAL CLIMATE CHANGE DECREASE

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Abstract: *The study presents the global world problems and climate changes caused by, inter alia, human activities from the time of industrial revolution to present and, above all, the use of fossil fuels. It points out to the necessity for substitution of a part of fossil fuels by alternative, renewable energy sources, biomass representing a considerable part of which, particularly in Serbia where more than 60% of energy generated from the renewable sources can be produced from biomass. Additionally, the study points to the opportunities of establishing energy plantation of short rotation woody crops for the production of biomass, with a particular attention paid to the crops planted on surface coal mine tailing ponds.*

The key terms: climate changes, GHG gases reduction, substitution of fossil fuels, biomass, short rotation plantations

MOGUĆNOSTI SUPSTITUCIJE DELA FOSILNIH GORIVA U SRBIJI KORIŠĆENJEM BIOMASE ZA ENERGIJU – DOPRINOS SMANJENJU GLOBALNIH KLIMATSKIH PROMENA

Izvod: *U radu su prikazani globalni svetski problemi i klimatske promene izazvane, između ostalog, delatnošću čoveka od industrijske revolucije do danas, pre svega upotrebom fosilnih goriva. Ukazano je na neophodnost zamene dela fosilnih goriva alternativnim, obnovljivim izvorima energije, u čemu korišćenje biomase ima značajan udeo, posebno u Srbiji gde preko 60% energije dobijene iz obnovljivih izvora može da se proizvede iz biomase. Takođe je ukazano na mogućnost osnivanja energetskih plantaža drvenastih vrsta kratke ophodnje za proizvodnju biomase, sa posebnim osvrtom na ovakve zasade osnovane na odlagalištima jalovine površinskih kopova uglja.*

Ključne reči: klimatske promene, redukcija GHG gasova, supstitucija fosilnih goriva, biomasa, plantaže kratke ophodnje

1. CLIMATE CHANGES

Global warming, climate changes, the earth pollution reduction and renewable fuels are global issues number one.

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Note: *This paper is the result of the researches within the project TR - 18201 which is financed by the Ministry of Science and Technological Development of the Republic of Serbia, with the participation of Mining basin "Kolubara".*

The effects of global warming can be felt today. This year the North Pole can be circumnavigated for the first time since the measurement began. The ice sheets are breaking off, the sea level is rising, droughts are destroying forests, deserts are expanding and from the all sides of the planet one can hear alternating news about catastrophic floods, hurricanes and droughts.

The complete eco systems are endangered, even the rain forests of the Amazon, the centuries lasting lungs of the planet. The snow from the summits of Kilimanjaro has melted for the first time. Maldives fear global warming most, since this island country is only two metres above the sea level on average and, unless something has been done urgently, it will vanish. Many island and coastal towns will follow. The Intergovernmental Panel on Climate Changes (IPCC), the supreme UN body in this area has calculated that food production will decrease for 40% by 2100, in case that climate changes continue to progress at this rate. Global warming is melting icebergs in Greenland and Antarctic, causing the sea level rise. The warmer climate can release millions of tonnes of methane from thefor centuries frozen layers of the earth. Furthermore, the forest destruction can greatly contribute to the creation of a greenhouse effect.

World scientists have agreed that global warming must be stopped, since only two degrees Celsius is the top limit that must not be exceeded. In order to accomplish that, by 2050., the emission of greenhouse effect gases (GHG) must be reduced for at least 80 percent in the comparison with the level in 1990., the year which is under the Kyoto Protocol the base year for greenhouse gas measuring.

Although there are different interpretation of the causes of the global climate change, a few key trends show that the global warming was induced by (and) human activities and that it is still in progress.

First of all, the global emission of carbon dioxide (CO_2), which originates from fossil fuel burning, has increased since the industrial revolution and continues to grow.

According to the Intergovernmental Panel on Climate Changes (IPCC), the concentration of carbon dioxide has been increased for 31% since 1750. and the global temperature has risen and continues to rise, as a result of increased emission of CO_2.

The Nature still manages to absorb the half of carbon dioxide which people produce, but the other half remains in the atmosphere. The remaining part must be taken care of by humans.

In the previous century the earth temperature was increased for about 0,74ºC, and the highest increase took place after 1970. The concentration of CO_2 in the air is now nearly 40 per cent higher than it was 200 years ago, and the emission was increased by two per cent per year in the last decade. The dramatic warnings were given in the last Intergovernmental Panel on Climate Changes Report in 2007. – unless the GHG emission is reduced, the average temperature will increase from 2 to 4.5 degrees Celsius by the end of this century. The warming will be even more drastic on land, particularly in the central part of the continent, as well as in the polar areas. We have been warned against more extreme climate – more frequent and destructive storms and hurricanes. The humid areas will have even more water, and drought areas will have less water. Draughts will be more frequent, intensive and they will cover larger areas. Melting of icebergs will raise the sea level.

More than one metre rise of the sea level can be expected by 2100, which would result in at least 100 million people from Asia losing their homes. 14 million Europeans and eight million people from Africa and the same number of people in the South America would face the same fate.

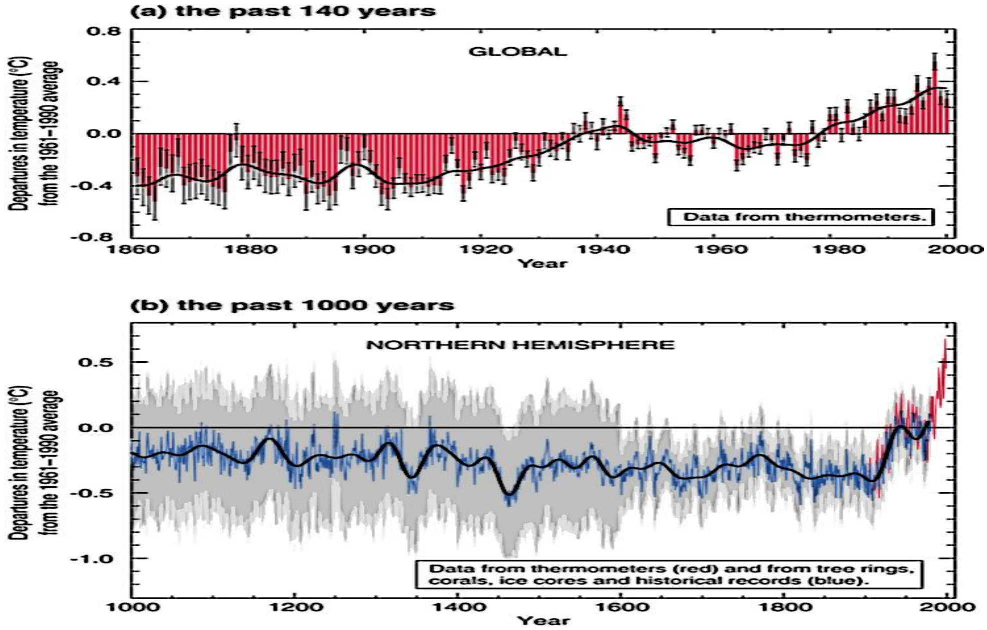
The Mediterranean, Middle East, central Asia and south Africa could expect less rain and a fissure of icy surface of Greenland and part of Antarctic is predicted.

In case that rain forests of Amazon disappear due to droughts and fire, additional amounts of CO_2 would be released, further planet warming increase would occur, which would endanger other forest areas and biodiversity which is already shaken today.

The release of billion of tonnes of methane locked in permafrost, the layer of, for centuries, frozen soil, would follow. The warming would disturb the regular flow of ocean currents, above all the Gulf stream, which would significantly reduce temperature in Europe and decrease the number of Asian monsoons, which are the largest source of water in the most populated continent.

The temperature increase in 20th century has been the higher than in any other century in the last 10,000 years. The link between the temperature increase and the increase of CO_2 concentration is clearly visible in the following graphs.

Graph.1. *Variations of earth surface temperature*

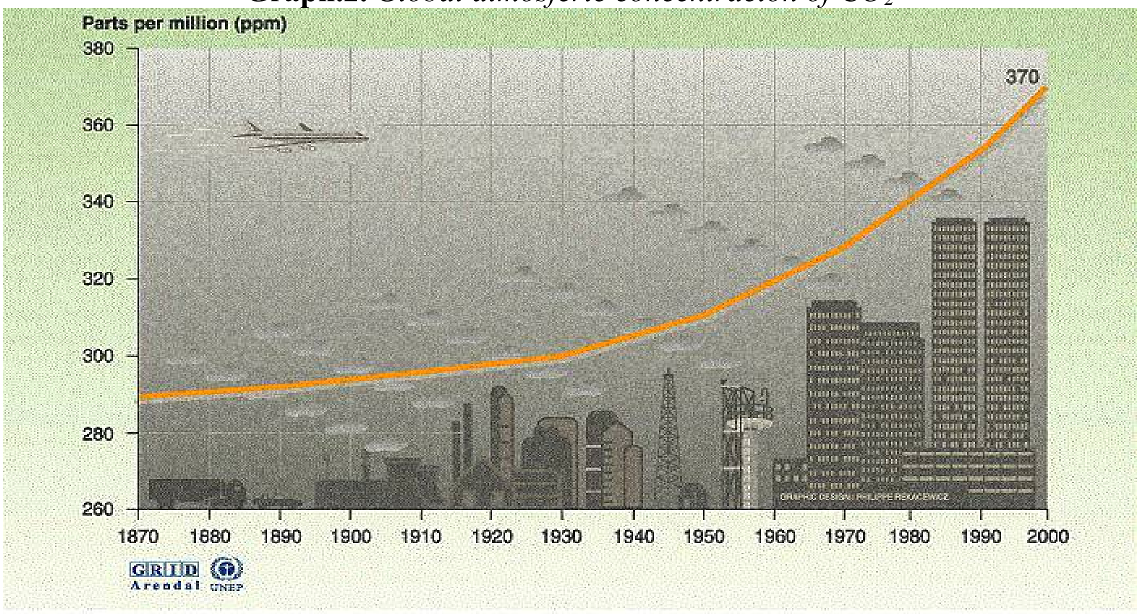


2.1. The short chronological evidence of CO_2 concentration increase

- Even since 1863. has been known that atmospheric CO_2 affects the earth temperature increase;
- 1865: It was scientifically confirmed for the first time that gases such as CO_2, when evaporating, warm the atmosphere;
- 1896: The term "greenhouse effect" was coined by the scientist Svante Arrhenius in 1896, who pointed to the fact that the fossil fuels burning could increase the CO_2 level in the atmosphere and earth temperature for a few degrees;
- 1958: The first continuous measurement was started which established the understanding of the rapid growth of CO_2 concentration in the air;
- 1970: The increase of the atmosphere temperature was officially named "global warming"
- 1988: The Intergovernmental Panel on Climate Changes (IPCC) was established in order to observe what happened to the planet.
- 1990: The first IPCC report was released containing future emission projections
- 1992: The Earth Summit on climate changes in Rio de Janeiro, which adopted The Framework Convention on Climate Change (UNFCCC), whose aim was to help global warming prevention.
- 1995: After a heated debate, with OPEC countries in particular, IPCC established a stronger link between GHG and climate changes. It was announced that the human kind is the main culprit responsible for global warming.
- 1997: The Kyoto Protocol was adopted, which for the first time involved the concrete obligations for the developed countries concerning the decrease of GHG emission
- 1998: It had been the warmest year in the warmest decade in last one hundred years

- 2001: The countries ratified The Kyoto Protocol. Only the USA and Australia refused to ratify.
- 2003: The heat wave in Europe left 30,000 people dead. The scientist later named these heats the first extreme weather conditions induced by human influence on climate.
- 2005: The European Commission published its thematic Strategy on Air Pollution which planned to reduce the number of premature deaths caused by pollution by 40 per cent by 2020.

Graph.2. *Global atmosferic concentracion of CO_2*



Sources: TP Whorf Scripps, Mauna Loa Observatory, Hawaii, Institution of oceanography (SIO), university of California La Jolla, California, United States, 1999

- 2007: Massive ice sheet broke off in Arctic. IPCC report revealed concern about rapid climate change
- 2007: The United Nation conference on climate change was held in Indonesia, at which the future of Kyoto Protocol was discussed;
- 2008: The Climate conference in Poznan, slow negotiation process. The USA position awaited.
- 2009: The Conference in Copenhagen (KO15):
- 2010: A new conference on climate changes was scheduled in Mexico.

2.2. The point of no return

The scientist have defined the moment of "the point of no return" – at which the concentration of CO_2 is such that catastrophic consequences for environment and the life on earth itself, cannot be stopped. Current concentration of CO_2 is approximately 385 ppm. With other greenhouse gases it reaches 462 ppm and constantly increases. Assuming that the increase continues at this rate, the level of CO_2 will reach 556ppm in 40 years.

Permafrost contains locked CO_2 and CH_4 in the amounts higher than we have in the atmosphere now. The research showed that 50% increased amount of CO_2 (approximately 550ppm) would lead to reduction of permanently frozen areas to one third. In order to avoid that, the level of CO_2 must be kept at far lower level than 450ppm.

The CO_2 concentration of 800-1000ppm would lead to the total disappearance of glaciers, the rise of sea level from 24 to 75m, the process of desertification of one third of the earth, droughts on one half of the earth. The above mentioned processes would further induce the disappearance of 70% of all species, as well as extreme acidification of the ocean.

The catastrophic consequences of the above mentioned scenario indicate that we must act urgently and energetically. The steps that mankind takes in the following years will determine the future of our planet and ourselves. The global GHG emission must have its peak and reduction in the following 10-15 years.

The decrease of gas emission is a major, but not the only remedy. The amounts of these polluters must be restored to the preindustrial level, and new mass afforestation, use of renewable sources of energy, energy efficiency, recycling, use of clean technologies must be initiated. Forest destruction which has taken place until now is responsible for one fifth of total emission of all GHG.

The pollution peak is expected in 2015., after which a forecast is a drop and restoring within tolerant limits by the end of this century.

The action must be the most serious in the industrial countries, and it is necessary to involve new industrial countries (Malaysia, South Korea, Saudi Arabia, Singapore) and the intensively developing countries (China, Brazil, India, Indonesia, South Africa and Mexico).

By 2020., the developed countries ought to reduce emission from 25 to 40 per cent in comparison with 1990. Norway is beyond the others in adhering to the agreed, with the intention to reduce gas emission by 40 percent, followed by Japan and EU countries which decided to achieve 30 per cent decrease. The US administration announced that it intended to restore the pollution level to the one in 1990., and than to gradually reduce it bellow that level. Canada promised to fulfil what was agreed in Kyoto Protocol.

2.3. The Kyoto Protocol and its mechanisms

United Nations Framework Convention on Climate Change – UNFCC and its Kyoto Protocol provide international framework for the combat against climate changes.

UNFCCC was adopted in 1992. and came into effect in March 1994. It binds all the countries signatories to define and establish national programmes for reduction of greenhouse gases. The signatories also bound to submit regular reports, and highly developed countries (not including developing countries) to restore their greenhouse gas emissions to the level in 1990. by 2000.

The Kyoto Protocol is an addition to the international agreement on climate changes, signed with the aim to reduce carbon dioxide and other greenhouse effect gases emission. The Protocol was open for signing in a Japanese city of Kyoto, at the Third Conference UNFCCC signatories, on 11th December 1997. The Protocol had been open for signing for one year, from March 1998. It was decided that it should come into effect within 90 days after being ratified by at least 55 Convention participants, including developed countries, which account for at least 55% of the total CO_2 emission in 1990. The EU and its member states ratified Kyoto Protocol in May 2002. The Protocol was signed by 184 countries, and it came into effect on 16th February 2005., when it was ratified by Russia. Only three countries involved in the Protocol did not ratify it (Australia, Monaco and the USA). The countries which ratified the Protocol account for 61% per cent of emission.

Serbia adopted the Kyoto Protocol on 24th September 2007.

Under the Kyoto Protocol, developed countries bound to reduce collectively the emission of six key greenhouse gases for at least 5 %. Each country individually bound to achieve this goal by period 2008/2012., which will be calculated as an average over five years, and the progress had to be visible by 2005. The reduction of the three most important gases (carbon dioxide, methane and nitrous oxide) will be measured against the base year 1990., while the reduction of industrial gases (hydro fluorocarbon (HFCs) perfluorocarbon (PFCs) sulphur hexafluoride (SF6)) will be measured against base year 1990. or 1995.

Within the Kyoto Protocol framework, the EU bound to reduce greenhouse gases emission by 8% in the first commitment period (2008/2012). 15 EU member countries bound to achieve this goal in the moment of ratification in May 2002. Out of 10 new EU countries, eight have individual goals concerning reduction, ranging from 6% to 8%. Only Cyprus and Malta were not included in Kyoto Protocol Annex 1. In February 2005., a set of strategy elements for the period after 2012. was adopted.

Total of 37 most developed countries bound to reduce emission of harmful gases by five per cent in relation to the 1990 level.

The realisation of the Kyoto Protocol requires a large amount of money and the rich will have to help the poor, but this is the only way to save the earth. According to the Kyoto Protocol, the 48 richest countries bound to help the others. Some studies show that the reduction of GHG gases by 35 per cent by 2030., in relation to 1990. would cost annually between 250 and 300 billion dollars. The funds would have to be invested in reduction of fossil fuel use, larger use of renewable sources of energy, increase of energy efficiency, afforestation and protection of large ecosystems. Since 2030. one third of the energy should be generated from renewable sources.

The period in which these obligations should be met is between 2008. and 2012.

The Kyoto meeting showed that the world leaders understood how important the global warming issue was. The Kyoto Protocol conclusions represent a framework for all other negotiations. The pollution levels for each country were determined and, related to that, the objectives that ought to be met. Different obligations were assumed by the rich, the developing countries and the poorest.

Some countries have seriously understood their obligations and immediately started to act. The European Commission has announced that the EU had nearly fulfilled the promises given in Kyoto. But there are those who have not done much. Canada, for instance, has the emission higher by 25 per cent in comparison with 1990, and its goal is to reduce it by 6 per cent.

The Protocol involves emission reduction of, above all, six gases causing the greenhouse effect: carbon dioxide, methane, nitrous oxide, hydro fluorocarbon, perfluorocarbon and sulphur hexafluoride.

Table 1. *Sources and the concentration increase of the main greenhouse gases compared with preindustrial period*

Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)***	Anthropogenic sources	Global warming potential (GWP) *
Carbon-dioxide	CO_2	278 000 ppbv	358 000 ppbv	Variable	Fossil fuel combustion Land use conversion Cement production	1
Methane	CH_4	700 ppbv	1721 ppbv	12,2 +/- 3	Fossil fuels Rice paddies Waste dumps Livestock	21 **
Nitrous oxide	N_2O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion	310
CFC-12	CCl_2F_2	0	0,503 ppbv	102	Liquid coolants. Foams	6200-7100 ****
HCFC-22	$CHClF_2$	0	0,105 ppbv	12,1	Liquid coolants	1300-1400 ****
Perfluoromethane	CF_4	0	0,070 ppbv	50 000	Production of aluminium	6 500
Sulphur hexa-fluoride	SF_6	0	0,032 ppbv	3 200	Dielectric fluid	23 900

Note : pptv= 1 part per trillion by volume; ppbv= 1 part per billion by volume, ppm v= 1 part per million by volume

* GWP for 100 year time horizon. ** Includes indirect effects of tropospheric ozone production and stratospheric water vapour production. *** On page 15 of the IPCC SAR. No single lifetime for CO_2 can be defined because of the different rates of uptake by different sink processes. **** Net global warming potential (i.e., including the indirect effect due to ozone depletion).

GRID Arendal UNEP

Source: IPCC radiative forcing report ; Climate change 1995, The science of climate change, contribution of working groupe 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

The United Nation Conference on Climate Changes was held in Indonesia in 2007. at which the future of Kyoto Protocol was discussed which was continued in 2009. in Copenhagen.

2.4. Copenhagen, 2009: The Conference of the Parties UNFCCC (KOP15)

Towards the end of last year, after two week conference at the highest level, the agreement was reached – ’Copenhagen Accord’.

The essence of the agreement reached was the reduction of the amount of CO_2 which is emitted in the atmoshpere, followed by the issue of transparency of achieving that goal and finally the issues of funding the expenses incurred by the reduction, primarily in the developing countries.

'The countries Conference participants promised to limit the global increase of temperature to two degrees Celsius' but this statement did not have a form of a legally binding document.

The Accord included 12 Clauses in which developed countries defined their climate objectives.

EU will reduce by 30% the amount of greenhouse gases emitted into the atmosphere by 2020. compared to the base year 1990;
Japan announced 25% reduction;

The USA announced the reduction of CO_2 amount from 14 to 17 per cent by 2020. compared with 2005;

China promised reduction between 40 and 50 per cent in comparison with the period of its intensive economic growth;

It was agreed that the rich countries provide help to the poor countries in their combat against climate changes with 30 billion dollars by 2012., and from 2020. with the total of 100 billion dollars.

It was decided that the next summite on climate would be held in one year time in Mexico.

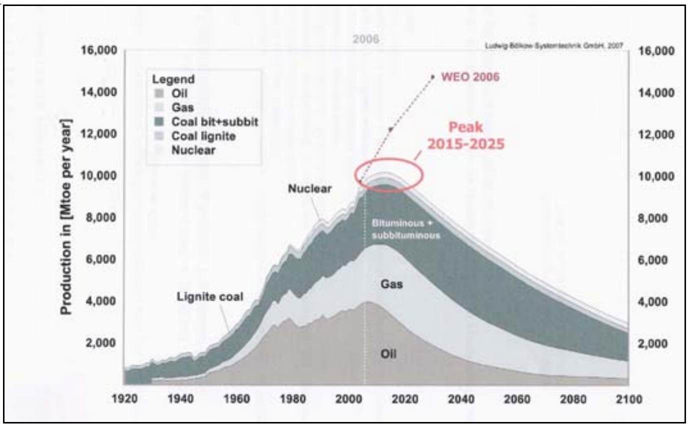
3. WORLD ENERGY NEEDS

It has been estimated that the current world needs for the primary energy are at the level of approximately 12,000 Mtoe (MT oil equivalents), out of which fossil fuels (oil, gas, coal) account for 80%.

The rest is generated from other sources, such as hydroelectric power plants, nuclear plants and renewable energy sources (wind, the sun, biomass, etc).

Considering the estimated reserves, fossil fuels will reach its maximum consumption in the 40’s of this century. In order to ensure estimated energy needs, it will be necessary to intensify the use of other sources, which are primarily, in addition to nuclear and hydro potentials, renewable sources. According to the WEO analyses, the uranium reserves are being exhausted rapidly, therefore they will be sufficient to satisfy the needs by the mid of the century only, as it can be seen from the following graph:

Graph. 2. *Scenario – Fossil and Nuclear Fuels and WEO 2006*



Other renewable sources of energy remain, whose only source is the sun and the gravity forces and the earth rotation. Solar energy can be transformed into thermal and electric energy or wind, wave, water flow energy and, most importantly, it is accumulated in biomass.

4. THE WORLD USE OF RENEWABLE ENERGY SOURCES SCENARIO

The forecasts show that the world population will reach 10 – 12 billion by the end of this century, which will entail new amounts of energy.

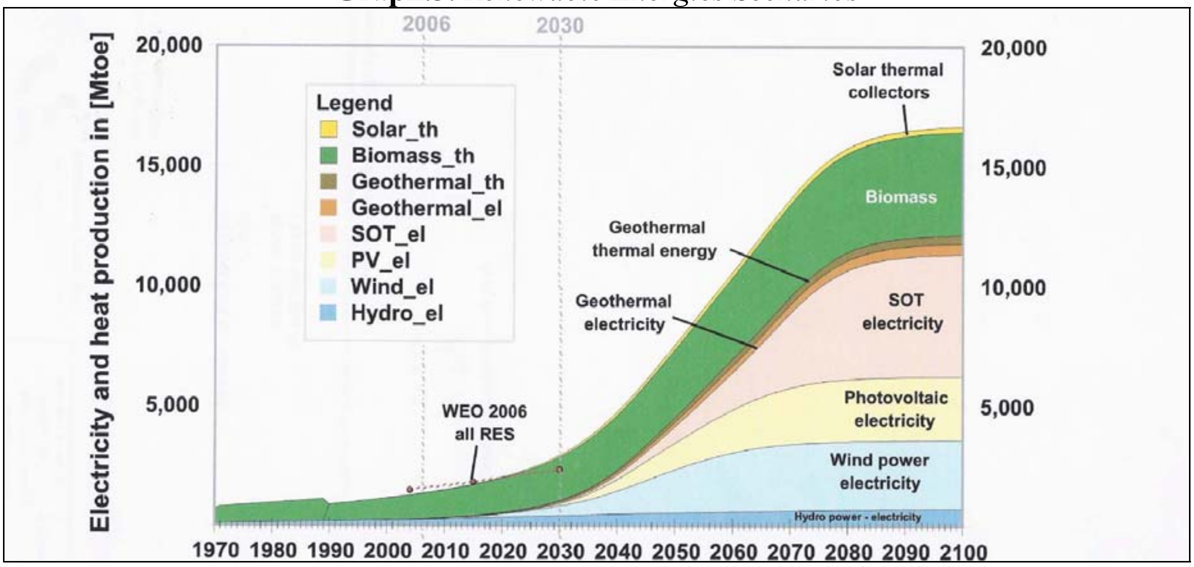
Considering the level of exhaustion of certain energy sources, the increased environment pollution and climate changes, as well as the fact that the new technological processes considerably advance the procedures in use of renewable sources of energy, it is clear that this is the potential key for resolving world energy problems.

Apart from the problems concerning the environment pollution, the fact is that the amount of fossil fuels is limited. The use of fossil fuels has always, even today, provoked economic and political tensions.

A number of minor and major global crisis have been provoked by the dependence on the countries in which fossil fuel sources are located (1956, 1970., 1999.,2003.,…)

The facts stated above show that the energy problem will become even more relevant in near future. The increased needs for all forms of energy impose the necessity of creating strategies which will ensure sufficient amounts of energy, while generating the least possible environment pollution, satisfying the needs of the entire population.

Graph.3. *Renewable Energies Scenarios*



Source: Ludwig-Bolkow-Systemtechnik GmbH, 2007.

It has been estimated that the use of renewable sources will experience its first period of expansion at the beginning of 30's of this century and from that time on it will continue to grow. With 2500Mtoe in 2030. the share of renewable sources of energy will increase to 16,000 Mtoe, while fossil fuels and nuclear energy will meet only approximately 20% of world needs. That means that situation will be reverse in comparison to present situation.

5. EU ENERGY POLICY

The EU itself is a large energy importer today, since 80% of its needs are satisfied from import. For the purpose of decreasing import dependence, environment protection and rational use of energy, the EU implemented a long term programme of energy development and, at the same time, alleviating climate changes. In planning the use of renewable sources and environmentally neutral technologies, it has made the most advanced steps. The EU goals by 2020. ('3 x 20') could be shortly reduced to:

- 20% reduction of greenhouse gases emission by 2020;
- 20% share of renewable sources of energy in gross immediate consumption by 2020;
- 10% share of renewable sources in all forms of transport by 2020. as a substitute for traditional fuels;
- 9% decrease of immediate energy consumption by 2016. by implementation of energy efficiency measures, that is, better use of energy;

For the purpose of realization of outlined programme, the EU has adopted a number of directives which bind member countries to implement the adopted strategies. Some of more important directives are:

- Directive on activity levels of new central heating boilers using oil and gas
- Directive on use of renewable sources for the production of electric and thermal energy
- Directive on reduction of energy consumption in buildings
- Directive on promoting use of biofuel and other renewable sources in transport
- Directive on introduction of eco design for products using energy
- Directive on promotion of rational use of energy
- Directive on promoting minimum efficiency requirements for mass consumption goods
- Directive on promoting use of co-generation, heat increaser for family houses and tertial sector

Among the stated directives, particular importance was placed on the Directive on Renewable Sources of Energy (Directive 2001/77/EC of the European Parliament and of the Council on the promotion of electricity produced from renewable energy sources in the internal electricity market) adopted back on 27th September 2001. with the aim to encourage wider use of electric energy from renewable sources. Not later than on 27th October 2002. and every five following years, member countries are obliged to adopt and make available to the public a report on national objectives concerning planned use of electric energy from renewable sources. These objectives ought to be compatible with the accepted obligations in context of climate changes under the Kyoto Protocol.

Particular importance is attached to 'The White paper on renewable sources of energy' - COM(97)599 final-(Energy for future: Renewable sources of energy, strategy and action plan), which the European Commission adopted in 1997. and which planned the total financial investments in order to achieve established objectives in the amount of 165 billion ECU for the period 1997-2010. The White paper expects biomass having the largest share among renewable sources of energy (90Mtoe), that is, tripling its share. Wind energy takes the second position with 40GW share. The increase of solar thermal collectors is significant (with share of 100 billion m^2 installed by 2010). Smaller contribution is made by use of PV (3 GWp), geothermal energy (1Gwe I 2,5 GWth). Hydro energy will probably remain second most important renewable resource, but having relatively small increase (13 GW), will maintain its total contribution at present level. Finally, passive solar energy will have the most important contribution in reducing energy for cooling and heating houses. Realistic contribution of 10% in this sector will present fuel save of 35Mtoe. Doubling the current electric and thermal energy from renewable sources plus significant increase of biofuel in transport by 2010. is an important element of EU scenario in this area.

6. NON-RENEWABLE ENERGY SOURCES: RENEWABLE ENERGY SOURCES

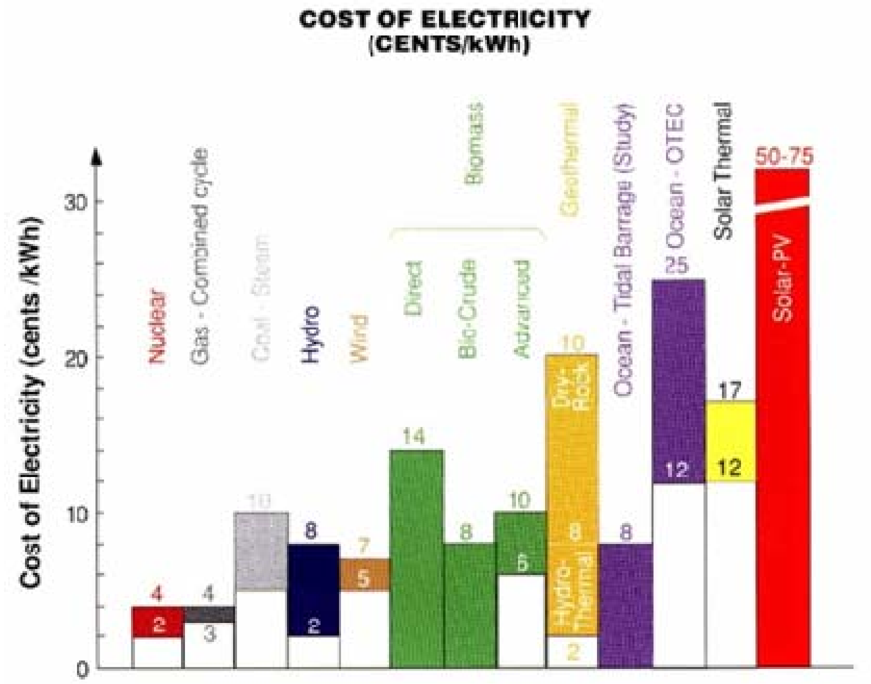
6.1. Non-renewable energy sources

Renewable energy sources present significant potential for future, but due to the relatively limited opportunities and costs, a certain period will have to pass before such energy sources are used more extensively. Until that time we have to rely on non-renewable sources of energy. They are: nuclear energy, coal, oil and natural gas. Coal, oil and natural gas are also known as fossil fuels. The name itself illustrates their origin. Millions of years ago remains of plants and animals began to deposit on the ocean bed or soil. By the time, these remains were covered by layers of mud, slime and sand. In these conditions extremely high temperatures and pressures developed, which presented ideal conditions for transforming plant and animal remains into fossil fuel.

The main energy source of fossil fuels is carbon (C) and their (fossil fuels) combustion releases large amounts of CO_2 into the atmosphere, which is the main problem of fossil fuels use from the environmental point of view. The last 150 years have been the period of increasing use of fossil fuels. At the beginning, coal was most used, which is also the most dangerous form of non-renewable fossil fuels since, together with the CO_2, it also releases sulphur into the atmosphere, as well as some other substances. Sulphur combines with vapour in the atmosphere and makes sulphuric acid, which falls on the soil in the form of acid rains. The problem of acid rains was most serious in the USA and Canada, but European countries also faced the same problem. Germany and the UK experienced most problems compared to other European countries.

Nuclear plants do not release CO_2, but after its use, nuclear fuel is extremely radioactive and it must be stored for tens and hundreds of years in secure concrete pools or underground bunkers. In normal circumstances, nuclear energy is a very clean source of energy, but the potential danger of accidents caused by damage is ever decreasing the number of newly installed nuclear plants. The fear of accidents was additionally increased by two, until now, largest nuclear accidents: Three Miles Island in 1979 and Chernobyl in 1986.

Graph.4. *Electricity production costs from some primary sources - 1998 (ABB: Renewable Energy, Status and Prospects, 1998)*



6.2. Renewable Energy Sources

Renewable energy sources can be divided into two main categories: traditional renewable energy sources (biomass and large hydroelectric power plants), and so called “new renewable energy sources” (solar energy, wind energy, geothermal energy, etc).

According to the data from 2006, 18% of the total energy in the world was generated from renewable energy sources, but the main part of it was generated by traditional use of biomass for cooking and heating – 13-18%.

Large hydroelectric power plants produce additional 3% of the energy.

Therefore, it is easy to calculate that, without traditional renewable energy sources, so called ‘new energy sources’ produce only 2.4% of the total world energy. 1.3 % refers to water heating installation, 0.8% production of electricity and 0.3% refers to biofuels.

That share should be significantly increased, since the non- renewable energy sources are diminishing, and their harmful effect is more and more apparent.

The largest source of renewable energy is the sun, whose radiation comes to earth and there transforms into other forms of renewable energy, such as wind energy, hydro energy, bio mass, wave energy and other. Annual radiation energy of 120 000 TW is 7 500 times larger than total world energy needs.

It is evident from the above mentioned that renewable energy sources can and must be better exploited and that there is no need for concern about the period when fossil fuel sources are exhausted.

The development of renewable energy sources (wind, water, sun and biomass in particular) is important for few reasons:

- renewable energy sources play very important role in the reduction of carbon dioxide (CO_2) emission into the atmosphere;
- increase of renewable energy sources share enhances energy sustainability, helps improvement of regular provision of energy in a manner which decreases dependence on imported energy raw materials and electric energy.
- it is expected that renewable energy sources will become economically competitive with the conventional energy sources within mid to long term period.

Few technologies, wind energy in particular, small hydroelectric water plants, biomass energy and sun energy are becoming economically competitive even today. The main problem concerning installation of new plants is the starting costs. That factor raises the cost of produced energy in first few years in comparison with other commercially available energy sources.

7. BIO ENERGY

7.1. Biomass

Biomass is in fact abbreviated form of biological mass. It is a renewable energy source and it includes many products of plant and animal origin. It refers to live or, until recently live, matter of plant or animal origin, which can be used as fuel or for industrial production. It is most frequently used in final energy consumption for heating and cooking, but it can be used also for electric energy and heat production, and, increasingly, for the biomass production. Fermentation into alcohol is presently the most developed method of chemical conversion of biomass. Biogas produced by fermentation without presence of oxygen contains methane and carbon and can be used as fuel, while other contemporary methods of biomass energy use include pyrolisis, dispersion and production of hydrogen. Additionally, it can be used in industry for fibre and chemicals production.

Biomass, according to its origin, can be divided into following forms:

- woody biomass
- purpose grown woody biomass (fast growing trees)
- purpose grown non-woody biomass (fast growing algae and grass)
- agricultural remains and waste
- animal remains and waste
- waste biomass

Biomass can substitute successfully non-renewable energy sources such as oil, gas and coal, while the energy generated from biomass products is approximately equal to the energy generated from coal and it can be even higher.

This form of energy plays particularly important role in undeveloped parts of the world and it has been estimated that it represents the primary energy source for approximately 2.4 billion people. (IEA,1998). In the developed part of the world reasons for use of renewable energy sources lie in the need for use of environmentally friendly energy sources as well as in the need for the higher energy independence.

The share of woody biomass in global energy consumption is estimated at 14%, which is very close to the share of electric energy (15%) and gas (16%) (IEA 2003).

The main advantage of biomass over fossil fuels is smaller emission of harmful gases and waste water. Additional advantage is use of agricultural, forestry and wood industry remains and waste, reduction of energy products import, investment in agriculture and undeveloped areas and increased energy supply security.

It has been forecast that the share of biomass in the world energy consumption will account for 30 and 40 per cent by mid of this century. Sweden, for instance, generated 18% of energy from biomass even in 1998. and Finland 10%. According to EU documents, it has been estimated that biomass energy production will account for 73% of total renewable energy sources production. For instance, Ukraine even today has the capacities of 320MW for biomass electricity production.

Biomass includes different types of waste, of plant and animal origin, such as cornstaks, fruit pits, manure but also different types of industrial waste.

About 110 tonnes of manure and 250 tonnes of corn stalks per year suffice for production of 8 million kW h electricity, which saves about 16,000 tonnes of lignite and does not produce a large amount of harmful ash. Even remains from biogas production are not wasted, but they are used as biofertiliser, and apart from this derivative, it is also possible to produce biodisel from rape plant. There are biomass plants which provide electricity, heat and biofertilisers for hundreds of households.

One and a half cubic metre of biogas equals one cubic metre of natural gas, which is imported. One hectar of corn silage is sufficient for production of 10,000 cubic metres of biogas, which produces more than 20,000 kW h of electricity, which is sufficent energy for five househols for one year. Five hundred thousand hectars of different plants produce power of one thousand megawatts, which equals the energy production of a larger power plant.

7.1.1. Wood power

58% of primary energy generated from renewable energy sources in the EU originates from wood. A large part in it has the traditional use of wood. In France, the largest part of primary energy is produced in this way, which amounted for 9.8 Mtoe in 2009. Sweden (8.3 Mtoe) and Finland (7.5Mtoe) make a substantial use of wood energy. Although heating energy represents the main part of energy production, a part of wood energy is transformed into electric energy. In 1999. 17.3 TWh of electric energy was produced in the European Union. The plan to produce 100 Mtoe from wood energy in 2010. has been partly accomplished with 62 Mtoe instead.

7.1.2. A tree by numbers

- 1 tonne of CO_2 from atmosphere is required in order to obtain $1m^3$ of wood during growth of a tree;
- $1m^3$ of wood in a growing tree contains 250 kg of carbon which is stored in tree fibre and 750 kg of oxygen which is released into atmosphere during photosynthesis process;
- European forests annually absorb approximately 140 million tonnes of carbon during photosynthesis process;
- $150m^3$ wood area releases into atmosphere the amount of oxygen sufficient for the annual needs of one person;
- one 60 year old beech tree provides enough oxygen for 10 persons;
- one 60 year old beech tree absorbs the amount of CO_2 released into atmosphere by 10 persons during one day, 1ha of wood absorbs 900kg of CO_2 and, at the same time, releases 600 kg of oxygen;

A number of biogas powered plants continually increased in the period between 1990. and 2000. There are 3,000 biogas powered plants today in Europe and 450 waste dumps which valorise biogas. The annual production of these plants is approximately 2304 ktoe, which accounts for 5% of total biomass produced energy in Europe. The UK is a leading biogas energy producer with 897 ktoe or 39% of European production. That energy is generated from more than 400 plants. Germany is the second producer with 525 ktoe in 2000. The most significant progress s achieved in Germany by the use of agricultural biogas. 400 additional plants were built in 2000., totalling 1050 today. France is the third European biogas energy producer with 167 ktoe produced annually. The EU objective is 15 Mtoe biogas energy. In order to achieve that objective, an annual growth of minimum 30% is required.

7.1.3. Biomass – the basis for biofuel production

It is a renewable energy source which is based on carbon cycle and as such differs from other natural sources, such as oil, coal and nuclear fuels.

One of the generally accepted definitions of biomass is: *"Biomass is biodegradable part of the product, waste and remains produced in agriculture (of plant or animal origin), forestry and other related economic sectors, as well as biodegradable part of industrial and public utility waste."*

Wood, harvest remains and manure biomass energy are the primary energy sources in developed regions. In some areas, biomass is the largest energy source, as it is in Brazil, where biomass energy is produced by transforming sugar cane into ethanol, or in Chinese province of Szechuan, where the fuel is produced from manure. Some world regions are well known for the use of certain sources of biomass in fuel production, as it can be seen from the above mentioned. Corn, high prairie grass and soya are primarily used in the USA, while rape plant, wheat and sugar beet are used for biofuel production in Europe. In southeast Asia it is primarily palm oil, and in China it is broomcorn and manioc. Numerous research projects are being conducted presently in the world, as well as in Serbia, in order to improve biomass and biomass energy production.

7.1.4. Biofuels

The simplest biofuel definition is: *"Biofuels are liquid or gaseous fuels for the transport need, produced from biomass."* Biofuels can be produced directly from plants or indirectly from industrial, commercial, home and agricultural waste. There are three main methods of biofuel production. The first method is based on burning dry organic waste, the second on fermentation of damp waste without presence of oxygen and the third on sugar cane or corn fermentation in order to produce alcohol and ester.

Finally, there is also energy obtained from purpose grown fast growing trees in short rotation plantation for fuel production. However, the best known method is fermentation, whose products are two best known forms of biofuel: alcohol and esters. Theoretically, they can replace fossil fuels, but the engine modification is required, hence they are used mixed with fossil fuels.

Biofuels have potential which aims at decreasing CO_2 production, primarily based on the fact that plants, used for biofuel production, absorb CO_2 during their growth, which is released in biofuel combustion. Most "Life Cycle Analysis (LCA)" proved that biofuels, compared with fossil fuels, create far less amounts of harmful greenhouse gases and, therefore, their use and substitute of fossil fuels would mean significant reduction of greenhouse effect.

Biofuels consist of two different sectors: ethanol and biodiesel fuels. Ethanol is used as a supplement for petrol engines, while biodiesel is a supplement for diesel engines. Some engines allow use of pure ethanol of biodiesel, but this is limited by state regulations. The amount of ethanol produced annually increased from 47,500 tonnes in 1993 to 191,000 tonnes in 2000. The main ethanol producer is France with 91,000 tonnes produced in 2000. Spain is the second largest producer with 80,000 tonnes. It is followed by Sweden with 20,000 tonnes. Biodiesel production has increased even more. From 55,000 tonnes in 1992 it increased to 700,000 tonnes in 2000. France is also a leader in this sector with 47% or 328,000 tonnes. Germany is the second largest producer with 246,000 tonnes. Only three other EU countries produce biodiesel fuel: Italy (78,000 tonnes), Austria (27,600 tonnes) and Belgium (20,000 tonnes).

The European Union plan is to produce 17 million tonnes of biofuel.

There are different types of biofuel which can be divided into first and second generation.

The first generation of biofuel (ethanol, biodiesel and biogas) is based on production of sugar, starch, vegetable oil or animal fat, while the second generation (bio hydrogen, bio-DME, bio methanol, DMF, HTU diesel, Fischer – Tropsch diesel and alcohol mixtures) uses agricultural and forest waste for production.

Biofuels as a substitute for fossil fuels certainly have positive influence on environment, but also pose numerous ethical dilemmas, particularly for poor countries.

8. WHERE IS SERBIA?

One of the EU membership requirements that Serbia has to comply with is adoption of series of laws concerning environment protection, based on European standards and their implementation. Until now, Serbia has adopted so called “Green Package of Laws’ which includes Air Protection Law, since, until recently, carbon dioxide emission in Serbia was twice bigger in comparison with the countries with similar gross national income.

EU has invested 450 million euros in ecological projects in Serbia since 2000., while 165 million euros refer to projects in progress. Only the “Administration Capacity Strengthening in the Area of Air Quality Managing” project has the value of one million euros. The project objective is information and trend exchange in the area of quality and protection of air, monitoring of its quality and assessing in accordance with the current EU regulations. This project started in November 2009. and it will last until 2011.

Serbia has a large potential in the area of using renewable energy sources, primarily wind, water, sun and biomass. As it has been stated earlier, more and more funds have been invested in that sector in the world, which is a part of so called “green economy’ and which employs a large number of people. On the other hand, this way of producing energy reduces the emission of harmful gases, which protects the environment, which represents one of the key issues for all countries, as well as the whole planet. Currently, 13% of the world primary energy consumption originates from renewable sources, despite the fact that the technological capacities are much higher.

Thanks to its favourable geographical conditions, Serbia has a significant potential for renewable sources energy production, which has not been used adequately. It is possible to produce 4.89 million toes (tonnes of oil equivalent) annually from renewable sources. Having in mind that the domestic energy production reached 8.79 million toes in 2007., it can be concluded that Serbia could produce a half of its primary energy from renewable sources.

0.86 million toes from renewable sources is produced in Serbia per year, which means that only 18% of total potential is used – and that nearly completely refers to electric energy production in large hydroelectric power plant (with installed power higher than 10MW).

8.1. The Republic of Serbia legislative framework in the area of renewable energy sources

The legislative framework in our country provides opportunities for the development of this sector. It primarily refers to:

- Energy Law (2004);
- The Republic of Serbia energy development strategy by 2015. (2005). determines the following priority directions in this sector:
- The improvement of technological and operative performances energy facilities
- The increase of energy efficiency ;
- The use of renewable energy sources;
- Building of new and capital intensive energy capacities
- Energy development strategy implementation programme of The Republic of Serbia from 2007 to 2012. (2006), with amendments and supplements (2009);
- The Republic of Serbia has signed the Treaty of Establishing South- East Europe Energy Community and EU, by ratification of which it assumed the obligation of implementation of directives concerning increased use of renewable sources (2001/77/EC [4] i 2003/30/EC [6]), stating that the 20% of the total energy production must be from renewable sources by 2020.
- The Kyoto Protocol Ratification (2007);
- Regulation on conditions concerning acquiring the status of favoured electrical energy producer and criteria for condition compliance assessment
- Regulation on measures encouraging electric energy production by using RES and combined production of electric and thermal energy
- The Republic of Serbia became a member and founder of International Renewable Energy Agency (IRENA) on 26th January 2009., which is first international (intergovernmental) organisation focused exclusively on renewable energy and it will continue to participate actively in its work in accordance with the Agency Statute and its own interests in the area of activating and using renewable energy sources. The main objective of International Renewable Energy Agency (IRENA) is to become the main driving force in the rapid transition towards widespread and sustainable use of renewable energies worldwide, and its main activities include:
- providing specific consulting services to the industrialised and developing countries governments – concerning the policy of renewable energy sources use;
- the technology transfer and consulting services concerning project funding;
- capacity building and construction in the sector of renewable energy use.
- In September 2008. The European Parliament adopted a package of regulations on climate changes which aims at providing reduction of greenhouse gases emission by 20% in total EU energy consumption by 2020., compared with the base year 1990.

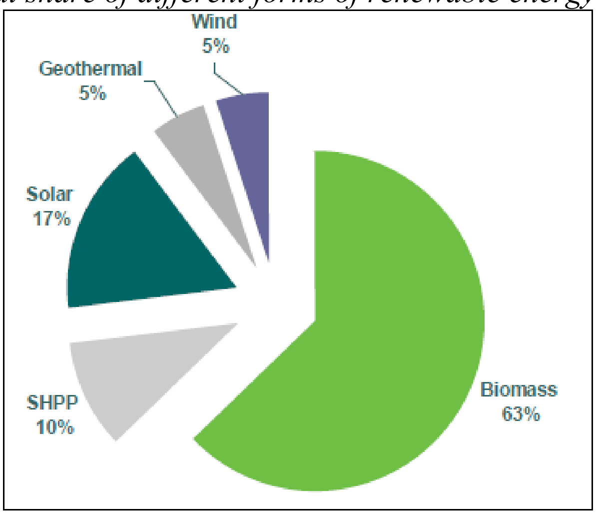
- A new directive on renewable energy 2009/28/EC establishes binding national objectives which EU member states should accomplish through promotion of renewable energy in electric energy, heating and cooling sector and transport sector in order to ensure that renewable energy represents at least 20% of total consumption in the EU by 2020. The directive also plans that the use of renewable energy in transport (biofuels, electric energy and hydrogen produced from renewable sources) will represent at least 10% of total fuel consumption in the EU by 2020.
- The Directive 2001/77/EC defines renewable energy sources (RES):
- national objectives for production of electrical energy generated from RES
- programme of measures for their accomplishing
- guarantee of origin – for the electrical energy generated from RES
- simplification of legal framework for building and exploitation of facilities
- the obligation for a transfer and distribution operator to receive and transport electric energy from RES defining conditions and tariffs concerning connecting to network
- The Directive 2003/30/EC defines biofuels and ensure emerging of certain amount of biofuel on the market 5.75% of the total amount of fuel which will be used in transport by the end of 2010.
- The Serbian Government adopted Regulation on measures encouraging electric energy production by using renewable energy sources and combined production of electric and thermal energy. The policy of encouragement involves guaranteed purchase price for all electric energy produced in mini hydroelectric power plants, plants using biomass, wind power plants, solar power plants and power plants using biogas, waste or sewerage gas, in period of 12 months after the start of the production.

Serbia could produce a half of its energy from renewable energy sources, but currently it is used only 18% of potential sources. Biomass could have the largest share, which could be used for production of one quarter ot total energy in Serbia, and a large amount of energy could be generated from hydro energy, sun and wind.

8.2. Serbia – biomass potentials

Biomass represent the most important renewable energy source in Serbia, taking into account large presence of agriculture (arable land constitutes approximately 55% of the territory) and abundance of forests (approximately 30% of the territory is covered by forest and an increased level of forest coverage of 40% is planned):

Graph.5. *Potential share of different forms of renewable energy sources in Serbia*



It is realistic to expect the following amounts:

- Forestry biomass: 1 Mtoe (Million Tons of Oil Equivalent)
- Agricultural biomass: 1.4 Mtoe
- TOTAL: 2.4 Mtoe

Forest biomass

The following amounts are estimated:

- Fire wood 7 milliona m^3 (55% from the state forests)
- Wooden waste 5 milliona m^3
- TOTAL 12 milliona m^3

The potential of this forestry energy product is not neglegible since the national plan aims to cover 40% of the Serbian territory by forests.

Table 2. *Wood based fuels energy value*

Wood based fuel type	Moisture content (%)	Energy value		
		Kwh/m^3 compact wood	Kwh/m^3 wood based fuel stacked in layers	Kwh/kg
Fire wood Beech damp	50	2,100	1,600	2.1
Fire wood Beech-dried (2years)	18-25	2,600	1,900	3,9
Conifer fire wood damp	60	1,900	1,200	2.3
Conifer fire wood dried (2years)	18-25	2,200	1,400	4.0
Sawdust	20-30	1,900	800	3.7
Briquettes	7-10	3,800	3,000	4.7
Pellets	7-10	3,900	3,100	4.9

There is an opportunity in Serbia for growth of so called ’energy forests’ on the area of 200,000 ha of untilled land, on which fast growing forest could be planted and further used for energy purposes.

The research has shown that it could be obtained from 15 to 20 tonnes of woody biomass per hectar per year, which is between three and four million tonnes of woody biomass. The use of biomass in Serbia has already found its application in household heating by the means of biomass briquettes and palettes. The investment value which could enable the electric energy production from biomass is estimated on 50 million euros.

Agricultural biomass

Biomass energy potential in agriculture is estimated at 3 million tonnes in crop growing, and in fruit and vine growing at 1.1 million tonnes.

The total biomass production generated from crops in Serbia is more than 12.5 million tonnes per year.

The potentials of produced biomass from some “more important” cultures, its thermal potentials and opportunities for liquid fuels saving, are represented in the following table:

Table 3. *The potentials of produced biomass from some agricultures*

Ordinal No:	Biomass type	The amount of biomass available(10^3 t)	Lower heating value (MJ/kg)	Ratio in comparison with the light heating oil*(kg/l)	Slight heating oil saving opportunities (10^3l)
1.	Wheat straw	2975.0	14.00	3.41	872
2.	Barley straw	412.5	14.20	3.46	119
3.	Oat straw	25.6	14.5	3.54	7
4.	Soya straw	320.0	15.7	3.83	84
5.	Cornstalks	7150.0	13.5	3.29	2,173
Total:		11,281.4			3,255
* With the light heating oil thermal power of hd = 41000kJ/kg					

If only one fourth of the above mentioned biomass (more than 2.8 million tonnes) were used for energy purposes, we would acquire energy which could satisfy all the needs of low temperature energy stationed energy systems (heating, product finishing in processing plants, drying in smaller hothouses and others, even cooling of absorption cooling machines), of the country's agricultural complex.

The physical – chemical characteristic of biomass produced in this way are the following: combustible part accounts for 50 -60%, there is a large share of oxygen in the structure of biomass generated from crops, up to 40% (which, despite helping combustion, decreases the fuel thermal power), sulphur is contained only in traces, amount of moisture varies, biomass thermal power ranges from 13 to 18 MJ/kg, ash melting point is at relatively low temperatures (about 8000C), which is negative, making biomass a highly inflammable material and therefore strict fire safety measures must be imposed.

8.3. Short rotation plantations

Short rotation plantations for biomass energy production are one of the realistic alternativs, primarily because of their ecological advantages:

- renewable production;
- emit very small amount of carbon in the atmosphere – 1/10 CO_2 in comparison with other fossil fuels;
- locally, the plantation can reduce the erosion process, provide funds for degraded land restoring, neutralise emission and local effect of fossil fuel energy production(for instance SO_2 i NOx) and reduce further endangering of existing woods;
- Different types of dendroflora can be used for double purpose:
  - biomass production;
  - polluted land cleaning from different pollutants -phytoremediation

Woody plants account for 63% of the total number of short rotation plantations, out of which different types of eucalyptus account for 38%, whereas poplar trees,willows and alders dominate in moderate climate zones. They are characterised by annual productivity of more than 10-12 t/ha of dry wood and bark, relativiely equal quantity of yield for energy capacity provision and cost of less than 50$ per dry tonne.

For setting up a plantation, selected, fast growing types of trees are used, depending on local conditions – willows, poplar trees and others.

They are characterised by very thick planting (poplar trees 6-12,000 plants/ ha, willows: 10-12,000 plants/ha), and they are harvested every 3 to 10 years.

Good plantations on good locations in tropical and moderate climate zones can achieve 2-10 times higher yield compared with natural forests. The average poplar tree yield in the east part of USA and north-west part of the Pacific is 9-20 dry t/ha and it can reach 43 dry t/ha. Willows in the

USA have an average yield of 13-24 dry t/ha, in Sweden it is 13-23 dry t/ha. Eucalyptus in north-west Spain produce 13-15 dry t/ha, in south-west Spain 5-8 or, the average for this country is 12.5 dry t/ha, in Brazil it is 9-26 and in Hawai 13-27 dry t/ha.

Although natural arable lands are most suitable for setting up plantations, lands with moderate limitations can be used, with previously solved the problems of water, erosion and lack of fertilizers.

In the USA and Europe, hybrid poplar trees and willows are in the most cases more suitable than natural species, although fast growing natural clones have been identified. In some moderate agricultural regions herbaceous crops, grass and others have been researched. One of the advantages of that type of crops is that they can be planted and collected by the means of existing agricultural mechanisation, without new investments into special forestry equipment.

Topography, soil, humidity condition variations dictate the use of larger number of different plants in order to optimise sustainable production. From the point of view of ecology, it is desirable to have mixed plantations with different types of trees, bushy and grass plants, since that type of plantation provides habitat for different animal and bird species. Besides woody plants, plantations of grass, herbaceous, semi- herbaceous vegetable species, such as Phragmites communis or Miscanthus sp., which behave as long lived species when planted for this purpose, can be set up.

8.3.1. Short rotation plantation in coal mine tailing ponds

The research conducted in surface mine tailing ponds in Germany showed that, even under unfavourable soil conditions, yield accounted for 5.2 to 19.6 tonnes of dry matter/ha at the age of 4 years. Biomass produced in this way is characterised by:

- low concetration of heavy metals
- high caloric value and
- favorable characteristics of ashe – high concetration of macronutritients
- use of ash for meliorisation can recompense for the loss of ferilizers for collecting biomass

There are significant tailing pond areas in Serbia which are not used at present. Similar new areas are created daily. These areas are located primarely within the surface lignite mines (Kolubarsko-tamnavski basin, Kostolački basin and others), surface non-ferrous metal mines, clay, stone and other raw materials exploitation sites. It has been estimated that, in Serbia, an area of approximately 1000 km^2 will be degraded by surface mineral and other raw materials exploitation. Part of these areas can be used for setting up short rotation plantations for biomass energy production.

The Government of The Republic of Serbia, via The Ministry of Science and Technological Development, within the framework of National Programme for Energy Efficiency, supported the projects EE273015 and TR18201 ”Opportunities for biomass energy production from wood short rotation plantation within the framework of electro energy systems in Serbia”, led by The Institute for Forestry – Belgrade, and with a collaborator, beneficiary and participant: P.K.”Kolubara”, whose objectives and research content are the following:

- Biomass volume production increase in fast growing dendroflora plantations in surface coal mine tailing ponds in Serbia;
- Increased share of energy generated from biomass in our country and enabling partial fossil fuels substitution according to the Kyoto Protocol regulations, The Davos summit conclusions and other international treaties;
- Determining ecologically and economically most suitable tree species
- Determining optimal technologies for setting up plantations
- Determining care, protection and supplementary nourishment measures with the aim to obtain the largest possible amount and best quality biomass;

- Determining the opportunities for use of waste mud from coal processing as a rational and accessible growth stimulus (fertilizers);
- Phytoremediation of contaminated substratum;
- Determining the economically most acceptable solution;
- Employment of local inhabitants and surplus work force, which will emerge in the process of public company restructuring in energy sector .

Lignite deposits in our country stretch across the area of more than 1,000km^2 and account for 83% of total reserve of fossil fuels energy potentials. But, due to the fact that it is non-renewable energy source, it is considered that we will exhaust the reserves of this potential in 50 years.

Present experience shows that in the process of biological recultivation of tailing ponds, the ratio of forest to agricultural recultivation is most frequently 60:40, which means that in the final phase it can be expected that forest ecosystems are established on 600km^2, while agricultural areas, urban ecosystems and infrastructure cover 400km^2. Taking into account the current experiences concerning achieved production effect of ten year old forest cultures, set up on deposol soils in external surface lignite mine tailing ponds in Kolubara basin, in extensive plantations, without prior technical recultivation and application of care measures, it is realistic to expect that intensive plantations, with previously conducted technical recultivation, with the application of optimum agro technical and agrochemical measures, with the plant distance of 1.2 x 0.8 m achieved in short rotation of 6 years, would achieve production of dry biomass represented in the following table:

Table 4. *The survey of potential dry biomass production in intensive short rotation plantations*

Type of tree	Number of trees per ha	Dry biomass production tonne/year		Planned area ha	Total potential production tonne/year
		Per 1 ha in last year	In 6 years		
Larch	10 460	31.2	187.2	1 080	202 176
Black alder	8 340	27.2	163.2	1 200	195 840
Birch	8 340	21.5	129.0	840	108 360
Black locust	8 340	22.4	134.4	660	88 440
Siberian elm	8 340	25.6	153.4	600	91 920
EA poplar tree	7 000	46.8	327.6	900	294 840
Willow	8 000	38.0	228.0	720	164 160
			Total	**6 000**	**1 145 735**

The orientational forecast for establishing other anthropogenic forest ecosystems on deposol soils in tailing ponds of the completely exhausted lignite deposits in 50 years time and on the area of 54,000 ha, with the average annual yield of 6.5 m^3/ha, that is 351,000 m^3 of raw wood annual yield and the amount of wood to be cut annually of 270,000m^3 of raw wood, out of which 20% can be used for energy purposes, which totals 54,000 tonnes or 27,000 tonnes of dry biomass which, together with 190,956 tonnes from short rotation plantations totals 217,956 tonnes per year of dry mass for energy purpose, from potentials realised by forest biological recultivation of surface lignite mine tailing ponds, provided that the rate of lignite exploitation is conducted on approximately 2,000 ha annualy.

Apart from the above mentioned woody biomass, the fire wood potential should be taken into consideration, representing 40% of the total net wood mass cut in forests, which is approximately 1,600,000 cubic metres of damp wood, that is, 800,000 tonnes of dry biomass used as heating energy potential of individual rural inhabitants.

Serbia consumes about 14 million tonnes oil equivalent. The biomass potential is 2.6 tonnes oil equivalent, which means that the use of biomass could satisfy one fifth of the total Serbia energy needs.

Currently, biomass is primarily used for heating, but it could be used for electric energy production.

Table 5. *Carbon dioxide (CO_2) emission during burning of oil based on wood and other types of fuel*

Fuel type	Carbon dioxide emission in kg/kWh energy
Gas	0.19
Gas in tanks	0.23
Crude oil	0.27
Coal (average)	0.29
Chopped wood	0.03
Wood pellet (packed in PVC sacks)	0,03
Wood pellet (packed in large sacks, from central heating strorages)	0.03
Sawdust	0.03
Briquette	0.03

Biomass has an outstanding importance for The Republic of Serbia since, apart from the fact that biomass represents environmentally friendly fuel which can make significant contribution to efforts aimed at CO_2 emmision reduction, it is a renewable energy source, provided that the measures for sustainable forest management are applied.

Table 6. *The survey of heating cost for different types of fuels in Serbia of a household with annual consumption of 20,000kwh*

Kostolac coal	0,015
Vreoci dried coal	0,017
Sawdust	0,019
Vreoci damp coal	0,023
Deciduous tree fire-wood (dried)	0,023
Wood briquettes	0,028
Natural gas (Srbijagas)	0,029
Natural gas (Novi Sad gas)	0,031
Wood pellets (1000 kg pack)	0,031
Wood pellets (15 kg pack)	0,033
Electric energy (two tariff electric metre)	0,041
Crude oil	0,041
Heating oil	0,065
Electric energy (one tariff electric metre)	0,082
Electric energy (two tariff electric metre)	0,082

Its intensive use will contribute to decreasing imported energy products dependence, and ensure economic development in rural areas, which is of vital importance for every country.

It has been estimated that 1,589,813 MWh, that is 5.7% of estimated potential, could be used by 2015. Whereas the total estimated potential amounts for 27,912,000 MWh.

Apart from use of remains originating from food grain growing, there is an opportunity for targeted grain growing for the purpose of fuel production generated from biomass, without endangering food production;

According to the data from the Ministry for Mining and Energy, biomass could be the source of the one fourth of the total energy produced in Serbia.

It is important to say that the realisation of projects concerning substitution of crude oil, coal and gas with the renewable energy source has began in Belgrade, the capital of The Republic of Serbia. Since this heating season, Heating plant "Barajevo" in Belgrade will start to produce thermal energy by means of wood pellets combustion, while "Beoelektrane" will introduce ecologically clean fuel in Heating plants „Sremčica" and „Senjak". At the beginning of this year, a building with the area of $220m^2$, using well water at the depth of 115m for both heating and cooling, was erected in the area of Heating plant ”Konjarnik”. Inhabitants of Cukarica and Rakovica will use hot water generated from the solar energy, processed in Heating plant ”Cerak” in two years, while plant in Krnjaca will use soya straw as primary fuel.

Serbia’s objective, to be accomplished by the end of 2012, is to increase the production of electricity generated from renewable energy sources by 7.4% compared with 2007.

Biomass as an alternative energy source represents a specific area. Serbia, being an agrarian country possesses sufficient amounts of biomass for energy production, which could heat the entire country. It refers to domestic raw materials, such as wood, straw, grain, corn waste, sunflower pods, fruit pits.

The total biomass potential in Serbia that can be used for energy purposes amounts to 2.4 million tonnes oil equivalent.

Bearing in mind the large biomass potential for energy production, The Ministry of Mining and Energy, in cooperation with the Dutch Ministry of economy state agency - Senter Novem – began work on creation of National action plan on biomass.

The adoption of Regulation on measures supporting electric energy production from renewable energy sources and combined production of electric and thermal energy will significantly contribute to attracting investments in this sector. For that reason, commercial banks, international financial institutions and state development funds are becoming involved in that issue by providing favourable credits.

Serbia has assumed obligation to prepare and realise the Directive 2001/77/EC implementation plan on promoting electrical energy production from renewable energy sources and Directive 2003/30/EC implementation plan on promoting use of biofuel and other fuels from renewable energy sources in transport sector.

There are several state institutions in Serbia responsible for development of renewable energy sources, including biomass, which can be seen from the following table:

Table 7. *State institutions responsible for development of use of renewable energy sources - biomass*

MINISTRY OF AGRICULTURE, FORESTRY AND WATERPOWER ENGINEERING	Responsible for development of agriculture and forestry, which represent raw material base for use of biomass for energy production
MINISTRY OF SCIENCE AND TECHNOLOGICAL DEVELOPMENT	National programme for energy efficiency - technological development and construction of pilot plants
MINISTRY OF ENVIRONMENT AND SPATIAL PLANNING	Planning and construction of plants using RES Protection system and sustainable development and use of resources Climate changes monitoring and RES development support Conducting activities concerning adoption and implementation of Sustainable Development Strategy of The Republic of Serbia
MINISTRY OF MINING AND ENERGY	Development and policies implementation for electric and thermal energy production from renewable sources
MINISTRY OF ECONOMY AND REGIONAL DEVELOPMENT	Implementation of activities encouraging regional development – particularly in less developed regions
AGENCY FOR ENERGY EFFICIENCY AND REGIONAL CENTRES	Programmes supporting use of renewable energy sources Trainings and campaigns aimed at raising awareness of importance of RES use Centres – Beograd, Novi Sad, Niš, Kragujevac, Kraljevo
COUNCIL FOR SUSTAINABLE DEVELOPMENT – GOVERNMENT VICE PRESIDENT FOR EUROPEAN INTEGRATIONS	Conducting activities concerning adoption and implementation of Sustainable Development Strategy of The Republic of Serbia

9. CONCLUSION

The data presented above point to significant, until now unused, woody biomass potential from the existing and future forest and non forest biomass resources, which could be use for energy purposes. Their share in the total energy potential could account for 25-40%, which could be exceptionally beneficial from the economic and ecological point of view.

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OPPORTUNITIES FOR FOSSIL FUELS AS ENERGY SOURCE PARTIAL SUBSTITUTION BY BIOMASS IN SERBIA – A CONTRIBUTION TO THE GLOBAL CLIMATE CHANGE DECREASE

Dragana DRAŽIĆ, Milorad VESELINOVIĆ, Ljubinko JOVANOVIĆ,
Biljana NIKOLIĆ, Vesna GOLUBOVIĆ ĆURGUZ

Summary

The study presents the global world problems and climate changes caused by, inter alia, human activities from the time of industrial revolution to present and, above all, the use of fossil fuels. It points out to the necessity for substitution of a part of fossil fuels by alternative, renewable energy sources, biomass representing a considerable part of which, particularly in Serbia where more than 60% of energy generated from the renewable sources can be produced from biomass. Additionally, the study points to the opportunities of establishing energy plantation of short rotation woody crops for the production of biomass, with a particular attention paid to the crops planted on surface coal mine tailing ponds.

MOGUĆNOSTI SUPSTITUCIJE DELA FOSILNIH GORIVA U SRBIJI KORIŠĆENJEM BIOMASE ZA ENERGIJU – DOPRINOS SMANJENJU GLOBALNIH KLIMATSKIH PROMENA

Dragana DRAŽIĆ, Milorad VESELINOVIĆ, Ljubinko JOVANOVIĆ,
Biljana NIKOLIĆ, Vesna GOLUBOVIĆ ĆURGUZ

Rezime

U radu su prikazani globalni svetski problemi i klimatske promene izazvane, između ostalog, delatnošću čoveka od industrijske revolucije do danas, pre svega upotrebom fosilnih goriva. Ukazano je na neophodnost zamene dela fosilnih goriva alternativnim, obnovljivim izvorima energije, u čemu korišćenje biomase ima značajan udeo, posebno u Srbiji gde preko 60% energije dobijene iz obnovljivih izvora može da se proizvede iz biomase. Takođe je

ukazano na mogućnost osnivanja energetskih plantaža drvenastih vrsta kratke ophodnje za proizvodnju biomase, sa posebnim osvrtom na ovakve zasade osnovane na odlagalištima jalovine površinskih kopova uglja.

ANALYSIS OF FOREST BIOMASS RESOURCES FOR ENERGY PRODUCTION

Ján TUČEK[1], Milan KOREŇ[1], Róbert SMREČEK[1], Ján ILAVSKÝ[2], Mária ŽIAKOVÁ[3]

Abstract: *The paper presents the overview of methodology for identification of forest biomass resources for energy production and its transportation to heating plant. The potential volume of wooded biomass was calculated from detailed description of forest stands. The evaluation includes several factors: the growing stock, planned fellings and felling types, assortments structure, forest age structure, ownership. Ecological limiting factors were evaluated including protected forests, level 5 of nature protection, sensitive and poor soils, regions with slope over 50%. Biomass production from ecologically sensitive regions was strongly restricted. Consequently transportation distances were analyzed and distance zones constructed. Finally the amount of exploitable wooded biomass and its costs were estimated. The results were summarized in report and presented in maps, tables and graphs.*

Key words: forest biomass, GIS, energy production

1. INTRODUCTION

The use of forest biomass as a source of renewable energy became an important tool in region development. Using of forest biomass as an alternative source of energy has several advantages like the reduction of CO_2 emissions and ash production, fulfillment of emission limits and obligations coming from the Kyoto protocol, warm and electricity production by affordable price, environment development, etc. In addition to the environmental benefits, it provides the economical development in region, like the creation of new work places, development of supplying and processing services in region and also the development of small and medium size enterprises.

The exploitation of forest biomass as a source of renewable energy required high costs. However, the investors are afraid to invest into installation of expensive combustion technologies without detailed information about usable biomass sources in region. Because of fact, that in Slovakia is not yet created regular market with biomass as a source of renewable energy, there is necessary to analyze carefully the technological, technical and economical aspects for forest fellings and long term supplies of biomass from forests and they best logistical cover by every investment. These aspects influence stability and regularity of biomass supplies, their quality, production costs as well as the price and the efficiency of biomass use for energy generation [3].

The study area for overall forest biomass resources identification, specifying the limiting factors of biomass availability for energy use and factors which enter into the calculation of available biomass volume was situated in the Banská Bystrica region, located in Central Slovakia [1], [2]. This region with 48,9 % woodiness belongs to the most forested regions in Slovakia. Woodworking industry has also been developed in the region. The high accumulation of wood

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secondary sources as well as the other biomass, suitable for energy generation, is typical feature of this region. Also several developmental projects and construction of several boilers for wood combustion has been implemented in the region. The biggest was the reconstruction of two brown coal firing boilers in the Zvolenská teplárenská, a. s. to co-firing of low sulphur brown coal and wood.

The allocation of biomass accessible sources, its transport, economical calculation is a complex task, where as a solution GIS is used [3]. Geographical database, data preparing and processing, maps creation were made in ArcGIS environment. Two and three-dimensional analysis was realized in external program [4].

2. METHODS AND APPROACH

The study was elaborated for the gravitation territory of the Zvolen CHP plant. The area was territorially delimited by the Banská Bystrica administrative region. The area had been demarcated in a way that allows information about various sources of biomass within the administrative unit. The information basis of biomass volume assessment in the region was the forest stand area, timber growing stock and annual allowable cuts. Furthermore, the age structure of forest, tree species composition, planned and real yield of roundwood assortments annually removed, forest categories, ownership and management structure of forest were taken into the account. To the volume of thick wood planned for harvesting, the volume of small-dimension wood (diameter less than 7 cm) had been added. The volume of thin wood was estimated to 18% uniformly for all tree species and felling types.

2.1 Processing of geographic data

The main objectives of geographical data processing and analysis were to prepare a geographical database of Banská Bystrica region, and to derive information needed for the estimation of biomass availability and costs[1]:

- data import and pre-processing,
- calculation of transportation distances,
- specification of limiting factors,
- determination of available biomass.

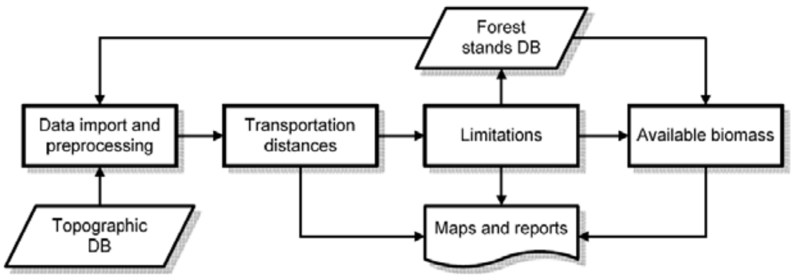

Figure 1: *Diagram of geographical data processing and analysis (source [1])*

2.2 Data import and pre-processing

For analysis support was the comprehensive geographical database built. It contains these vector and raster layers:

- digital elevation model (DEM) with 10 meters resolution,
- roads and other features of planimetry,
- borders of forest stands,
- limiting features.

All layers were transformed to the S-JTSK national coordinate system.

2.3 Calculation of transportation distances

The availability of biomass and costliness are highly affected by transportation distances and costs [3]. There was estimated the biomass availability and also calculated the costs of the shortest transportation distance for each forest stand to the heating plant. The input road layers contained all type of roads in region. The resulting transportation distance approximated the sum of forwarding and truck transportation distances. The calculation was performed in consecutive steps [4]. In the first step, there was the shortest route assigned to every pixel of raster representing the road network in region. In the next step, there was determined the shortest route to the heating plant from each pixel in raster. The algorithm starts at pixels representing the road objects. These two steps were done in three-dimensional raster. Consecutively, there was done the projection of transportation distances in two-dimensional raster. The transportation distance for each forest stand was calculated, next the raster of transportation distances was classified to the 10 kilometers wide zones. The results were represented in cross-tables, maps, etc.

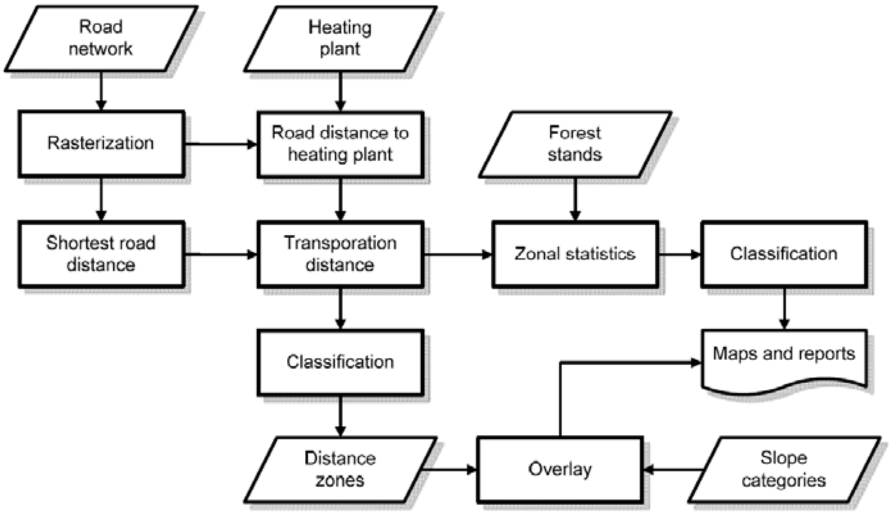

Figure 2: *Diagram of transportation distances calculation (source [1])*

2.4 Specification of limiting factors

The limiting criteria which constrain the total amount of compartments to the disposable ones were defined. The compartments were the criteria which were excluded from the basic set. The limiting factors are:

• forest stands belonging to the category of protective forests, where the drain of biomass is not allowable due to nature protection regulations,

• forest stands under the 5th degree of the IUCN nature conservation categories – non intervention reserves,

• forest stands which, according to the site quality, belong to the groups of forest management types, where the drain of biomass other than large wood (over 7 cm in diameter) is not appropriate due to the high soil acidity or, vice versa, unbalanced nutrient contents on carbonate parent rocks, rocky and skeletal soils etc.,

• forest compartments with slope inclination (grade) over 50%, where the access for biomass harvesting is limited for the ecological, technical and economic reasons.

All above mentioned stands were excluded from the database. After this were the set of forest compartments for calculation of available biomass created.

The morphometric parameters of relief (slope, aspect, elevation) were calculated from the DEM using the standard ArcGIS modules. These morphometric parameters were calculated for each pixel of raster. The minimum, maximum and standard deviation values of slope and elevation were estimated for each of forest stand units. The results were stored in the forest stands database. The borders of regions in the IUCN protection level 5 were stored in vector layers. Further, limiting factors were adopted from forest management plan database. Forest stands with slope above 50%, protected forest and regions in the IUCN protection level 5 were excluded.

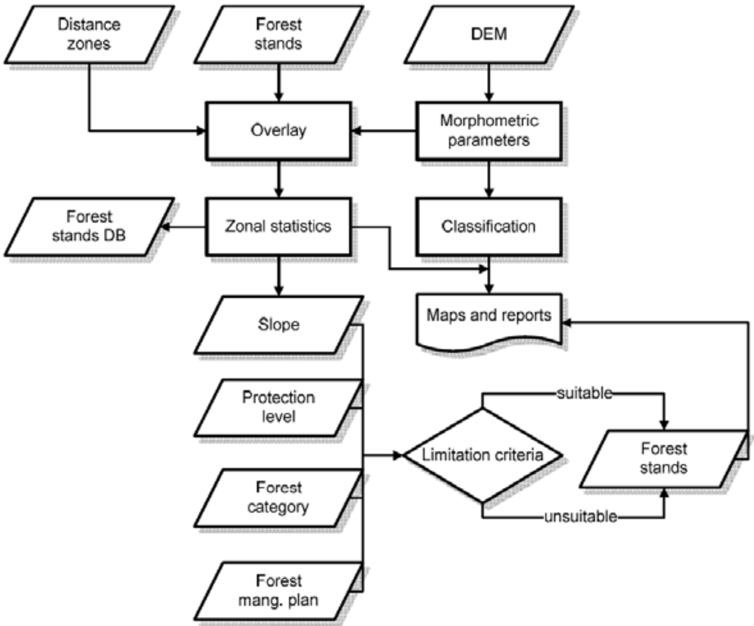

Figure 3: *Diagram of process of limiting factors calculation (source [1])*

2.5 Calculation of available biomass

All information needed for the final analysis and reports were stored in the geographical database. For example, the digital map of forest stands, the transportation distances, the limiting factors etc. Data from this database were exported to the database of biomass sources. The final determination of available biomass for energy use was done. The final tables and maps were generated.

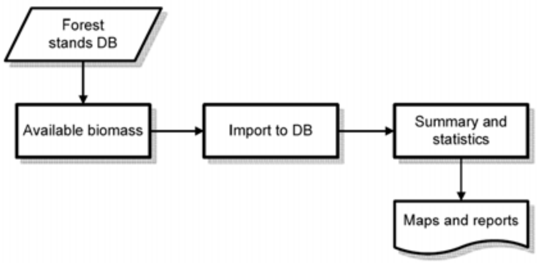

Figure 4: *Diagram of available biomass for energy use determination (source [1])*

2.6 Other sources of biomass for energy use

The purpose was the assessment of another biomass sources like the forest stands. There were two another sources:

• Biomass from energy plantations on farmlands not used for the agriculture production - the information sources have included information on the recipients of subventions, which have been subject to annual monitoring by the Slovak Chamber for Agriculture and Food and its Regional

Chamber, Statistical Yearbook on Land in Slovakia, and complementary land registry data regarding the identification of parcels not used for agricultural production [1].

• Sources of wood residues from the wood processing industries - the volume was assessed in all enterprises involved in primary wood processing in region. Also the volume of usable biomass coming from maintenance of park, greenery and recycling were collected. Information about volume in both case was collected by the personal meetings with managers or by telephone. These sources were excluded from the biomass, potentially available for energy generation, because the supply from these sources was not consecutive.

2.7 Technological and economical factors

According to the various local conditions three main technological schemes have been considered [1]:

• Chipping at the roadside landing
• Chipping at the central wood yard of supplier
• Chipping at the CHPs yard

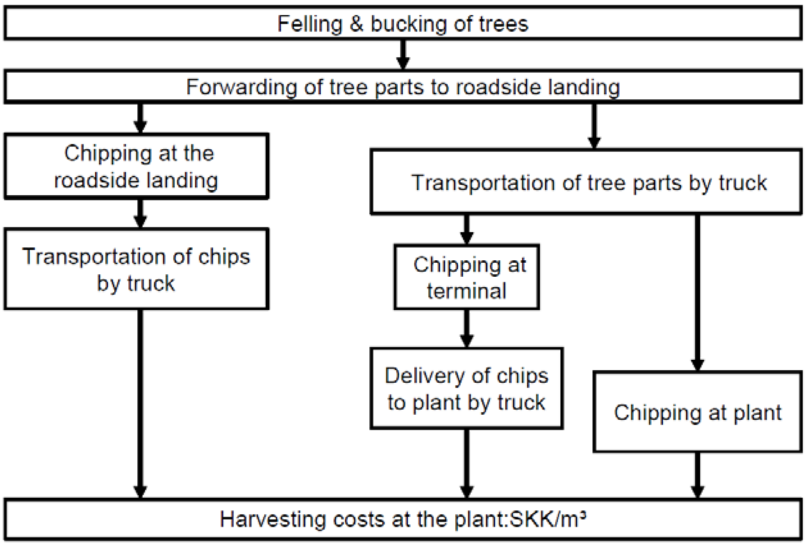

Figure 5: *Diagram of harvesting chain analysis (source [1])*

Also the costs and structure for different harvesting methods were assessed as a summary for the following partial operations [1]:

• Costs of felling and bucking trees
• Costs of forwarding
• Transporting costs
• Costs of chipping

3. RESULTS

The total forest land area of the Banská Bystrica region is about 453 000 ha. Applying the limiting factors the area will decreased to 258 300 ha. The growing stock of biomass is 1 245.1 ths.m^3. Application of another technical potential criteria resulted in assessment of the biomass potential volume which is potentially available for energy generation of 302.4 ths. m^3. This volume equals to 18.3% of planned annual cut and to 24.3% of total available biomass resource in the region. Results of the assessment have been aggregated and classified by the age classes, tree species (broadleaves and conifers), ownership and management structures, by the administrative districts and for region itself.

The lowest costs showed the cases when chips are produced from harvesting residues from final fellings, chipped at the roadside landing and directly transported to the customer. Production costs for chips production from thinnings are by 50-60% higher due to the increased felling and forwarding costs [1].

4. CONCLUSIONS

Applying the limiting factors described in the methodology, the decrease of biomass volume available for energy generation was from more than 1 200 ths.m3 to the more than 300 ths.m3 available biomass. Definition of these limiting factors is very important for studying of suitable supplies of biomass to the CHP plant. The transportation distance, harvesting and transporting technologies shows influence on the costs and efficiency of this technology.
Analysis of available biomass for energy generation is important for decision making about location of new plant or by reconstruction of technologies in existing plants. Bad location of heat plant can influence the final cost of warm, because the biomass needs to be transported from far away. This is also important for the calculation of recoverability for investors.

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