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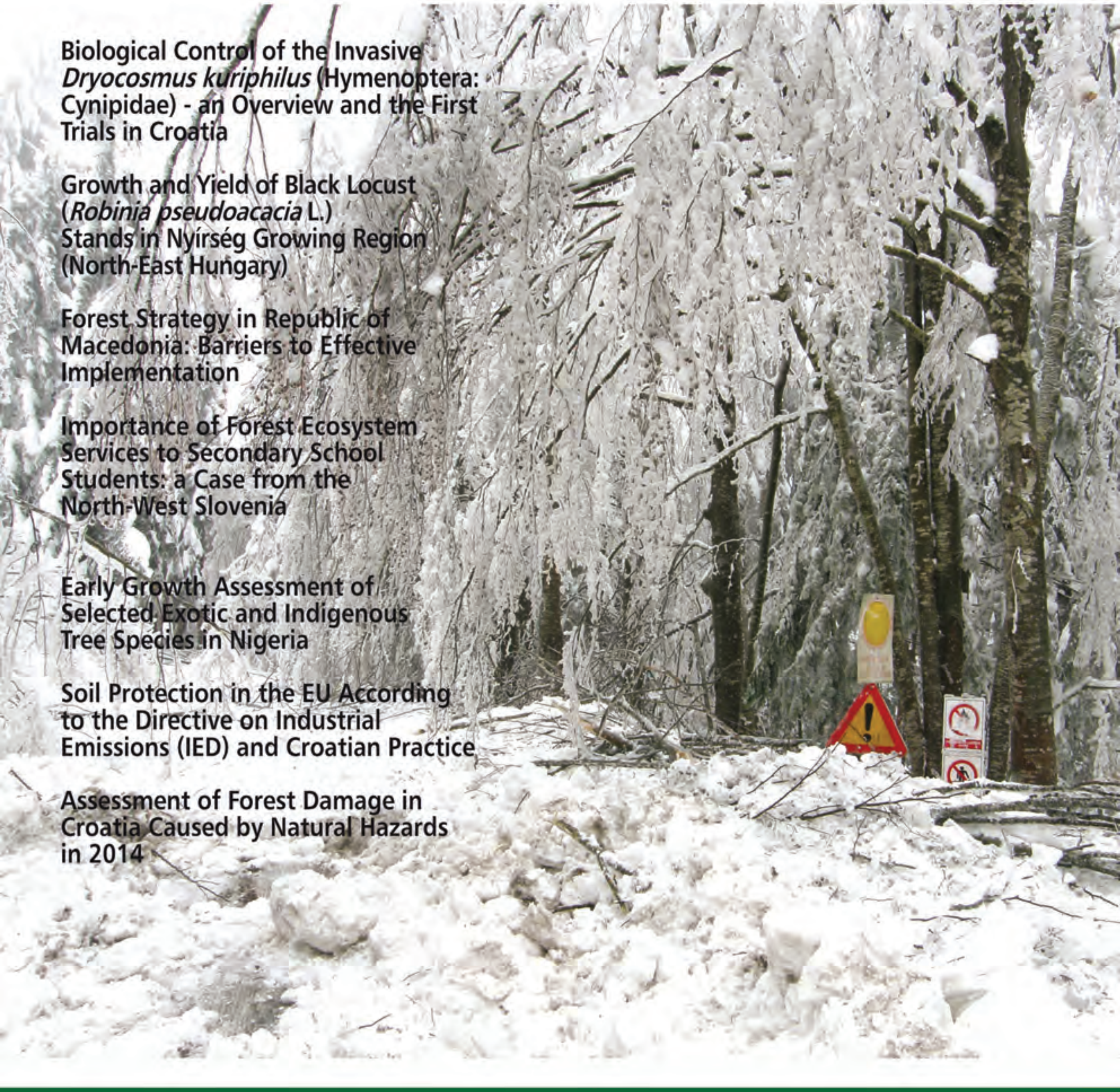

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Editorial

In the last 6 months we have unfortunately been witnessing natural disasters of large scale on the territory of South-eastern Europe.

During May, in this area, the territory of Croatia, Bosnia and Herzegovina and Serbia have been struck by floods of unprecedented scale. The significant amount of constant rainfall in May has resulted in outpouring of the rivers Sava, Una, Vrbasa, Bosna and Drina which consequently resulted with catastrophic consequences for the population of Croatian Posavina, Bosnia, and Western Serbia. Many villages have been completely flooded, people lost their homes, their cattle, their property, and unfortunately, floods have also taken many human lives. While the water from the flooded area is slowly retrieving and leaves behind devastating scenes of destroyed villages, people are trying to return to their homes as soon as possible. Due to the fact that numerous households are oriented towards agriculture, the population of that area is faced with a difficult and uncertain future and we hope that the help from all of us and from the governments of the flooded countries will facilitate easier recovery of the population and the return to a "normal life" for as much as possible.

Even though the damage from floods is far greater due to the fact that human lives were at risk, the foresters from the territory of Slovenia and Croatia are still adding up damages in forest ecosystems that were caused by ice-breaks and floods at the beginning of February of this year. The ice storm, specifically, ice rain struck the territory of Slovenia and a part of Croatia (Gorski Kotar) on the night of the 1st February, and created an ice coat on branches and on tree tops, which consequently had catastrophic consequences on forest ecosystems. Due to pressure and weight of ice, practically whole stands have been destroyed, particularly beech stands in which the ice coat caused breaking of the entire tree crowns. Furthermore, the roads covered by broken trees, destroyed and torn electric cables, knocked down transmission towers have resulted in terrifying apocalyptic scenes.

In order to apply to EU solidarity funds, it was necessary to assess the losses in the shortest period possible. The damage of forests and forest ecosystems in Slovenia has been assessed to 214 million € without VAT. It is assessed that 9.2 million m^3 of timber volume on the area of 550 000 ha had been destroyed, which is double the amount of the total planed annual timber cuts (felling volume) of Slovenia. In Croatia, the ice-break has in the most part struck the area of Gorski Kotar (Primorje - Gorski Kotar County). According to the initial estimation, around 1.65 million m^3 of timber volume on the area of 56 000 ha had been destroyed or damaged. Hence, compared to Slovenia, ice-breaks in Croatia had caused significantly less damage. However, at more less the same time, specific areas in Croatia (Karlovačka County, Zagrebačka County and Sisačko-moslavačka County) had been affected by floods caused by abundant rainfall and water inflows from the Slovenian territory. The floods have activated torrents in forests and consequently caused significant damage on forest infrastructure, notably forest roads.

It is necessary to mention that apart from the economic function, the ice-breaks have completely ruined the aesthetic function of the destroyed forests. Furthermore, these natural catastrophes have also significantly violated forest ecosystem services. Consequently, a state of natural disaster has been declared in all disaster-affected areas in Croatia. Due to the fact that both ice-breaks and floods have affected forest ecosystems in five Croatian Counties at the same time, a team of experts from the Croatian Forest Research Institute and employees from the Croatian Forests have created a Framework for damage estimation of forest ecosystems after natural disasters (ice-

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breaks, floods, torrents). The methodology and results, that is, the estimate of the damage have been presented in this number of the journal in the paper by Vuletic et al. By summarizing the damage estimation due to ice-breaks, floods and torrents, Vuletic et al., have reached an amount of around 940 million € without VAT. Furthermore, the paper also suggests measures for the recovery of affected forest areas.

There is no doubt that the process of recovery of damaged and destroyed forest stands due to ice-breaks will be demanding and long-lasting. However, it is of utmost importance to implement the recovery in a qualitative and timely way. Otherwise, if the damage is not recovered on time, i.e. if the sick or damaged trees which attract various pests (e.g. European spruce bark beetle, Decaying fungi) and diseases are not timely removed from the forest, there is a high risk of their spreading on healthy trees. In Slovenia, an additional problem is the ownership structure of forests. Namely, about 80% of the damaged forests are privately-owned, and a large number of private cadastral plots (around 1.3 million) is complicating the organization and implementation of the extraction and sale of timber material from forests. In order to solve the problem, Slovenia has requested a loan from the European Investment Bank for the establishment of a company on a national level which would deal with the sale of raw material from damaged forest stands. In Croatia, the process of recovery of damaged forest stands started almost immediately after the damage appeared and is currently in its full swing. In Croatia, according to the action plan of the Croatian forests Ltd, the process of recovery should be completed in three years' time. However, the action plan refers only to state-owned forests, while private forests owners have to take care of their own forests.

Dijana Vuletić, Editor-in-Chief
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Review paper

Biological Control of the Invasive *Dryocosmus kuriphilus* (Hymenoptera: Cynipidae) - an Overview and the First Trials in Croatia

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Abstract

Background and Purpose: *Dryocosmus kuriphilus* is a globally invasive insect pest, spreading very quickly in new habitats and making serious damage to sweet chestnut forests in Croatia and in several other European countries. Indigenous parasitoid species trophically associated with oak gallwasps have adapted to this new host but cannot effectively regulate its population density. Classical biological control using parasitoid *Torymus sinensis* has been proven to be the only effective method of controlling the populations of *D. kuriphilus* and has been successfully applied in Japan, South Korea, the USA and Italy. The aim of this review paper is to provide overview and up-to date knowledge about biological control of *D. kurphilus* and to describe first steps of introduction of *T. sinensis* to sweet chestnut forests in Croatia.

Conclusions and Future Prospects: Results presented in this paper show adapted biology and behavioural traits of *T. sinensis* to its host *D. kuriphilus.* The history and results of introductions of *T. sinensis* to Japan, the USA, Italy, France and Hungary are shown. The first report of release of *T. sinensis* to sweet chestnut forests in Croatia is given with discussion on native parasitoids attacking *D. kuriphilus*. Possible negative effects of *T. sinensis* on native parasitoid fauna and risks that could influence the successful establishment of *T. sinensis* in Croatia are discussed. Previous experiences have shown that *T. sinensis* can successfully control the population density of *D. kuriphilus,* slowing down the spread and mitigating negative impact of this invasive chestnut pest and keeping the damage of *D. kuriphilus* at acceptable level. High specificity of *T. sinensis* suggests that it has limited potential of exploiting native hosts but further detailed monitoring of native parasitoid and possible interactions with introduced *T. sinensis* is strongly suggested.

Keywords: *Torymus sinensis, Dryocosmus kuriphilus,* classical biological control, parasitoid, sweet chestnut, host specificity, gallwasp, release

INTRODUCTION

Alien species may become invasive in new environment due to - among other factors - lack of natural enemies [1, 2]. Such an invasive species can spread quickly and have negative influence on native ecosystems. If it attacks economically important plants, the invasion can develop into a serious problem [3]. *Dryocosmus kuriphilus* Yasumatsu (Hymenoptera: Cynipide) is globally invasive species and considered as one of the most damaging pests of sweet chestnuts [4]. During its expansion into new territories it has shown all the typical traits of an invasive species: easy establishment, quick spread and damage [5, 6]. It was first recorded in Croatia in 2010 [7] in Istria and Zagreb area and it spread very quickly to other parts of Croatia [8]. Currently the infestation rates are very high and the pest is spreading to new uninfected areas in Croatia.

Sweet chestnut (*Castanea sativa* Mill.) plays an important role in Croatian forest ecosystems: this is a multipurpose tree used for timber and tannin production, chestnuts are prized and nutritious food, honey is of high quality and it is a valuable landscape and heritage tree [9]. Sweet chestnut trees and forests in Croatia are threatened by two highly invasive species: chestnut blight (*Cryphonectria parasitica* (Murrill) Barr. and *D. kuriphilus* [10, 11]. Chestnut blight fungus has devastated sweet chestnut forests in Croatia and recent research shows that galls of *D. kuriphilus* are facilitating the infection by chestnut blight [12]. These are new negative developments that could worsen the fragile and already weak health status of sweet chestnut forests.

Although within its native range in China *D. kuriphilus* populations are kept at low densities by natural enemies, in Japan, South Korea, the USA, Italy, Slovenia, Croatia, France and Switzerland the attack rates of indigenous parasitoid species are low (typically less than 2%) [5, 13-19]. The parasitoid complex which trophically associates with oak gallwasps (Hymenoptera, Cynipidae, Cynipini) in Europe adapted to the native hosts and parasitoids' phenology differs from that of *D. kuriphilus* and thus these species cannot effectively regulate the population density of the new invasive cynipid, *D. kuriphilus* [20]. Insect communities associated with oak gallwasps, Cynipini, to which *D. kuriphilus* belongs, also include a large number of so-called obligatory cynipid inquilines, Synergini, some of which are lethal to the gall-inducer larvae. No cynipid inquilines were reared from the galls of *D. kuriphilus* yet [18, 21].

Classical biological control using parasitoid *Torymus sinensis* Kamijo (Hymenoptera: Torymidae) has been proven to be the only effective method of controlling the populations of *D. kuriphilus* and has been successfully applied in Japan, South Korea, the USA and Italy [6, 16, 22-25].

The aim of this paper is to provide overview and up-to date knowledge about biological control of *D. kurphilus* so the experiences of the methods used and results achieved in other countries, in as well as outside Europe, can be used in Croatia. First steps of introduction of *T. sinensis* to sweet chestnut forests in Croatia are also presented.

BIOLOGY AND SOME BEHAVIOURAL TRAITS OF *TORYMUS SINENSIS*

T. sinensis is native to China and is the only parasitoid of *D. kuriphilus* known to be host specific and phenologically well adapted to the biology of its host [6, 16, 17, 23, 26, 27]. The parasitoid has one generation per year, as its host, which is quite different to other native polyphagous parasitoid species that are present in the new invaded areas of *D. kuriphilus*. They mostly have more than one generation per year and their phenology and biology, particularly those from the genus *Torymus,* are not closely matched with *D. kuriphilus* [28-31]. *T. sinensis* adults emerge from withered galls, mate and females lay eggs in the newly developed galls of *D. kuriphilus* in spring (mostly late April). Each female can lay 70 eggs on average. The emergence is synchronized with the budburst of sweet chestnut and development of new galls [24]. Females locate the host with a combination of visual and olfactory stimuli from fresh galls and chestnut foliage [32] which could also explain its specificity to *D. kuriphilus.* Parasitoid larva feeds ectoparasitically and pupates in late winter the following year. The parasitoid aestivates as larva, and overwinters as last larval or early pupal stage [33]. Females have pre-ovipositon period of 6 days, during which the mating occurs and additional imaginal feeding is necessary for the egg-load development; females lifespan is 37 days in the field [27]. This life longevity makes them suitable for raising and manipulating in the laboratory prior to release in the field. *T. sinensis* selects the body surface of the host larva for oviposition rather than the chamber wall as observed in other *Torymus* species [27]. According to Piao and Moriya [27] this oviposition behaviour in the selection of the host larva is most probably caused by the adapted ovipositor length of *T. sinensis* to the *D. kuriphilus* gall structure and size compared to other species which makes this parasitoid species more able to exploit the available resources of the host. In Asia and USA *T. sinensis* is able to parasitise larger galls than native parasitoids due to its longer ovipositor [17, 27]. However, this is different in Europe where a number of native *Torymus* species (e.g. *T*. *auratus* (Müller), *T*. *cyaneus* Walker, *T*. *flavipes* (Walker), *T*. *notatus* (Walker)) have the same length of the ovipositor as *T*. *sinensis*, thus they can parasitize the same sized *D*. *kuriphilus* galls as *T*. *sinensis*.

One of the adaptive advantages of *T. sinensis* when compared to other univoltine parasitoids present in the invasion range (e.g. *Torymus beneficus* Yasumatsu & Kamijo) of *D. kuriphilus* is only one emergence period without peaks which makes this species better synchronized with its host. This very fine phenological difference together with other morphological features (ovipositor length) makes *T. sinensis* highly efficient as biological agent against *D. kuriphilus* [34, 35]. In case if mating does not occur, females lay unfertilized eggs, parthenogenetically producing only males [27]. These details should be considered when planning rearing and release to new sites and proper male/female ratio. Personal experience of authors of this paper (A. Quacchia and G. Melika) has shown ability of *T. sinensis* to survive at 15° C when fed with honey up to 4 months. *T. sinensis* also has a specific strategy to survive temporary extinction of its host - a prolonged diapause over 2 years [36] which makes it species specific and less likely to parasitize other members of Cynipidae family (e.g. oak gall wasps, Cynipini).

T. sinensis tracks the expanding populations of *D. kuriphilus* [16, 25]. During the early years of the release, population of *T. sinensis* will disperse very slowly and, over the years, the dispersion will be faster and exponential. Two release sites 8 km away from each other will see the merging of the populations of the parasitoid in 5 years, two sites 20 km apart in 7 years [25, 37].

A study on potential of *T. sinensis* as viable management option for biological control of *D. kuriphilus* [4, 6] has raised some important questions to be further studied and answered: (i) the general risk that *T. sinensis* could shift to native gall wasps related to *D. kuriphilus* and (ii) could hybridize with native *Torymus* species. It was suggested that a host specificity test should be performed for evidence of attack of native oak galls [6]. First tests were done with *T. sinensis* females offering them alternative host galls: *Mikiola fagi* Hartig (Diptera: Cecidomyiidae) developing on *Fagus*, galls of asexual generation of oak gall wasps as *Cynips quercusfolii* Linnaeus (Hymenoptera: Cynipidae) and *Andricus kollari* Hartig (Hymenoptera: Cynipidae) and no oviposition was recorded [24]. These tests were considered insufficient [4, 6] so additional host range tests have been performed [36]. Seven species of oak cynipids (Cynipidae: Cynipini) which occur at similar times in the field as *D. kuriphilus* were tested: *Andricus crispator* (Tschek), *A. curvator* (Hartig), *A. cydoniae* (Giraud), *A. grossulariae* (Giraud), *A. multiplicatus* (Giraud), *Biorhiza pallida* (Olivier) and *Dryocosmus cerriphilus* (Giraud). All the seven mentioned oak gallwasp species are known to have two alternate generations per year; in spring the sexual generations are developing. These species were chosen for the host specificity tests, proposed by EFSA [4] according to their ecological similarity, spatial and temporal attributes and accessibility and availability for *T. sinensis* at the period of parasitation. Few and brief ovipositor pricking were observed on *A. cydoniae, B. pallida* and *D. cerriphilus* but no eggs were laid [36]. These results additionally confirmed the host specificity of *T. sinensis*. *Torymus sinensis* was introduced to the USA in late 70s [16], to Japan in 1979 (reviewed in Aebi et al. [5]), to Italy in 2004 [24]. However, no other host than *D. kuriphilus* was ever mentioned in the literature to be parasitized by introduced *T. sinensis* [38]. The risk assessment of possible shift of *T. sinensis* onto other hosts (native oak gallwasps) was discussed in details in Gibbs et al. [6]. Hybridization of a biological control agent with native species is considered as an environmental risk to non-target species [6]. Till now, the only reported case of *T. sinensis* hybridization is with the native *T. beneficus* in Japan: *T. sinensis* and *T. beneficus* were successfully crossed in the laboratory to produce fertile hybrid females [39]. Hybrids were also detected in the field and their hybrid origin proved with molecular markers [40].

The probability of hybridization with native European *Torymus* species (Hymenoptera: Toymiidae) was tested in mating experiments on *Torymus flavipes (*Walker)*, T. auratus* (Muller)*, T. affinis* (Fonscolombe) *and T. geranii* (Walker). No mate recognition and mating were recorded in the laboratory experiments using these native species [36]. However, these species have potential to hybridize with *T. sinensis* as these closely related species overlap geographically (they may even parasitize identical galls on single chestnut trees), and partially also can overlap in their seasonality. Recently the risk of hybridisation between *T. sinensis* and native *Torymus* species was evaluated by molecularly analysing *Torymus* specimens reared from oak and chestnut galls, collected in Switzerland and Italy. Hybridisation between *T. sinensis* and *T. cyaneus* was documented in only one case [38], however, this result must be confirmed.

BIOLOGICAL CONTROL OF *D. KURIPHILUS* IN JAPAN

The introduction of *T. sinensis* is regarded as a successful case of classical biological control of invasive species in Japan [23] and was the first introduction of *T. sinensis* as biological control agent outside its native range. *D. kuriphilus* arrived in Japan around 1941 and after long years of research of the host and most suitable control measures, 260 mated females of *T. sinensis* were released in 1982 in Ibaraki prefecture [41]. The parasitoid population grew by factor of 25 times by 1989 [23], the parasitoid expanded its range soon after the release, adults being raised more than 12 km from release point showing good dispersal ability. In the first few years the parasitoid spread at rate less than 1 km/year but the speed increased in the following years to app. 60 km/year. Over the years the parasitoid has dispersed naturally several hundred kilometres from the release point (Figure 2) [23]. The infestation rate of *D. kuriphilus* decreased rapidly to tolerable injury level of 30% (Figure 1) [23].

This classical biological control program succeeded in drastically reducing the damage caused by *D. kuriphilus* in Japan [42]. Japanese experience shows that the tolerable injury level from *D. kuriphilus* is about 30% infestation [23]. After the introduction of *T. sinensis* the infestation rates decreased steadily from 43% to less than 1% [23] which is the result of established population of introduced *T. sinensis.*

BIOLOGICAL CONTROL OF *D. KURIPHILUS* IN THE USA

D. kuriphilus was first observed in the USA in 1974 negatively influencing chestnut production and health status of chestnut trees [16]. *T. sinensis* was introduced for biological control, expanding together with its host to

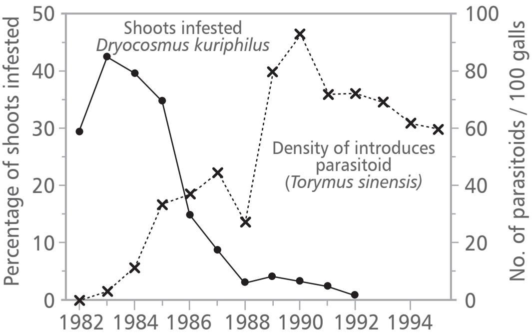

FIGURE 1. Decrease in infestation rate with *Dryocosmus kuriphilus* after the release of *Torymus sinensis* in Japan (source Moriya et al. [42])

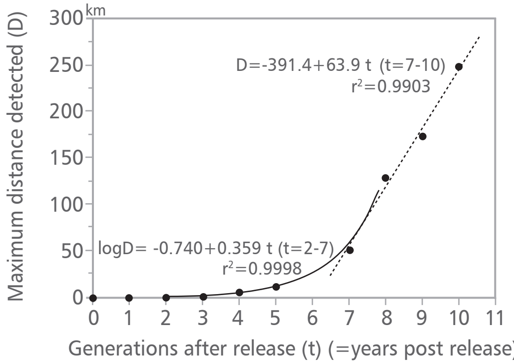

FIGURE 2. Range expansion of *Torymus sinensis*, relationship between the number of generations (t) after the release in Japan (Tsukuba) in 1982 and maximum distance (D) from the release site to the locality where T. sinensis has been detected (source Moriya et al. [22, 23])

new sites [16]. Recent study [17] confirmed that *T. sinensis* is the dominant parasitoid of *D. kuriphilus* in eastern USA. *T. sinensis* was not present in oak galls collected on the sites and it can be considered as specialist on *D. kuriphilus* in North America [17]. Studies [16, 17] have also provided evidence that *T. sinensis* is hyperparasitized by native cynipid parasitoids which could potentially suppress *T. sinensis* populations and influence its potential as biological control agent. At present it is effective control agent of *D. kuriphilus* in the USA [17].

BIOLOGICAL CONTROL OF *D. KURIPHILUS* IN ITALY

D. kuriphilus has been introduced to Italy with infested plants around 2002 and quickly spread through Italian peninsula [43]. First releases of *T. sinensis,* raised from galls imported from Japan, were in 2005 (90 females and 80 males) and 2006 (1 058 females and 889 males) [24]. The increase of parasitoid populations has been exponential, surpassing 90% in 5-7 years after release, which is significantly bigger than the parasitism rate of native parasitoids of 3-5% [25]. The biological control of *D. kuriphilus* is giving visible results in Italy, in Cuneo region (the region of first European infestation by *D. kuriphilus*), where first releases began 5-7 years ago. The parasitisation rates nowadays often exceed 85-90% with a significant reduction of number of infested leaves and shoots. The galls are decreasing in numbers and vegetative growth of chestnut trees is recovering [25].

BIOLOGICAL CONTROL OF *D. KURIPHILUS* IN FRANCE

Based on previous successful operations in other countries, a classical biological control using the parasitoid *T. sinensis* has been implemented in France since 2011 [44]. During the two first years 42 releases of *T. sinensis* were made in different parts of France (one single introduction of 100♀ and 50♂ versus two introductions of 50♀ and 25♂ with a one-year interval per site). First results indicate that even though very few specimens of this biocontrol agents were released, the rate of establishment of *T. sinensis* is high (app. 80%) [44].

BIOLOGICAL CONTROL OF *D. KURIPHILUS* IN HUNGARY

In May 2014, *T. sinensis* was released also in the southwestern part of Hungary, Zala County in two sites (Dobri and Kerkateskánd) where the population of *D. kuriphilus* is rapidly growing [45]. In Dobri were 200 females, while in

Kerkateskánd 100 females previously mated with males in the laboratory conditions were released. The males and females originate from the Cuneo region in Italy (G. Melika, personal comm.).

NATIVE PARASITOIDS OF *D. KURIPHILUS* IN CROATIA AND POSSIBLE NEGATIVE EFFECTS OF *T. SINENSIS* ON NATIVE PARASITOID FAUNA

After the first record of *D. kuriphilus* in Croatia [7] 15 species of native parasitoids have adapted to the new host in few years [18]. The indigenous parasitoids fauna fails to exert sufficient biological control of *D. kuriphilus* and reduction in leaf area and sweet chestnut fruit yield are reported from all attacked areas in Croatia. *Torymus flavipes* was the most abundant species and first to adapt to a new host [18], with two more *Torymus* species (*T. geranii* and *T. auratus*). The biology of native parasitoids differs from that of *T. sinensis*, where native *Torymus* species emerge just before the emergence of *D. kuriphilus* (end of May, early June) [46] and have two generations per year [28-31]. Therefore their development is not entirely synchronized with the phenology of *D. kuriphilus*. Low attack rates of natural parasitoids make therefore *T. sinensis* a viable solution. Visible damage and rapidly expanding pest in Croatian sweet chestnut forests have prompted for initiation of biological control of *D. kuriphilus.* In all invaded sweet chestnut forests in Croatia large and multiple *D. kuriphilus* galls have been found which could also be a reason for low success of native parasitoids but a favourable trait for *T. sinensis* population due to its longer ovipositor and ability to parasitize larger galls [17, 27].

BIOLOGICAL CONTROL OF *D. KURIPHILUS* IN CROATIA

The biological control of *D. kuriphilus* in Croatia has started in spring 2014. Before the release all the necessary aspects and precautions have been considered: host-specificity, effects on non-target species, location of the site of first release, good settlement prospects, gall size (larval stage) and national regulations regarding the introduction of alien bio control species. Approximately 1 300 withered galls have been imported from Italy in March 2014 from two localities i.e. Borgo d'Ale and Torre Canavese in Torino region, where multiple releases of *T. sinensis* occured and high parasitism rates were achieved. The galls were kept at 7°C to delay the emergence of adults and to synchronize it with development of galls in the field. A natural sweet chestnut forest in Pazin (locality Lovrin) (area 12 ha) on Istria Peninsula was chosen as a site of first release of *T. sinensis*. When the *D. kuriphilus* galls started to develop in the field, the withered galls with *T. sinensis* were taken from the fridge and kept at room temperature, until after few days first males and then females started to emerge. They were coupled together (10 females/5 males) in plastic tubes, fed with honey and kept at 15°C in climatic chamber (L:D=12:12) until release. On 11 April 2014, 1 200 females and 600 males were released in Pazin (45.233482N; 13.920008E). This is the first attempt of biological control of a forest pest with introduced bio control agent in Croatia and hopefully the population of *T. sinensis* would be dense enough and parasitism rate high so that Pazin site could be used as a "bank" of *T. sinensis* population for raising adults for the release in other parts in Croatia in the next years.

CONCLUSIONS AND FUTURE PROSPECTS

Release and establishment of *T. sinensis* in Japan, the USA and Italy is an example of successful biological control of an invasive species. However, several risks that could influence the successful establishment of *T. sinensis* should be considered.

Hyperparasitism of *T. sinensis* by native parasitoids could limit the establishment of *T. sinensis* in forest habitats [16, 17].

Throughout Europe, *Eupelmus urozonus* Dalman (Hymenoptera: Eupelmidae) is raised as one of the most common *D. kuriphilus* native parasitoid. This species very often acts as a facultative hyperparasitoid in oak cynipid galls [28]. Thus it is possible that hyperparasitoids can influence the population densities of *T. sinensis* [24], which should be confirmed by further studies.

The sex ratio of first Croatian population of *T. sinensis* should also be monitored as there is a possibility of male-biased sex ratio due to the failure of mating. This can happen when the density of individuals is low and finding a mate is difficult [24].

The failure in establishment due to the mismatch between the emergence of adults and suitable gall development stage can also pose a risk, but this can easily be avoided by regulating the emergence dates of *T. sinensis* by adjusting the emergence and rearing temperature in laboratory. The unavailability of hosts is not expected to be a risk in the establishment *T. sinensis* population as *D. kuriphilus* is present in high densities in Croatia and expanding its range very quickly. Native parasitoids are not able to influence the population density of *D. kuriphilus* [18] in such an extent that it could cause the extinction of *T. sinensis* population.

All previous experiences have shown that *T. sinensis* can successfully control the population density of *D. kuriphilus* (Figure 1) [17, 23, 24]. The synchrony of biology of *T. sinensis* with the biology of its host and ability to disperse into the invading territory with pest population and spread rapidly (Figure 2) make this parasitoid suitable for mitigating negative impact of this invasive chestnut pest as well as keeping the damage of *D. kuriphilus* at acceptable level. High specificity of *T. sinensis* suggests that it has limited potential of exploiting native hosts [36]. However, there is still a possibility of hybridization with native *Torymus* species [6, 38] so we strongly suggest further detailed monitoring of native parasitoids and possible interactions with introduced *T. sinensis* populations and competition of native and introduced parasitoids in Croatia. To assess indirect effects of introduction of *T. sinensis* (i.e. influence on non-target species) molecular methods will be used for identification of potential hybrids of *T. sinensis* with native *Torymus* (if any will be found in Croatia).

There is also a possibility of augmentative biological control [6] using native parasitoids in Croatia. Therefore, the research on native parasitoids and their influence on population densities of *D. kuriphilus* will continue, in first as well as in the last invaded sites so the results and effects can be compared with classical biological control using *T. sinensis.* In conclusion, on the basis of the review of references, an extensive experience of scientists and personal experience of the authors, the use of *T. sinensis* as biological control agent together with the potential of natural parasitoids should be considered the best possible solution to control the invasive pest *D. kuriphilus* in natural sweet chestnut forests in Croatia.

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Growth and Yield of Black Locust (*Robinia pseudoacacia* L.) Stands in Nyírség Growing Region (North-East Hungary)

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Abstract

Background and Purpose: In Hungary the black locust (*Robinia pseudoacacia* L.) can be considered as the most important fast-growing stand-forming exotic tree species. Due to its favourite growing technological characteristics as well as its wood utilization possibilities the present area occupied by black locust stands amounts to 460 thousand hectares. Of its growing districts Nyírség (North-East Hungary) has a distinguished importance where the area of black locust stands is appr. 22 700 hectares. The Nyírség region can also be considered as one of the best black locust growing regions in the Carpathian basin. To determine their growth rate and yield as exact as possible a local numerical yield table has been constructed on the basis of surveys of the experimental plots established in pure, managed black locust stands.

Material and Methods: The local black locust yield table was constructed from data gathered on 105 sampling plots with average area of 1 000 m^2. The total area of the experimental plots was 9.295 ha. In the course of the stand surveys the key stand characteristics were measured, and then, on the basis of data collected, were calculated the average height, diameter (DBH), volume, basal area and stem number given separately for the main (remaining), secondary (removal) and total stands per hectare.

Results and Conclusion: Black locust yield table presented in this paper is the first local one in the history of the Hungarian black locust research. The programmable editing procedure allows extension and formal change of information content of the yield table according to different demands. This type of yield tables (standards) somewhat reflects the local growing-technological (forest tending) characteristics better way, on the other hand refer to the trend of quality and quantity changing of black locust stands growing in a given area.

Keywords: Black locust (*Robinia pseudoacacia* L.) stands, growth, local yield table

INTRODUCTION

Black locust (*Robinia pseudoacacia* L.) was introduced to Europe from its natural range in south-eastern United States more than 300 years ago. It has been well adapted for growth in a wide variety of ecological conditions and planted throughout the world from temperate to subtropical areas. It is fast growing, excellent coppicing, drought tolerant, has high survival rates and yield as well as very hard durable wood. Due to its symbiosis with the nitrogen fixing bacteria, *Rhizobium* sp. black locust is capable of colonising very low nutrient substrates. Black locust is also a promising tree species for short rotation forestry (SRF) including energy plantations. The development of an integrated landscape includes forests, agricultural fields and shelterbelts. In these cases afforestation with black locust is focused on improving the natural environment and the living conditions of the population as well [1, 2].

In Hungary, black locust has played a role of great importance in the forest management for more than 280 years, covering approximately 24% of the forested area (460 000 ha) and providing about 20% of the annual timber output of the country. Being aware of the importance of black locust, forest research in Hungary has been engaged in resolving various problems of black locust management for a long time, and numerous research results have already been implemented in the practice [3-8]. In the country in the lowlands characterized with forest steppe climatic type, the annual precipitation is not more than 500 mm, most of which is outside the growing season. Thus, drought is a frequent phenomenon in the summer period coupled with very high atmospheric temperatures. Due to these facts about 40% of the black locust stands in Hungary grow under marginal site conditions [9, 10]. Several countries have started research programmes on improving black locust wood quality and/or increasing production of biomass for energy purpose. Black locust has also been considered as a promising tree species for animal feeding and for recultivation of drying out devastated lands as well as nectar production.

At present, black locust breeding and improvement is undertaken in the United States [11, 12] Greece [13], Germany [14, 15], Slovakia [16], Poland [17], Turkey [18], India [19, 20], China [21] and South Korea [22]. Increasingly number of countries are interested in black locust improvement and management paying special attention to its response to climate change effects. In the future there are two regions where the fast spread of black locust can be expected. In Europe the Mediterranean countries (Italy, Greece and Turkey), while in Asia China and Korea may become the most prominent black locust growers [23].

On the other hand it can be said that the literature reviews related to the yield and above ground dendromass of black locust stands have primarily domestic aspects [3, 24-27] with moderate international communication [28-31].

MATERIALS AND METHODS

The Nyírség black locust growing district can be found in the north-eastern part of Hungary. The main ecological conditions of the region: forest-steppe climate where the relative air humidity between 50 and 55%, hydrology: free draining, dominant soil type: humus sand soil, annual precipitation varies between 500 and 550 mm. One of the main characteristics of the region is the large temperature fluctuation which is a very typical feature of the continental climate. Besides the cold winters and hot summers the daily variation is also very significant factor.

The yield table was constructed from data gathered on 105 subcompartments (sampling plots) (Figure 1). The sampling plots in pure, managed black locust stands were square shaped, their area 1 000 m^2 on average and their boundaries were marked by lasting white paint. The total area of the experimental plots was 9.295 ha. The following parameters were measured in the plots: number of stems, tree height, dbh (diameter at breast height) over bark. We classified each tree according to their height (1-4) and tending operation (1-3) classes.

On the basis of data, the average height, diameter (DBH), volume (V), basal area (G) and stem number (N) were calculated separately for the main (remaining), secondary (removal) and total stands per hectare.

Stem volume was estimated by the following volume function (Sopp-Kolozs, 2000) [27]:

$$v = 10^{-8} d^{2} h^{1} \left(h/[h-1.3]\right)^{2}$$
$$[-0.6326\, d\, h + 20.23\, d + 0.0\, h + 3034]$$

where

v is stem volume (m^3),

d is diameter at breast height (cm),

h is tree height (m).

In the course of separating the main (remaining) and secondary (removal) stands, the principles and regulations of the national black locust tending operation model were taken into consideration, namely:

a. the ecological conditions and the continuation of basal area and the stem number per hectare close to the optimum at different periods of the growing cycle depending on the growing target,
b. production of the target assortments during the shortest possible time by controlling of certain factors of the stand structure.

TABLE 1. Distribution of the measured stands by age groups

Age group (years)	**Number of stands**	**Rate** (%)
1-5	2	1.9
6-10	10	9.5
11-15	9	8.6
16-20	13	12.4
21-25	13	12.4
26-30	18	17.1
31-35	19	18.1
36-40	10	9.5
41-45	5	4.8
46-50	6	5.7
Total	105	100.0

FIGURE 1. Locations of the sampling plots

The age and origin of the measured stands were identified on the basis of the particular forest management plans (Table 1, 2).

Yield class is called the intensity of height growth of a given stand compared to the all same tree species of the country, from best to worst from I to VI marked by Roman numerals (stands are classified into the yield class I-VI).

TABLE 2. Distribution of the measured stands by yield class [26]

Yield class	**Number of stands**	**Rate** (%)
I	26	24.7
II	36	34.3
III	23	21.9
IV	14	13.3
V	3	2.9
VI	3	2.9
Total	105	100.0

RESULTS

The yield table was constructed from data measured on 105 stands. To control main basic correlation of the yield table construction (mean height of the main stand plotted against the age) further 90 data of the Hungarian Forest Research Institute stand survey made for other purposes were also used. Evaluation of the data proved that as a mean height growth pattern of main stand of the investigated black locust stands can be considered analogous with that of the Hungarian national black locust yield table [26, 32] (Figure 2).

The numerical yield table contains the main stand structural and yield data with respect to the main-, removal and total stands divided into six, equal relative height growth pattern and equal bandwidth yield class (Table 3).

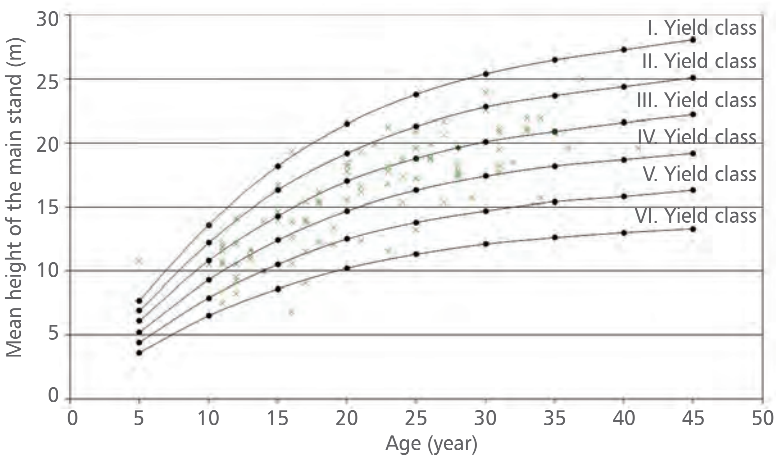


FIGURE 2. Standard deviation of height growth plotted against the age and the mean height of the main stand (Yield classes: Hungarian national yield tables [26, 32])

TABLE 3. Yield table for black locust stands (Nyírség)

Age of stand	Main remaining stand					Removal stand					Total stand					Cummulative volume of intermediate cuttings	Share of intermediate cuttings	Total yield		
	Average		Volume	Basal area	Stem number	Average		Volume	Basal area	Stem number	Average		Volume	Basal area	Stem number			Volume	Mean annual increment	Current increment
yr	m	cm	$m^3 \cdot ha^{-1}$	$m^2 \cdot ha^{-1}$	ha^{-1}	m	cm	$m^3 \cdot ha^{-1}$	$m^2 \cdot ha^{-1}$	ha^{-1}	m	cm	$m^3 \cdot ha^{-1}$	$m^2 \cdot ha^{-1}$	ha^{-1}	$m^3 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	$m^3 \cdot ha^{-1} \cdot yr^{-1}$	$m^3 \cdot ha^{-1} \cdot yr^{-1}$
Yield class I.																				
5	7.7	6.4	33	6.0	1887	5.8	3.4	8	1.5	1587	7.2	5.2	41	7.5	3474	8	19.8	41	8.3	0.0
10	13.6	11.9	84	10.7	963	10.4	8.0	37	4.6	924	13.1	10.2	121	15.4	1887	45	34.7	129	12.9	17.5
15	18.2	16.6	141	14.6	673	13.8	11.5	29	3.0	290	17.6	15.3	169	17.6	963	73	34.3	214	14.3	17.0
20	21.5	20.6	194	17.8	535	16.4	14.0	23	2.1	138	20.8	19.4	217	19.9	673	97	33.2	291	14.5	15.4
25	23.8	23.8	241	20.4	457	18.2	15.8	18	1.5	78	23.1	22.8	259	21.9	535	115	32.2	356	14.2	13.0
30	25.4	26.5	280	22.4	407	19.4	17.0	14	1.1	50	24.7	25.6	294	23.6	457	129	31.5	409	13.6	10.6
35	26.5	28.8	312	24.2	373	20.2	17.8	11	0.8	34	25.8	28.0	323	25.1	407	140	30.9	452	12.9	8.7
40	27.3	30.8	341	25.8	347	20.8	18.4	9	0.7	26	26.6	30.1	350	26.5	373	149	30.4	490	12.3	7.6
45	28.1	32.8	369	27.3	323	21.4	19.0	9	0.7	24	27.3	32.1	378	28.0	347	158	30.0	527	11.7	7.5

TABLE 3. Yield table for black locust stands (Nyírség) - continuation

Age of stand	Main remaining stand					Removal stand					Total stand					Cummulative volume of intermediate cuttings	Share of intermediate cuttings	Total yield		
	Average		Volume	Basal area	Stem number	Average		Volume	Basal area	Stem number	Average		Volume	Basal area	Stem number			Volume	Mean annual increment	Current increment
yr	m	cm	$m^3 \cdot ha^{-1}$	$m^2 \cdot ha^{-1}$	ha^{-1}	m	cm	$m^3 \cdot ha^{-1}$	$m^2 \cdot ha^{-1}$	ha^{-1}	m	cm	$m^3 \cdot ha^{-1}$	$m^2 \cdot ha^{-1}$	ha^{-1}	$m^3 \cdot ha^{-1}$	%	$m^3 \cdot ha^{-1}$	$m^3 \cdot ha^{-1} \cdot yr^{-1}$	$m^3 \cdot ha^{-1} \cdot yr^{-1}$
Yield class II.																				
5	6.9	5.7	28	5.4	2126	5.2	2.8	6	1.1	1802	6.5	4.6	34	6.5	3928	6	17.4	34	6.8	0.0
10	12.2	10.6	70	9.7	1085	9.3	6.9	28	3.9	1041	11.7	9.0	99	13.6	2126	34	32.8	105	10.5	14.2
15	16.3	14.9	117	13.2	758	12.4	10.0	23	2.6	327	15.7	13.6	140	15.7	1085	57	32.9	174	11.6	13.9
20	19.2	18.4	161	16.0	603	14.6	12.3	18	1.8	155	18.6	17.3	180	17.9	758	76	31.9	237	11.8	12.5
25	21.3	21.3	200	18.4	515	16.2	13.9	14	1.3	88	20.7	20.4	214	19.7	603	90	31.1	290	11.6	10.6
30	22.8	23.7	232	20.3	459	17.3	15.0	11	1.0	56	22.1	22.9	243	21.3	515	101	30.4	333	11.1	8.6
35	23.7	25.7	258	21.8	420	18.1	15.7	9	0.8	39	23.0	25.0	267	22.6	459	110	29.9	368	10.5	7.0
40	24.4	27.6	282	23.3	391	18.6	16.3	7	0.6	29	23.7	26.9	289	23.9	420	118	29.4	399	10.0	6.2
45	25.1	29.4	305	34.7	364	19.2	16.8	7	0.6	27	24.4	28.7	312	25.3	391	125	29.1	430	9.5	6.1
Yield class III.																				
5	6.1	5.0	24	4.8	2431	4.6	2.2	4	0.8	2070	5.7	4.0	28	5.6	4501	4	14.3	28	5.5	0.0
10	10.8	9.4	58	8.6	1241	8.2	5.8	21	3.2	1190	10.3	7.9	79	11.8	2431	25	30.3	83	8.3	11.1
15	14.3	13.1	95	11.7	867	10.9	8.5	17	2.1	374	13.8	11.9	113	13.9	1241	43	30.9	138	9.2	11.0
20	17.0	16.3	131	14.3	689	12.9	10.6	14	1.6	178	16.4	15.3	145	15.8	867	57	30.3	188	9.4	9.9
25	18.8	18.8	162	16.4	588	14.3	12.0	11	1.1	101	18.2	18.0	173	17.5	689	68	29.7	230	9.2	8.4
30	20.1	20.9	188	18.1	525	15.3	12.9	9	0.8	63	19.4	20.2	196	18.9	588	77	29.0	264	8.8	6.9
35	20.9	22.7	209	19.5	481	16.0	13.6	7	0.6	44	20.3	22.1	216	20.1	525	64	28.6	292	8.4	5.6
40	21.6	24.3	228	20.8	447	16.4	14.1	6	0.5	34	20.9	23.7	233	21.3	481	89	28.2	317	7.9	4.9
45	22.2	25.9	247	22.0	417	16.9	14.5	6	0.5	30	21.5	25.3	252	22.5	447	95	27.8	342	7.6	4.9
Yield class IV.																				
5	5.2	4.4	19	4.2	2834	3.9	1.6	2	0.5	2453	4.9	3.4	22	4.7	5287	2	10.5	22	4.3	0.0
10	9.3	8.1	47	7.5	1447	7.1	4.7	15	2.4	1387	8.9	6.7	62	10.0	2834	17	27.1	64	6.4	8.5
15	12.4	11.4	76	10.3	1010	9.4	7.1	13	1.7	437	11.9	10.3	89	12.0	1447	30	28.4	106	7.1	8.4
20	14.7	14.1	104	12.5	803	11.2	8.8	10	1.3	207	14.2	13.2	114	13.8	1010	41	28.1	144	7.2	7.6
25	16.3	16.3	128	14.3	686	12.4	10.1	8	0.9	117	15.7	15.6	136	15.3	803	49	27.6	177	7.1	6.5
30	17.4	18.2	148	15.8	612	13.3	10.9	6	0.7	74	16.8	17.5	154	16.5	686	55	27.2	203	6.8	5.3
35	18.2	19.7	164	17.1	560	13.8	11.5	5	0.5	52	17.6	19.1	169	17.6	612	60	26.9	225	6.4	4.3
40	18.7	21.1	179	18.2	521	14.2	11.9	4	0.4	39	18.1	20.6	183	18.6	560	65	26.5	244	6.1	3.8
45	19.2	22.5	194	19.3	486	14.6	12.3	4	0.4	35	18.6	22.0	198	19.7	521	69	26.2	263	5.8	3.8
Yield class V.																				
5	4.4	3.7	15	3.6	3388	3.3	1.0	1	0.2	2964	4.1	2.8	16	3.8	6352	1	6.0	16	3.3	0.0
10	7.9	6.9	36	6.5	1730	6.0	3.6	10	1.7	1658	7.5	5.5	46	8.2	3388	11	22.7	47	4.7	6.1
15	10.5	9.6	57	8.8	1208	8.0	5.6	9	1.3	522	10.1	8.6	67	10.1	1730	19	24.8	78	5.2	6.2
20	12.5	11.9	79	10.7	961	9.5	7.1	7	1.0	247	12.0	11.1	87	11.7	1208	27	25.0	106	5.3	5.6
25	13.8	13.8	97	12.3	820	10.5	8.1	6	0.7	141	13.3	13.1	103	13.0	961	32	24.9	130	5.2	4.8
30	14.7	15.4	113	13.6	732	11.2	8.9	4	0.5	88	14.2	14.8	117	14.1	820	37	24.7	149	5.0	3.9
35	15.4	16.7	125	14.6	670	11.7	9.3	4	0.4	62	14.8	16.2	129	15.1	732	40	24.5	165	4.7	3.2
40	15.8	17.9	136	15.6	623	12.0	9.7	3	0.3	47	15.3	17.4	139	15.9	670	43	24.2	179	1.4	2.8
45	16.3	19.0	147	16.5	581	12.4	10.0	3	0.3	42	15.7	18.6	150	16.9	623	46	24.0	193	4.3	2.8
Yield class VI.																				
5	3.6	3.0	12	3.0	4200	2.7	0.4	0	0.0	3742	3.3	2.2	12	3.1	7942	0	1.4	12	2.4	0.0
10	6.5	5.6	27	5.4	2144	4.9	2.5	5	1.0	2056	6.1	4.4	32	6.4	4200	5	16.7	33	3.3	4.1
15	8.6	7.9	43	7.3	1497	6.5	4.2	5	0.9	647	8.2	7.0	48	8.2	2144	11	19.8	54	3.6	4.2
20	10.2	9.8	58	8.9	1191	7.7	5.4	5	0.7	306	9.7	9.0	63	9.6	1497	15	20.8	73	3.7	3.9
25	11.3	11.3	71	10.2	1017	8.6	6.2	4	0.5	174	10.8	10.7	75	10.7	1191	19	21.0	90	3.6	3.3
30	12.1	12.6	82	11.3	907	9.2	6.8	3	0.4	110	11.6	12.1	85	11.7	1017	22	21.1	104	3.5	2.7
35	12.6	13.7	91	12.2	831	9.6	7.2	2	0.3	76	12.1	13.2	93	12.5	907	24	21.0	115	3.3	2.2
40	13.0	14.6	98	13.0	772	9.9	7.5	2	0.3	59	12.5	14.2	100	13.2	831	26	21.0	125	3.1	2.0
45	13.3	15.6	106	13.7	720	10.1	7.8	2	0.2	52	12.8	15.2	108	14.0	772	28	20.8	134	3.0	2.0

Editing procedure of the yield table in the order of columns is the following:

1. Age of stand (A),
2. H_m = average height of main (remaining) stand (height of dominant and co-dominant trees) in m:

$$H_{m\%} = 0.07940 + 7.19170 \cdot A - 0.16029 \cdot A^2 + 0.00130 \cdot A^3$$

(base age: 25 year, where $H_{m\%}$ = 100)

3. D_m = average DBH of main (remaining) stand in cm:

$$Dm = (78.78434 + 0.84862 \cdot A)H_m / 100$$
$$(r = 0.799, n = 105)$$

4. V_m = volume of main (remaining) stand in $m^3 \cdot ha^{-1}$:

$$V_m = BA_m \cdot H \cdot F$$

where H x F = form-height quotient

$$H \ x \ F = 2.52726 + 0.39091 \ Hm,$$
$$(r = 0.989, n = 105)$$

5. BA_m = basal area of main (remaining)stand in $m^2 \cdot ha^{-1}$:

$$BA_m = \frac{D \cdot \Pi}{4 \cdot 10000} \cdot N_m$$

6. N_m = stem number of main (remaining) stand in ha^{-1}:

$$N_m = e^{9.52993 - 1.07376 \ln D}$$
$$(r = 0.952, n = 105)$$

7. H_r = average height of removal stand in m:

$$H_r = -0.08079 + 0.76572 \cdot H_m$$
$$(r = 0.941, n = 105)$$

8. D_r = average DBH of removal stand in cm:

$$D_r = -2.39714 + 0.76294 \cdot H_m$$
$$(r = 0.939, n = 105)$$

9. V_r = volume of removal stand in $m^3 \cdot ha^{-1}$:

$$V_r = BA_r \cdot H \cdot F_m$$

10. BA_r = basal area of removal stand in $m^2 \cdot ha^{-1}$:

$$BA_r = \frac{D_r^2 \cdot \Pi}{4 \cdot 10000} \cdot N_r$$

11. N_r = stem number of removal stand computed from reduction of stem number of main crop in five year intervals in ha^{-1}
12. H_t = average height of total stand in m:

$$H_t = -0.28441 + 0.98240 \cdot H_m$$
$$(r = 0.998, n = 105)$$

13. D_t = average DBH of total stand in cm:

$$D_t = \frac{BA_t \cdot 10000}{N_t \cdot \Pi} \cdot 2$$

14. V_t = volume of total stand in $m^3 \cdot ha^{-1}$:

$$V_t = V_m + V_r$$

15. BA_t = basal area of total stand in $m^2 \cdot ha^{-1}$:

$$BA_t = BA_m + BA_r$$

16. N_t = stem number of total stand in ha^{-1}:

$$N_t = N_m + N_r$$

17. Cumulative volume of intermediate cuttings = total volume of removing stands in $m^3 \cdot ha^{-1}$
18.
$$\mathrm{SIC} = \frac{\mathrm{CVIC}}{\mathrm{CTV}} \cdot 100 \ (\%)$$

where

SIC - share of intermediate cuttings
CVIC - Cumulative volume of intermediate cuttings
CTV - Cumulative total volume

19. Cumulative total volume ($\sum V_t$) = volume of total stand (V_t) in age A + volume of removal stand (V_r) in age A-5 in $m^3 \cdot ha^{-1}$
20. Mean annual increment of cumulative total volume = ($\sum V_t$) · A^{-1} in $m^3 \cdot ha^{-1} \cdot yr^{-1}$
21. Current increment of cumulative total volume = one year increment of (∑Vt) in five year intervals in $m^3 \cdot ha^{-1} \cdot yr^{-1}$.
22. When using the yield table for determining

the actual volume per ha (Vact) of a stand, a basal area ratio is to be recommended:

$$V_{act} = V_{tab} \cdot BA_{act} \cdot BA_{tab}^{-1}$$

where:

V_{tab} = volume of the stand by yield table according to the age and yield class,
BA_{act} = actual basal area of the stand per ha,
BA_{tab} = basal area by yield table according to the age and yield class of the stand.

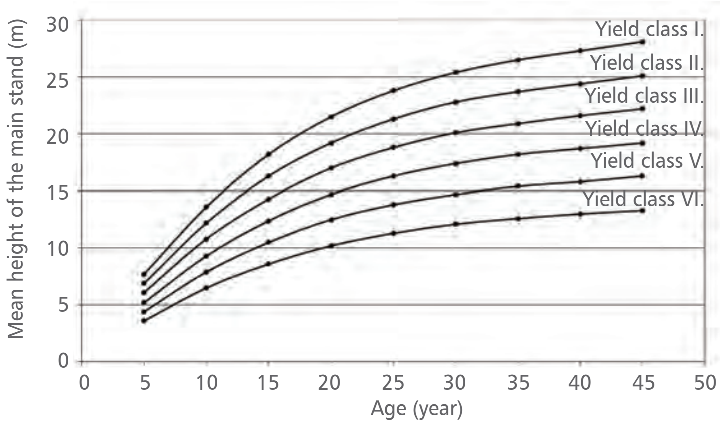
For determining the actual basal area the stem number and the diameter at breast height can be used by calculation or by using one of the known measuring devices directly.

The rates of percentage difference related to the stem number of main stand in decreasing order of yield classes (with its deterioration) at age of 30 is the following: 92.3 – 91.4 – 90.1 – 89.6 – 88.5 – 87.1. The main correlations of the yield table are presented in graphical form, too.

Figures 3.a to 3.e show the height, DBH, and volume indices for main stand as well as the total volume and the mean annual increment of total volume indices in function of age and yield class.

FIGURE 3. a-e. Data of stand structure and yield of black locust (*Robinia pseudoacacia* L.) stands as a function of the age

a)



b)

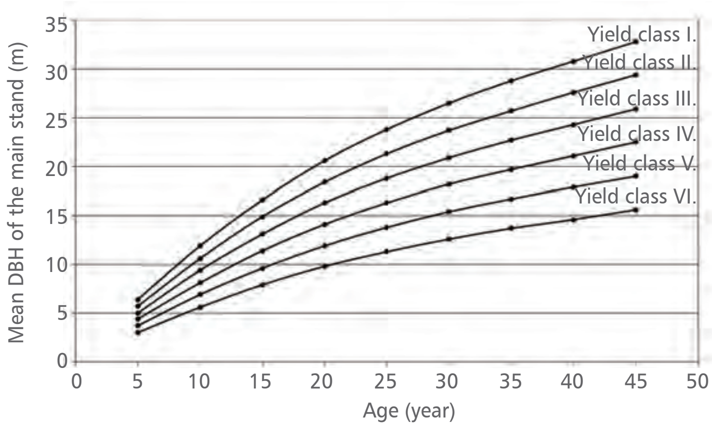
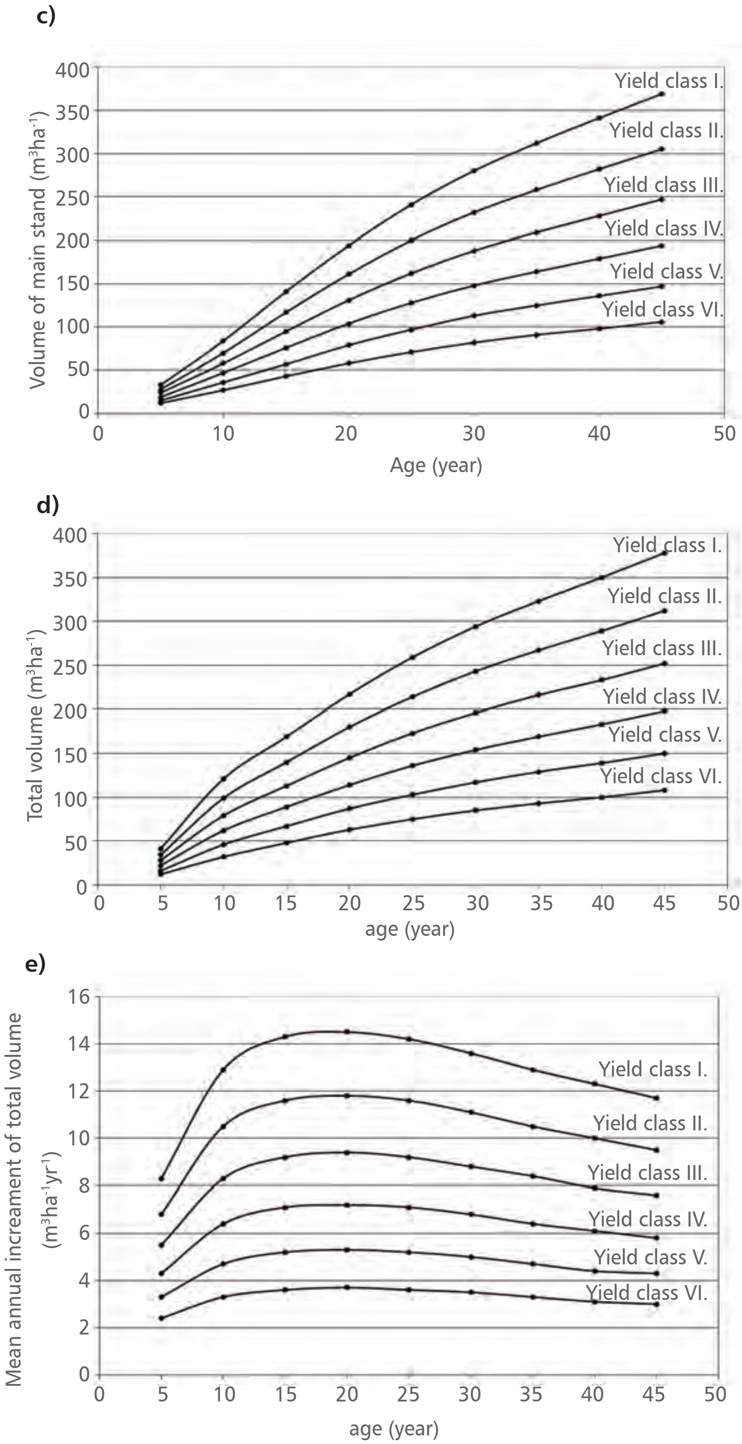


FIGURE 3. a-e. Data of stand structure and yield of black locust (*Robinia pseudoacacia* L.) stands as a function of the age - continuation



DISCUSSION AND CONCLUSIONS

Height = f (age) is the fundamental relationship for the construction of the yield table presented in this paper. It states that forest stands at a given site follow a particular height development with age. The stand age – stand height scatter plot obtained from the monitoring plot data is divided into a number of height curves, which form the basis for the yield table construction. As the height curves are used for assigning stands to site quality classes-site index (yield classes) we also call the above-mentioned relationship the yield classes assigning one. Despite some resistance in the beginning, the use of stand age and height for the estimation of stand productivity has become so prevalent that the concepts site index and yield class are rarely distinguished from one another today. The yield table constructed by us can be regarded as a "traditional standardised computer supported yield model" where the stand development was modelled from stand level data. Black locust yield table presented in this paper is the first local work in the history of the Hungarian black locust research. The programmable editing procedure allows extension and formal change of information content of the yield table according to different demands. This type of yield tables (standards) somewhat reflects the local growing-technological (forest tending) specialities better way, on the other hand refer to the trend of quality and quantity changing of black locust stands growing in a given area. This fact has already been proved by the Hungarian forest inventory practice.

The yield table can be successfully utilized in the following fields:

- appraisal of statistical nature of the black locust stands,
- harvest scheduling of black locust stands, implementing the volume estimations,
- elaborating and further developing silvicultural (tending operation) models for black locust stands,
- elaborating and explaining the guidelines of the tree species policy and,
- evaluation of sprouting criterion of black locust stands based on yield.

In the past decades some new methods have been developed for construction of yield models. Individual-tree, small area or gap, matter balance as well as landscape models have primarily served as research tools to date [33]. But most of this type models can be characterized with increasing demand for information about the reaction of forest ecosystems to changing ecological conditions which needs much more comprehensive research than we have done until now.

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Original scientific paper

Forest Strategy in Republic of Macedonia: Barriers to Effective Implementation

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Abstract

Background and Purpose: In recent years, implementation of forest strategies and programs has been acknowledged as an important phase of the forest policy process. Forest policies such as conflict management concepts between deferent interests of stakeholders, are a dynamic route that needs to be managed carefully to achieve its goals. Creation of the forest policy document entitled "Strategy for sustainable development of forestry in Republic of Macedonia" was introduced for the first time in 2005 as cooperation between the Government and United Nations Food and Agriculture Organization (FAO). Action Plan was brought in the same year including the strategy and validity until the end of the year 2009 now is out of date for undetermined reasons, due to lack of analysis of the level of implementation, monitoring and evaluation.

Materials and Methods: Through exploratory qualitative method using a case study, this paper attempts to explore different stakeholders perception of the most common barriers for implementation of the Strategy for sustainable development of forests in Republic of Macedonia and ascertain if implementation variables are identified as barriers in the implementation stage.

Results: The research showed that environmental and organisational barriers such as legal restrictions, political willingness, social change, control, leadership and clear responsibility are the most common barriers impeding forest strategy implementation in Macedonia.

Conclusions: The paper concluded that the three year action plan was too ambitious, given the existing human and technical capacities in the forestry sector, recommending participation of all included stakeholders in the implementation as an important fact in overcoming the current barriers and moving forward the process.

Keywords: forest strategy, implementation barriers, organizational structure, environment, change management

INTRODUCTION

Strategic management consists of the analysis, decisions, and actions an organization undertakes in order to create and sustain competitive advantages [1].

The study of strategic management is concerned with the relationship between an organisation and its environment in order to be successful [2, 3]. However, the strategies will not benefit organisations unless implemented successfully [4]. Although the importance of strategy implementation is widely acknowledged, strategy implementation remains a process, which is poorly understood [4].

Creation of the forest policy document in Macedonia was introduced for the first time in 2005 as cooperation between the Government and the Food and Agriculture Organisation of the United Nations (FAO). The process started with a project entitled "Institutional development and capacity building in forestry and forest industry sub-sectors" for duration of one year resulting in a document named "Strategy for sustainable development of forestry in the Republic of Macedonia" with Action Plan. Following the course where national forest policy facilitates communication, coordination and collaboration across government, non-governmental organisations and the public [5], the formulation process was assessed as open, participatory and transparent by all parties included, in as much as "mutually accepted forest policy builds a sense of joint ownership, which is essential for its implementation" [5].

Social and political changes in the Republic of Macedonia brought by shifting from centrally oriented to market economy in a relatively young democracy along with Governmental aspirations for European Union integration, inevitably required addressing priorities and responding to new realities. The Strategy reflects forestry described needs of all stakeholders, in line with national development, environmental action plans and European Union standards, and serves as a guideline on how to sustainably conserve and manage forest resources for their contribution in the society.

Action Plan brought in the same year with the Strategy and valid until the end of the year 2009 is now out of date and its implementation stage is unknown due to lack of analysis of the level of implementation, presence of neither monitoring nor evaluation. Shifts in social and demographic trends, along with changes in economic, environmental, technological and political contexts, inevitably require that policy respond to new realities, risks and opportunities [5].

The terms "policy" and "strategy" are frequently used interchangeably [5]. Certain countries use the term "strategy" to specify forest policies, and others "national forest programs" to define strategic base for forest policy. In countries in the South Eastern Europe region, (for example in Serbia, Croatia, Montenegro, Bulgaria, Albania), national forest programs, and forest policies or in some cases named strategies, are developed. However, analysis of the level of implementation or effectiveness is lacking. The reasons are unknown and insufficiently researched.

Through the research question "What are the barriers that impeded effective Forest Strategy implementation in Republic of Macedonia?" this paper will explore different stakeholders perception of the most common barriers for implementation of the Strategy for sustainable development of forests in Republic of Macedonia and ascertain if implementation variables are identified as barriers in the implementation stage. The implementation process is one of the most important aspects of strategic management because "effective strategies are of no value if they are not properly executed" [1].

Implementation stage is important and considered as one of the instruments to achieve the goals prescribed in the formulation part of the Strategy. Even though all three stages of the strategic process (analysis, formulation and implementation) are equally important, scientific literature [6] showed that the implementation stage is least researched and explored.

MATERIALS AND METHODS

The focus of this paper is exploratory, based on existing studies done in the area of strategy implementation. As this research intends to explore the area of strategy implementation where there appear to be an inadequate understanding of the phenomena [7], qualitative method is a suitable approach for it.

Case studies are exploratory [8] and may also be developed to explain, in comprehensive detail, how or why a particular phenomenon came into being [8]. Yin [9] defines a case study as an "empirical enquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used".

Therefore, a case study of the implementation of the Strategy for forestry in Macedonia was prepared to answer the research question by gathering, from multiple sources and methods, as much data as possible of the phenomena being researched.

Triangulation

In social science research, the inclusion of multiple perspectives (i.e. triangulation) contributes to achieving a more comprehensive and accurate accounting of the issue under investigation.

Triangulation can be accomplished through utilizing multiple methodologies (thereby employing both deductive and in-ductive reasoning) (e.g., telephone survey and key informant interviews), datasets (e.g., census data and historical records), observers from varied perspectives, and / or analysis at multiple scales (e.g., individual, group, region) [8].

In order to enhance confidence of the research findings, the research employs literature review, conducting semi structured interviews and secondary data analysis. The review of scholarly articles in the field of strategic and policy implementation provided the theoretical and conceptual framework and aided the formulation of the research question.

A questionnaire was assembled and semi-structured interviews with open-ended questions were conducted with the identified stakeholders. Secondary data source were compared with the results and provided validations for the research.

Semi Structured Interviews

The process involved identifying key individuals and involving them in structured exercises designed to elicit their views on the researched topic.

Intended research sample was found with all parties included in the process of creation and implementation of the Strategy, such as governmental bodies, research institutions, nongovernmental sector, public enterprises, national parks etc. (heads of units, middle management and top level management).

The questionnaire for the interview was designed to answer the research question - to identify the barriers for successful Strategy's implementation.

Interviews were conducted with nine members of the projects' Steering Committee and Working Group at the time of formulation of the Strategy. All participants are employed in different forestry and forestry related institutions or projects, and are on different management level in the respective organisations. Several of them were also included in the implementation stage of the Strategy. Table 1 provides list of interviewees' professional background and working institution.

After the ninth interview, no new information appeared therefore, in order to avoid repetition; the researcher concluded the process of gathering data (saturation principle). The interviews were anonymous, and coded names were used for each participant.

Secondary Data

In addition to interviews, secondary data were another source of data used for this research. Internal data such as different documents, emails, presentations, minutes from meetings and workshops, implementation documents, etc. presented source for analysing from the period of the formulation process. Most of these data were found in the former project office (FAO Office) and the Ministry for Agriculture, Forestry and Water Management, Department for Forestry as implementing body of the project.

Total of forty-six documents in form of reports, minutes and presentations in the process of formulation of the Strategy were considered in the method of secondary data analysis.

Specific Methods for Data Analysis

During the interviews, notes were made, recording observations and thoughts on each of the interviews. After each interview, a transcript of the interview was typed and specific dates were set. These transcripts were then converted into text files so that a computer program MaxQDA could process them. MaxQDA is a type of Qualitative Data Analysis software that supports all individuals performing qualitative data or content analysis by helping to systematically evaluate and interpret textual data. As the secondary data were found in text files form, the MaxQDA software was also used for analysis.

The data were organised using an objective coding scheme. Each code was assigned to selected segments of text. Codes and sub codes were ordered into a hierarchical structure for better visualisation.

THEORETICAL BACKGROUND

Strategy Implementation Framework

Strategy implementation is defined as the communication, interpretation, adoption, and enactment of strategic plans [10]. Analysing the literature in the field of strategy implementation, Yang Li et al [6] define strategy implementation as a dynamic, iterative and complex process, which is comprised of a series of decisions and activities by managers and employees affected by a number of interrelated internal and external factors to turn strategic plans into reality in order to achieve strategic objectives.

Policies that work in practice need to be designed with implementation in mind [5].

TABLE 1. Institution and background of the interviewees

Interviewee	Institution	Background	Date of the interview
1	International non-Governmental Organisation	Forestry consultant	27.2.2012
2	Ministry for Agriculture Forestry and Water Economy	Forestry officer	28.2.2012
3	Ministry for Agriculture Forestry and Water Economy	Forestry officer	28.2.2012
4	Public Enterprise “Macedonian Forests”	Forest management	29.2.2012
5	Forestry Faculty	Professor	2.03.2012
6	FAO Project Office	Forestry consultant	9.03.2012
7	FAO Project Office	Forestry consultant	11.03.2012
8	Forestry Faculty	Professor	13.03.2012
9	Forestry Faculty	Professor	13.03.2012

This requires agreement on the approach and on responsibilities as well as flexibility on the methods to achieve objectives. It also needs an understanding on funding and on re-aligning legal and institutional frameworks with the new or amended policy [5].

Key authors in the field of strategic management have developed different implementation frameworks. Studies concluded that the most commonly occurring strategy implementation problems among others are: uncontrollable external factors, inadequate leadership and direction by departmental managers, co-ordination of implementation not effective enough and major problems which surfaced that had not been identified earlier [11].

In a study of senior managers six key barriers to strategy implementation are identified: top down or laissez-faire senior management style; unclear strategy and conflicting priorities; an ineffective senior management team; poor vertical communication; poor co-ordination across functions, business or borders; and inadequate down-the-line leadership skills and development [12].

A comprehensive list of implementation frameworks, highlighting significant implementation variables researched by key auth-ors [13] identifies ten common variables: strategy formulation, environmental uncer-tainty, organisational structure, culture, operational planning, communication, resource allocation, people, control and outcome [13]. Researchers have originally been classified these variables into categories such as “content”, “context”, “process” and “outcome” [13], however, the classifications are not fixed on what is included in which categories. If the variables are important to the success of strategy implementation, and not accomplished well, they could become obstacles to implementation. The frameworks emphasise the continuous interactions among these variables and it is believed that it is these on going interactions, which make implementation possible [13].

The research will take an approach considering that the environmental and organizational structure variables may potentially be barriers to the process of strategy implementation.

Environment as a variable can exist from external or internal nature. If there are significant changes in the environment, reaction is needed if effective implementation of the strategy is a high priority. The implementation process itself makes environment uncertainty and a possible barrier to strategy implementation. Ignorance or inabi-lity to determine and recognise environ-mental changes will possibly lead to strategy’s non-performance in the implementation stage.

Organisational structure is one variable which management can adapt to lead the organisation to its desired goals and objectives [14]. Organisational performance is based on ensuring a fit between strategy and structure. In order for strategy to create superior performance, it must be complemented by appropriate organisational characteristics and employee behaviours. [15].

Change Management

Due to the lack of literature in strategy implementation, change management theory is useful in providing a theoretical base for this research.

Change to organisations implies persuading people to abandon their existing beliefs and values and the behaviours that stem from them and adopt new ones [16]. There are several aspects in change management [17] and studies of strategic change illustrate its complexity: the political battles, the cultural barriers, the inertia of organisation structures, and systems and the bounded rationality of managers [18]. This complexity and several potential problems associated with the strategy itself, the way it was developed, or the management of the change process makes realising strategy an extremely difficult task [18]. The challenges presented in managing change are very similar to those of implementing strategy.

Lewin’s Freeze Phases explains change involving a move from one static state, via a state of activity, to another static status quo [19]. All this via a three-stage process of managing change: unfreezing, changing and re- freezing [19].

Kotter's eight-step strategy for change management consists of: establish a sense of urgency; create the guiding coalition; develop a vision and strategy; communicate the change vision; empower employees for broad- based action; generate short-term wins; consolidate gains and produce more change; and anchor new approaches in the culture [20].

The demand for creation of the Forest Strategy in Macedonia and the manner in which was created is derived from a real need for forest policy change which in the case of Macedonia, was externally driven. For example, a participatory approach in decision-making process was introduced for the first time. It further introduced new relations, communications and collaboration between involved stakeholders. The document prescribes deliberate course of actions, which needs to be implemented for the purpose of achieving the overall objectives. It also relates to what happens on a local level: the document is worth nothing unless it results in actual change.

RESULTS

Common Barriers to Strategy Implementation

In this section, interviewee's findings of barriers of strategy implementation are presented. Participants were asked to identify barriers that in their perspective impede Strategy's implementation in Macedonia. The transcript's software analysis ranked identified barriers based on numbers of codes:

Throughout the analysis, new sub-codes emerged based on responses from the transcripts, specifying each code in more details. The following matrix presents the coding and sub-coding tree with frequencies of presence in interviews analysis. Frequencies of a certain code are presented by square where, the bigger the square is, the bigger the presence of a code or sub code is in the transcripts.

In the following sections, the results of each barrier will be presented together with detailed outcomes of the sub-codes.

Environment

Most of the participants in this research identified the environment as the biggest barrier in the implementation of the Strategy. Sub codes that the interviewees identified were: legal restriction, political change, political will and social change. Almost all respondents indicated the lack of political willingness for implementation as the greatest barrier for effectiveness.

"The political support and will that existed in the process of formulation, even with the change of the political structure at the beginning of the implementation process in 2006, melted and disappeared in 2007."

Respondents referred to the decision at the end of the process of formulation: the Ministry for Agriculture, Forestry and Water Economy is responsible for Strategy's implementation. As one interviewee explained, this is a Governmental document and it is their responsibility to implement all proclaimed strategic documents. Politics has vast influence, especially in the complex organisational structure such as the Ministry

TABLE 2. Identified barriers based on number of segmented codes in the transcripts

Identified barrier	Number of segmented codes
Environment	48
Organisational structure	48

FIGURE 1. Code and sub-code tree with frequencies of presence in the transcripts

for Agriculture, Forestry and Water Economy, where several departments are competing and lobbying to obtain higher segment from the national budget.

"What was planed to be implemented as actions, financed by the state budget, is done. But, what needs external investments is not implemented due to someone's political will." Responsible people are now in a status quoi position, keeping their heads down. There is no control mechanism to react to bad political decisions".

Another important notice is that two months after the Strategy's governmental proclamation, parliamentary elections occurred with change in the political structure. Participants were asked if this change influenced the implementation process however most of the answers were uncertain. Still, they all agreed that the implementation of the Strategy is not on the agenda of the current Government.

Looking at the situation from this perspective, the interviewees highlighted that the previous Governmental structure pushed the proclamation of the Strategy to occur before the elections, for gaining political points. It is a situation where the responsibility over the implementation is lost. The respondents expressed their view that the political influence falls only upon those actions that refers to institutional reforms, such as the transformation of the forest public enterprise and creation of a separate agency for forestry as an independent body in the Government.

Identified as one of the key element for successful formulation, the participants in the formulation-working group were coming from different political parties.

The secondary data analysis showed the political change and legal restrictions to have an influence in the implementation process. Project reports, issued after the official proclamation, stated the expectation to have personnel changes in the head management team after the change of the Government, predicting a period of uncertainty and inactivity of the forestry administration. Also, the position of the National Coordinator of the project, coming from the head of the forestry department in the Ministry was unstable. Hence, an extension of the project was demanded in order to finalise important planned activities such as the Donor Table meeting.

Regarding legal restrictions as a barrier for implementation, participants believed that several changes in the legislation are needed in different sectors, for example in the public procurement. Another view is expressed in the following statement: "The Strategy was proclaimed at the governmental level, and not in the Parliament, therefore it is not legally binding. Fiscal implications are missing for successful implementation".

Likewise, secondary data analysis showed the need of forest legislation revision in several segments for more efficient Strategy implementation. To follow the proposed institutional reforms stated in the Strategy, new legal adoption would need to succeed.

The social change, especially in the transition period of the country, also played a part in the implementation. As some of the interviewees explained, over-employment, inadequate qualifications for high positions and political influence for distribution of personnel resulted in negative impacts in the implementation stage.

Organisational Structure

Additional barrier identified by the participants in this research is the organisational structure with the following sub codes: leadership, formation of the implementation body, control and clear responsibility.

Members of the formulation-working group stated lack of leadership as the most common barrier in the case of implementation stage of the Macedonian Strategy. Non-capability of the leading management structure to assign and delegate tasks or actions was identified as weakness in the implementation process.

"The responsibility is in the management structures, their readiness to respond to challenges and global trends. Coming to the office and signing documents are not the only tasks to be fulfilled, but looking at the situation in a long term perspective should be In their terms of references".

Instead, the need of assigning a high position political person in charge for implementation was identified by several respondents. In the discussion for creating an implementation body it was stated that one of the members has to be a minister or high governmental personnel such as vice prime minister to give higher value of the process.

After finalising the formulation project, the leading project personnel discussed the need to create a separate implementing body with main task, being the implementation of the Strategy according to the three-year action plan. Even though for some interviewees this was not defined as a main barrier, others stated that the ministry rejected this proposal to prioritise other actions, such as the inventory project.

"Another element is a lack of strategy on how to implement the Strategy. Yes, the proposal for creating implementing secretariat was on the table, but the Ministry stated that the priority is to start with the Inventory project rather then to deal with the implementation body. The Ministry set up its priority because at that time the political support for the Strategy was on a very high level and good will existed for the implementation. Nevertheless, the Ministry did not even assign one person who would be responsible for implementation, it was left on the Forestry Department employees to deal with it between their daily tasks. "

Respondents stated that unclear responsibility for implementation led to the current situation. The Strategy and the project documents state that the overall responsibility is in the hands of the Ministry, but other stakeholders also have a role in the implementation. It was lack of assigning responsible institution that created an unclear situation. Additionally, lack of control for non-implementation also facilitated the implementation aside.

In one of the project reports it was mentioned that the current institutional setup caused overlap of responsibilities of the forestry administration with those of other authorities, which could result in potential conflict. Accordingly, the evolution of institutional arrangement should be gradual.

The secondary analysis also showed that lack of delegating tasks from the action plan to the local level government led to failed effectiveness of the Strategy implementation. Reports from participatory workshops showed that local stakeholders asked for more decentralised action plan and greater cooperation with the local population.

DISCUSSION AND CONCLUSSIONS

This paper is part of a broader research of a master thesis entitled "Factors that impede Forestry Strategy implementation in Republic of Macedonia". One of the reasons for this paper and overall of the thesis, was the lack of research in the implementation phase as part of the forest policy process in Macedonia but also in the South Eastern Europe region. The main purpose was not to lead the responsible forestry management team, but rather to create a better understanding of the implementation stage and bring contribution for more efficient and effective results of the Strategy for sustainable development of forestry. Besides, policies tend not to prescribe how goals should be reached, but instead specify expected results - a change that better allows stakeholders to contribute according to their respective means and to adapt the means over time, taking into account experiences and changing contexts [5].

Further on, the analysis of this research did not concentrate on the inner relations between different barriers of implementation. The interaction and interface was obvious during the research and could be studied in further exploration.

All invited persons, except for one, replied to the invitation to participate in this research and gave their views and feelings about the research field. Respondents' interest and support was obvious, followed by their curiosity in the results.

A simple explanation of the findings is that the formulation of the Strategy was very successful, mainly because it was externally driven project. The process had defined time frame, responsibilities and foreign budget. It was first of a kind happening in the forestry department, and therefore it gained high political support.

The formulation of the Strategy introduced new democratic decision- making process in the forestry sector for the first time. The initiated change imposed introduction of new parties working according to governance principals, in a participative and transparent manner, negotiating between each other and resolving conflict situations. However, changing as little as possible, the administrative stakeholder's coalition is focused on keeping the power of future management and decision-making process as it was before the formulation of the Strategy. Reasons could be found in the traditional top down mentality and cultural background of the high-level management team. In this sense, the role of the civil society is still weak and undeveloped. Effective implementation of policies and policy processes requires, first and foremost, synergy between State and citizens [5].

Even though it is not certain if the change of the Government at the beginning of the implementation process was a barrier to the Strategy's implementation, it definitely influenced future development. The new forestry head management team did not received the same political support, as it was the case in the formulation phase. They also faced the problem of re- introduction of the Strategy to the new governmental structure, where higher ranking politicians were not informed about the formulation process.

Another point is that the Strategy is a non-legally binding document, leaving space for lack of control and low responsibility for not implementing the prescribed goals.

Assigning a high political figure with leadership and communication skills to lead an efficient implementation team, as a separate body in the forestry department, is the missing step for a successful implementation.

The forest policy process in Macedonia does not define the monitoring and evaluation phases of the Strategy. One of the conditions for moving the process forward is establishing regular monitoring, not only as quantitative measurement of implemented actions, but also as a qualitative measurement of effects of change. It is always advisable, even necessary, to monitor implementation and to evaluate whether a policy is achieving the desired outcomes [5]. Therefore, arrangements for monitoring and review should be an integral part of the strategy and any follow- up plan [5]. The evaluation of the past process would give the course in which future direction implementation should follow.

To assess the situation of the Macedonian Strategy, separate and independent body should evaluate the current capacities of the forestry staff, the presence of participation of stakeholders, and transparency and accountability in the implementation process. Reasons could be found in the absence of abilities for transparent and non-biased self evaluation unrestricted by political influence. Even though training for open and transparent functioning was conducted in the formulation stage, the traditional way of working and mentality are present. For example, the use of new information and communication technologies, such as online tools are missing in the daily working tasks. In line with this, existence of human and financial capacities for sharing information, such as public relation unit, is lacking. Adaptation to new requirements and changing conditions for Strategy implementation would involve the existence of tools, information and capacities to evaluate head management team self performance in providing information, conducting consultation and engaging stakeholders.

In the preparation and implementation of the policy, it is crucial to make accountability clear - who is responsible for what and the consequences of non-performance. It is impor-tant to ensure that responsibilities, authority and accountability are aligned – that people are not held responsible for occurrences over which they have no control, but that they also pay the price if they use their responsibility, authority and resources badly [5].

It is important to realise that all inter-viewees understood the solutions for overco-ming previously identified barriers. This indi-cates that the knowledge to move forward is present but not used. Conclusion from this outcome is that the participation of all the stakeholders included in the implementation is an important fact in overcoming the current barriers and moving the process forward. It is also important to realise that the implementation of the Strategy is a dynamic and vivid process. Changes should be recognised and included, or necessary adaptation should be made to enhance the effectiveness of the prescribed goals. Or as the literature describes: "Implementation is a dynamic process of negotiations between multiple actors, operating at multiple levels, within and between multiple organisations" [21].

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Importance of Forest Ecosystem Services to Secondary School Students: a Case from the North-West Slovenia

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Abstract

Background and Purpose: Forest managers are facing challenges in balancing the demands for forest social services raised by the general public and forest productive services. Knowing local people's attitudes, taking into account their needs and respecting their opinions, introducing social aspects should become a management priority to ensure success of conservational activities and sustainable use of natural resources. This study investigates the attitudes of one category from the general public which is secondary school students related to forest ecosystem services in order to determine and present a useful basis for further research of people's attitudes towards forests and forest management.

Materials and Methods: In 2013 and 2014 410 Slovenian students from secondary schools in the Vipava valley and Goriška area in northwestern Slovenia completed a questionnaire testing for the influence of gender and frequency of forest experiences on attitudes to forest ecosystem services. Students' attitudes to forest ecosystem services were investigated via 15 statements about provisioning, regulating, cultural and supporting services. The gathered data was analysed by the Statistical Package for the Social Sciences (SPSS), using ANOVA, Tukey post-hoc test, Spearman's product moment correlation and the nonparametric Mann–Whitney (U) test.

Results and Conclusions: Students acknowledged the high benefits of ecosystem services provided by forests, though not all forest ecosystem services hold the same importance to secondary school students. Students placed the highest importance on supporting services; especially on the value of forests as habitats for animal and plant species. Also the importance of forests for clean air production was emphasized. Students with more frequent experiences in the forest environment placed more importance on cultural services as well as regulating services, especially for clean water and air production. Gender differences were not significant, other than in the valuation of the forest as a place for relaxation and reflection, where female students were more supportive than male students.

Keywords: ecosystem services, forest, attitudes, secondary school students

INTRODUCTION

Forests are identified as key landscape elements for the provision of many environmental services provided, such as flood regulation [1], moderation of the urban climate [2], air pollution reduction [3] and biodiversity conservation [4]. Worldwide, approximately 60% of the ecosystem services are being degraded or used unsustainably, including fresh water, capture fisheries, air and water purification, and the regulation of regional and local climate, natural hazards, and pests [5]. The full costs of the loss and degradation of these ecosystem services are difficult to measure, but the available evidence demonstrates that they are substantial and growing. These trade-offs often shift the costs of degradation from one group of people to another or defer costs to future generations (*ibid*.). For these reasons managing forests is highly participatory, aiming to become multifunctional and multidisciplinary, involve experts from natural as well as social sciences, and geared toward developing partnerships between all stakeholders.

Alarming environmental changes, such as extinction of species and environmental degradation, encouraged scientists to begin promoting the idea of services offered to humans by biodiversity and natural systems in order to get support for conservation [6]. In a highly influential paper by Costanza et al. [7], they calculated the economic value of 17 ecosystem services in order to raise the importance of these issues. The concept of ecosystem services is the way to communicate societal dependence on ecological life support systems [8].

With almost 63% of the land mass covered by forest, Slovenia is the third most forested country in Europe [9]. Consequently, forests are an essential feature and a constituent of Slovenia's environment and hold a high protective and social significance [10]. For a considerable length of time, forest management was based on the paradigms of sustainability, close-to-nature management and multifunctionality, all of which have been implemented through the hierarchically organized system of forest management plans [11]. Until recently, the main objective of forest management was to secure sustainability of all forest ecosystems, regardless of ownership and their productive roles, ignoring the needs and preferences of the general public as one of the main stakeholder groups [12]. Given the great natural and socio-economic diversity of forest conditions in Slovenia, the key for ensuring sustainable forest management and the multifunctional role of forests is the development of a decentralized integrated approach (the 'bottom-up approach' and 'multi-stakeholder process') [13]. Therefore, public participation in the decision-making process should be introduced in order to favour a dialog in civil society on all forestry related topics (*ibid*.).

Despite immense natural capital and ecosystem services that flow from it, only few studies comprehensively address human attitudes toward ecosystem services and values provided by forests [14-18]. In order to make an informed decision, forest managers need an understanding of the benefits local residents would like the resource to produce [18]. Lindemann-Matthies with others [15] investigated the attitudes of Chinese and Swiss people, both environmental experts and laypersons, toward forest biodiversity and ecosystem services. They found out that all participants highly valued the forest ecosystem services, especially the regulating and supporting services. They also found out that city dwellers and forest visitors placed more importance on the regulating services, whereas environmental science students and farmers placed more importance on the provisioning services. Similarly, Gao with others [14] found that ecosystem services were important to local residents in Southeast China and were the motivation to protect culturally important forests. Participants especially valued cultural services which they mostly use and benefit from in these forests.

Knowing local people's attitudes, taking into account their needs, and respecting their opinions should become a management priority for success of conservational activities and sustainable use of natural resources [19]. Schools should develop students' knowledge, attitudes and responsible behaviour towards the environment and nature [20] in order to improve the forestry related decision-making processes in the future. Therefore, the aim of the present study was to investigate attitudes of secondary school students toward forest ecosystem services in NW Slovenia. The main research questions were (a) how students value different forest ecosystem services, (b) why students visit forests, (c) does gender influence valuation of ecosystem services and (d) how frequency of experiences in the forest ecosystems affect their valuations.

MATERIAL AND METHODS

Study Area

The study area of 2 200 km^2 is located in northwest of Slovenia, and includes municipalities within Tolmin Slovenian Forest Service Regional Unit (Figure 1). The climate is sub-Mediterranean in the southern part and sub - Alpine in the northern part. The highly heterogeneous landscape con-sists of rivers, valleys, hills, mountains and steep limestone walls. The complex terrain ranges from 50 m above sea level in the lowlands to the highest point in Slovenia - mount Triglav (2 864 m). Forests cover 67% of the area. *Lamio orvalae-Fagetum praealpinum, Enneaphyllo-Fagetum, Anemone-Fagetum, Larici-Fagetum, Abieti-Fagetum dinaricum, Clematidi-Abietetum, Lycopodio-Abietetum, Festuco-Abietetum, Carici albae-Fagetum, Calamagrostido variae-Fagetum, Seslerio-Ostryetum* [21] are the most represented forest associations. According to the forest management plans for the Tolmin Regional Unit, the most important forest functions are wood production, protection of soils, forest stands and infrastructure, as well as recreation and tourism [22]. This study area was chosen because it well represents the diversity of forests present in Alpine, Submediterranean and Dinaric phytogeographical regions [23].

Sample

In fall 2013 and winter 2013-2014, first and second year Slovenian students attending randomly selected secondary schools in Vipava, Ajdovščina and Nova Gorica were questioned via a self-administered questionnaire (N = 410). More than 90% of students from this study area attend secondary schools in selected towns [24]. The sample consisted of 134 (32.7%) males and 276 (67.3%) females. Their average age was 15.64 years (SD = 0.59, Min = 15, Max = 18). At all data collection steps, full anonymity was guaranteed to the participants.

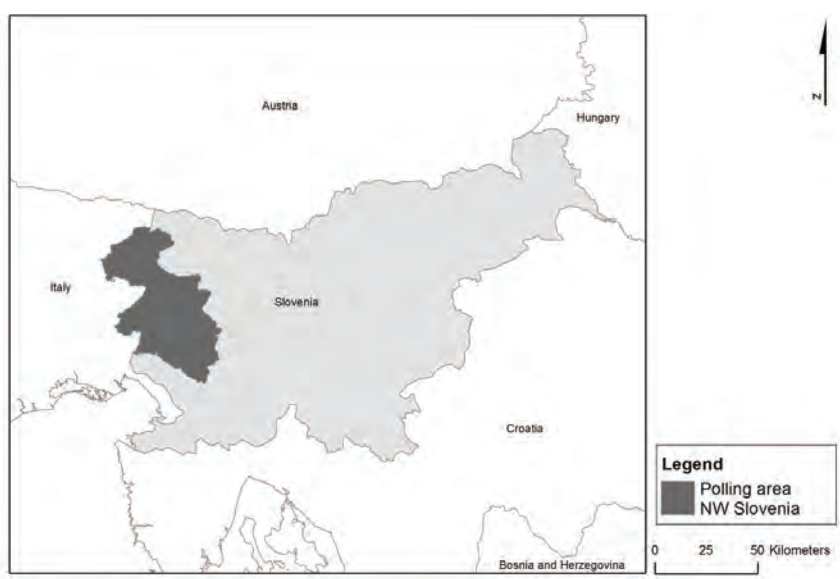

FIGURE 1. Polling area

Design and Procedure

All selected secondary schools are situated in Vipava valley and Goriška area in northwest of Slovenia (Figure 1). Schools were contacted by phone and later visited by a researcher, who provided printed copies of the questionnaire and instructions for teachers. Teachers conducted questioning in the classrooms, at the beginning of science or biology lessons.

The students were asked to complete a questionnaire which allowed us to test for the influence of gender and frequency of experiences in the forest on attitudes toward forest ecosystem services. Student's attitudes toward forest ecosystem services were investigated with the help of 15 statements about provisioning (A), regulating (B), cultural (C) and supporting (D) services, as defined by the Millennium Ecosystem Assessment [5]. Specific ecosystem services are described in Table 2. The statements were adopted from the study by Lindemann-Matthies with others [15] (for statements see Table 1). For each service, students answered on five-step Likert scales (1- unimportant, 2- somewhat unimportant, 3- neither unimportant nor important, 4- somewhat important and 5- important) [25]. Five-step Likert scale was also used to collect information about the frequency of experiences in the forest ("How often do you visit forests?": 5- several times a week, 4- weekly, 3- twice a month, 2- monthly, 1- rarely). Students also answered open-ended question asking them to name their reasons for visiting the forests. Their answers were then categorized as cultural, provisioning, regulating or supporting services, and the frequency of answers in each category was calculated.

Data Analyses

Data entry and analysis was conducted using the Statistical Package for the Social Sciences (SPSS). ANOVA and Tukey post-hoc test were used to analyze student's attitudes toward specific forest ecosystem services. Spearman's product moment correlation (rs) coefficient was used for exploring the relationship between attitudes toward forest ecosystem services and the frequency of experiences in the forest. The nonparametric Mann–Whitney (U) test was used to test for significant gender differences in attitudes toward forest ecosystem services.

RESULTS

Results show that not all forest ecosystem services have the same importance to secondary school students (Figure 2) ($F = 45.88$, $p < 0.001$). Multivariate testing of differences between ecosystem services was used (Supplementary material 1 - http://www.seefor.eu/supp_material/torkar_et_al_1.pdf.) In general, students placed the highest importance on supporting services; especially on the value of forests as habitats for animal and plant species (D1, D2). The value they placed on forests as habitats for mushrooms is significantly lower than that for animals and plants. They also placed high importance on regulating services. Importance of forests for the production of clean air is especially emphasized. Surprisingly, they placed a lower importance on provisioning services compared to supporting and regulating services. Importance of the forest for food production was significantly lower to students compared to the role forests play in wood and fuel production. The students placed the lowest importance on cultural services. The lowest score was placed on the aesthetic value, which the students ranked significantly lower than the other three cultural services of forests.

Students were asked how frequently they visit forests (Figure 3). Half of the students visit forests weekly or multiple times a week. The reasons for visiting forests were divided into four categories of ecosystem services: provisioning, regulating, cultural and supportive. The main reasons for visiting the forests fall into the category "cultural services" ($f = 343$); most of these students use forests for walking, running and relaxation. In the category "provisioning services" ($f = 30$) students mentioned logging and mushroom picking. Fresh air is the only reason for visiting forests in the category "regulating services" ($f = 29$). In the category "supportive services" ($f = 10$) students mentioned observation of nature, animals and plants.

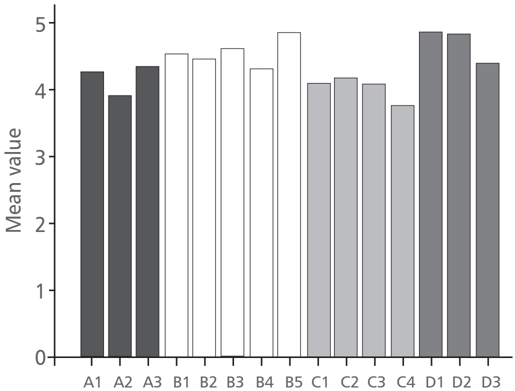

FIGURE 2. Importance of ecosystem services, assigned by students to forests: provisioning (A), regulating (B), cultural (C) and supporting (D) services. Specific ecosystem services are described in Table 1.

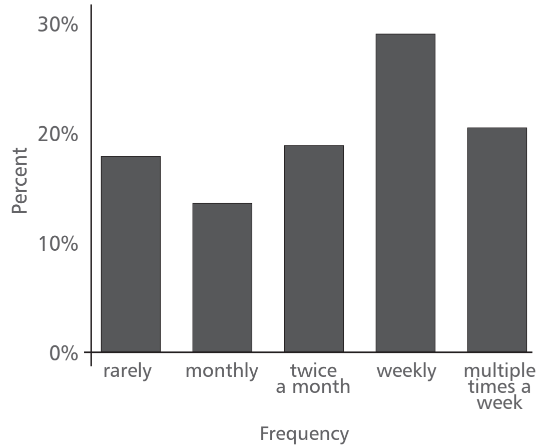

FIGURE 3. Students' frequency of experiences in forests.

Students with more frequent experiences in forest placed more importance on cultural services; they especially recognized the value of forests as a place to be physically active, to exercise, and for relaxation and deep thinking (Table 1). They also placed more importance on regulating services, especially for production of clean water and air. More frequent forest visitors

TABLE 1. Influence of student's frequency of experiences in forest has on the importance assigned to forest ecosystem services.

Forest ecosystem services		Code	rs
Provisioning services	Produces timber	A1	-0.047
	Produces food	A2	0.100*
	Produces fuel	A3	-0.012
Regulating services	Regulates the climate	B1	0.107*
	Protects against natural hazards	B2	0.002
	Produces clean water	B3	0.126*
	Soil production	B4	0.078
	Produces clean air	B5	0.102*
Cultural services	Is a place for exercise	C1	0.260**
	Is a place for relaxation and deep thinking	C2	0.175**
	Is a place for physical activities	C3	0.156**
	Is a place of aesthetic value	C4	0.043
Supporting services	Habitat for animal species	D1	0.087
	Habitat for plant species	D2	0.047
	Habitat for mushroom species	D3	0.017

* $\alpha = 0.05$, ** $\alpha = 0.01$

TABLE 2. Influence of student's gender on the importance assigned to forest ecosystem services.

Forest ecosystem services		Code	Gender	Mean	SD	U	p-value
Provisioning services	Produces timber	A1	female	4.27	0.70	18098.50	0.852
			male	4.26	0.79		
	Produces food	A2	female	3.96	0.91	16583.50	0.107
			male	3.77	1.05		
	Produces fuel	A3	female	4.37	0.71	18194.00	0.871
			male	4.34	0.76		
Regulating services	Regulates the climate	B1	female	4.53	0.64	17425.50	0.534
			male	4.47	0.69		
	Protects against natural hazards	B2	female	4.44	0.68	16873.00	0.306
			male	4.37	0.70		
	Produces clean water	B3	female	4.64	0.64	15970.50	0.074
			male	4.53	0.66		
	Soil production	B4	female	4.31	0.65	17177,50	0.759
			male	4.22	0.87		
	Produces clean air	B5	female	4.86	0.39	18033.00	0.487
			male	4,84	0,38		
Cultural services	Is a place for exercise	C1	female	4.14	0.70	16732.50	0.128
			male	3.94	0.96		
	Is a place for relaxation and deep thinking	C2	female	4.22	0.79	15501.00	0.005**
			male	3.91	1.03		
	Is a place for physical-sport activities	C3	female	4.12	0.76	17446.00	0.445
			male	4,01	0,95		
	Is a place of aesthetic value	C4	female	3.81	0.86	17965.50	0.960
			male	3.73	1.12		
Supporting services	Habitat for animal species	D1	female	4.89	0.33	17279.00	0.064
			male	4.78	0.55		
	Habitat for plant species	D2	female	4.82	0.47	18107.50	0.590
			male	4.80	0.47		
	Habitat for mushroom species	D3	female	4.41	0.78	18045.00	0.657
			male	4.34	0.88		

* $\alpha = 0.05$, ** $\alpha = 0.01$

also recognized importance of forest for food production. However, there were no significant differences in students' attitudes for supporting services, like the value of forest as habitat for animals and plants.

The importance assigned to forest as a place for relaxation and deep thinking in the group of female students was significantly higher than the group of male students (U = 15501, p = 0.004) (Table 2). Other gender differences were not significant.

DISCUSSION

Students acknowledged the high benefits of ecosystem services provided by forests. Results confirm that concept of ecosystem services is an effective means of communication stressing our dependence on ecological life support systems [8].

Interestingly, they placed the highest importance on supporting and regulating ecosystem services and the lowest on cultural services, even though the most frequent reasons for their visiting of the forests were cultural services (e.g. walking, running, relaxation). Result is contradictory to findings by Gao with others [14], where a local residents in SE China highly valued forest cultural services. However, in the study focusing on trade-offs between fire prevention and provision of some forest ecosystem services (e.g. recreation, water purification, animal and plant diversity) was found that water purification (i.e. regulating service) followed by animal and plant diversity were considered as the most important for the welfare of the Slovenian population [12]. In addition, policy and decision makers from Slovenia recognized watershed function, water purification and air purification (referring to regulating services in the present study) as the most important ecosystem services, followed by wildlife and biodiversity protection (referring to supporting services in the present study) [13].

Present study shows that students with more frequent visits to forests have higher valuations of cultural services, which could be explained by place attachment theory [26]. This theory describes a functional attachment to a specific place that can influence the perception of social and environmental site conditions [27]. In addition, more frequent presence in the forests positively influenced on students' valuations of regulating services and food production provided by forests. Explanation could be that the human experiences in natural environments contributes to ecological literacy and more complex assessment of the environmental properties and changes [28].

Some empirical studies confirm that females were more supportive of the environment and nature then males [e.g. 29, 30] while others indicate a more protective stance among men than women or lack of a substantial association in the vast majority of cases [e.g. 31, 32]. In our study gender differences were not significant except in the valuation of forest as a place for relaxation and deep thinking, where female students were more supportive than male students.

CONCLUSIONS

Findings of the study could be summarized into three main conclusions: a) students placed the highest importance on forest ecosystem supporting and regulating services, particularly production of clean air and water and habitat for animal and plant species; b) students visit forests mainly for recreation purposes; c) gender influenced only the evaluation of forest as a place for relaxation and deep thinking, whereas female students put a higher value on those services and that d) more frequent visits to forest positively influenced students' attitudes toward cultural services.

Forest managers are facing challenges in balancing the demands for forest social services raised by the general public and forest productive services in Central and South-east Europe today [13]. The results of the study show that supporting (e.g. habitat for animal and plant species) and regulating (e.g. clean air production) services in forest management should be particularly emphasised, as shown also by Mavsar et al. [12] and Vuletić et al. [13]. Caution should be exercised in generalizing the results of this study, because only secondary school students from one region in Slovenia were considered. Nevertheless, the findings and methodological approach could be a useful basis for the further research of people's attitudes towards forests and its management.

Acknowledgments

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Original scientific paper

Early Growth Assessment of Selected Exotic and Indigenous Tree Species in Nigeria

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Abstract

Background and Purpose: Nigeria is greatly endowed with numerous tree species of which majority of them are native while few are exotic. Report shows that high percentage of man-made forests in the country is dominated with exotic species. This culminated from the assumption that exotic trees are fast growing. However, this study investigated the growth of indigenous trees in tandem with that of exotic species with a purpose to clarify the assumption about the growth and conservation of indigenous species in natural forests.

Materials and Methods: The study was conducted at the nursery unit of the Department of Forest Resources Management, University of Ibadan, Nigeria. Five (5) different one year old tree species seedlings were used for the study. Two of the species (*Tectona grandis* and *Gmelina arborea*) are exotic while the other three species (*Khaya senegalensis, Khaya grandifolia* and *Afzelia africana*) are native to Nigeria. They were planted on the field in a completely random design and then replicated eight times. Data were collected every month on their height growth, collar diameter and leaf number. Data obtained were subsequently analyzed with ANOVA.

Results and Conclusions: Results show that *K. grandifolia* (45.39 cm) grew significantly better ($p<0.05$) in height than *G. arborea* (38.11 cm) and *T. grandis* (22.36 cm), while *A. africana* (40.03 cm) closely followed *K. grandifolia*. Based on the results, the selected indigenous species displayed promising potentials for conservation purpose. Hence, further research in this aspect is encouraged to confirm the findings.

Keywords: height growth, collar diameter growth, *Tectona grandis, Gmelina arborea, Khaya senegalensis, Khaya grandifolia*, *Afzelia africana*

INTRODUCTION

Forest resources are renewable natural resources and Nigeria as a nation is copiously gifted with these resources [1]. Of all the forest resources, trees have been categorized as the major produce based on the high economic value generated from them. Ecologically, trees can be further classified into indigenous and exotic taxon. A tree species is regarded as native or indigenous to a given region or ecosystem if its presence in that region is the result of natural processes, with no human intervention. Every natural organism has its own natural range of distribution in which it is regarded as native. There are numerous indigenous tree species in Nigeria that have equivalent timber quality or better timber quality than the exotic species [1]. These include *Milicia excelsa, Entandrophragma* spp. *Khaya senegalensis, Khaya grandifolia Mansonia altissima, Albizia zygia, Afzelia africana,* etc.

Exotic tree species on the other hand is a species living outside its native distributional range, which has arrived there by human activity, either deliberately or accidentally. There are various economic tree species that are exotic to Nigeria, but the two widely known and cultivated species are *Tectona grandis* and *Gmelina arborea*. In other words, these two species dominate various forest plantations in Nigeria [2-4]. However, majority of these plantations are monospecific, which is ecologically detrimental to the environmental balance of forest biodiversity. Additionally, reports have revealed that some exotic tree species have tremendous damaging impact on the indigenous trees as well as other natural resources in the forest or the ecosystem. For instance, they cause decline in abundance, contraction of geographic ranges, and extinction of native species [5-7]. According to Nwoboshi [8], *Tectona grandis* does not support the growth of some indigenous trees because of its allelopathic nature. In other words, where *T. grandis* is grown, economic indigenous tree species like *Mansonia altissima, Ricinodendron heudelotii,* and *Albizia zygia* cannot survive [8]. Apart from the environmental issues caused by exotic species, there are also problems of meeting the livelihood and cultural needs of the local communities that depend on forest products and services [9]. For instance, a study [1] has shown that parts of indigenous tree species are used by masquerades as paraphernalia during cultural festival in some villages in southwestern Nigeria. In this case, exotic tree species cannot be used as surrogates for indigenous species. In addition, it is interesting to know that *Gmelina arborea,* which has been formally categorized as less known species is being utilized for our major forest restoration in Nigeria. The species was originally introduced to Nigeria for pulping purpose. As a result of the fact that it overgrew the stage of its utilization for pulp and paper in tandem with unavailability of better indigenous timber species in the natural forest, it is now being utilized for timber purpose.

Generally, it is believed that exotic trees in Nigeria grow faster than indigenous trees, although, there is no pragmatic research to corroborate this fact. Hence, this general belief has encouraged a higher level of conservation of exotic tree species than of our indigenous tree species [8]. According to Emtage [10], the established supply chain and generally more rapid growth rates of exotic species have led to them being favored for plantation use rather than the indigenous species. Hence, the indigenous tree species are perpetually being neglected while the exotic species are encouraged. Due to the promotion of exotic trees for plantation purposes, the indigenous are being threatened in the natural forests [1-2]. In order to conserve the threatened indigenous tree species in natural forests of Nigeria, it is expedient that the early growth of indigenous and exotic trees is simultaneously studied.

There are studies [11-12] which have assessed the early growth of some trees in Nigeria, but none has been able to simultaneously study the growth of indigenous and exotic trees. For instance, Gbadamosi et al. [11] studied the effect of four provenances on early seedling growth of *Parkia biglobosa* and discovered the provenance of Ibadan to have the best growth. They recommended that the seed of the species should be sourced from Ibadan if its plantation is to be established. According to Mohammed et al. [12], height growth of *Balanites aegyptiaca* can be very slow at the seedlings stage, but at the saplings stage, the growth rate increases drastically. This paper therefore investigated the early growth of selected indigenous trees in tandem with that of exotic species with a purpose to clarify the assumption about the growth and conservation of indigenous species in natural forests.

MATERIALS AND METHODS

This study was embarked upon at the nursery unit of the Department of Forest Resources Management, University of Ibadan. The site is located approximately on latitude 07°26.981'N and longitude 0003°53.733'E. It is at an altitude of 277 m above sea level [8]. The annual rainfall of the area is 1258 mm - 1437 mm with mean daily temperature ranges from 22°C - 31°C and the soil of the area is ferric luvisols [8].

Five tree species were used for the study. Two species (*Tectona grandis* and *Gmelina arborea*) are exotic while the remaining three species; namely *Khaya senegalensis, Khaya grandifolia* and *Afzelia africana* are native to Nigeria. The exotic species were selected for this study due to their high rate of utilization while the native ones were used because they are severely threatened and almost extinct in Nigeria.

The seedlings used for this study, which were a year old, were obtained from the Department of Forest Resources Management Nursery. Each tree species was replicated eight times in a completely random design and planted on the area of 1 m x 1 m on the field. However, the same environmental treatments were imposed on the tree species. In other words, they were all left to experience the real natural conditions on the field.

Data were collected every month in the period of six months on their height growth, collar diameter and leaf number. Height growth measurement was achieved by taking the vertical distance from the ground level to the tip of each tree using a long meter. Collar diameter was obtained by measuring the diameter at the collar point of the trees with the use of a vernier caliper while number of leaves on each tree was obtained by visual counting. Statistical analysis was carried out using a one way analysis of variance (ANOVA). Duncan Multiple range test was used for post hoc analysis.

RESULTS

Results (Figure 1) show that after a month of assessment, *G. arborea* increased in height for 7.03 cm and was the highest of all the species. It was followed by *K. grandifolia* (2.76 cm), *A. africana* (1.49 cm), *K. senegalensis* (1.23 cm) and *T. grandis* (0.7 cm), which had the least height growth. The growth followed a similar pattern from the first month to the 4th month *G. arborea* having the highest height growth while the least was recorded in *T. grandis* all throughout this period. However, at the 5th month, the growth pattern changed. *K. grandifolia* overtook all other species in its height growth as it measured 34.49 cm while *G. arborea* measured 31.54 cm, *A. africana* (31.33 cm), *K. senegalensis* (25.90 cm) and *T. grandis* (15.70 cm). At the final assessment of the height growth, *K. grandifolia* still had the highest cumulative height increment of about 45 cm; it was closely followed by *A. africana* (40.03 cm), while the species that had the least growth rate was *T. grandis,* with just 22.36 cm of height growth after six months. Table 1 shows that height increment differs significantly ($p<0.05$) among the species.

The results of collar diameter increment are shown in Table 1 and Figure 2. Statistically, there was a significant difference in the collar diameter increment ($p<0.05$) among the tree species after the period of six month. *G. arborea* depicted the highest average collar diameter increment (4.23 cm) among the tree species, but it did not differ significantly from the three indigenous species (i.e. *K. grandifolia* [4.14 cm], *A. africana* [3.94 cm] and *K. senegalensis* [3.90 cm]). In addition, as an exotic species, *T. grandis* was observed to be the species with the smallest collar diameter increment of 2.51 cm.

During the assessment of leaf number over the period of the experiment (Table 1), *K. grandifolia* (26.7) has showed the highest leaf production compared to other species. The species that followed *K. grandifolia* was *K. senegalensis* (21.2), *A. africana* (19.0), and *T. grandis* (13.8) having the least number of leaves. Hence, statistical variation of the leaves produced amongst all the species showed a significant result ($p<0.05$). The periodic change in the number of leaves from the first to sixth month of the experiment is shown in Figure 3.

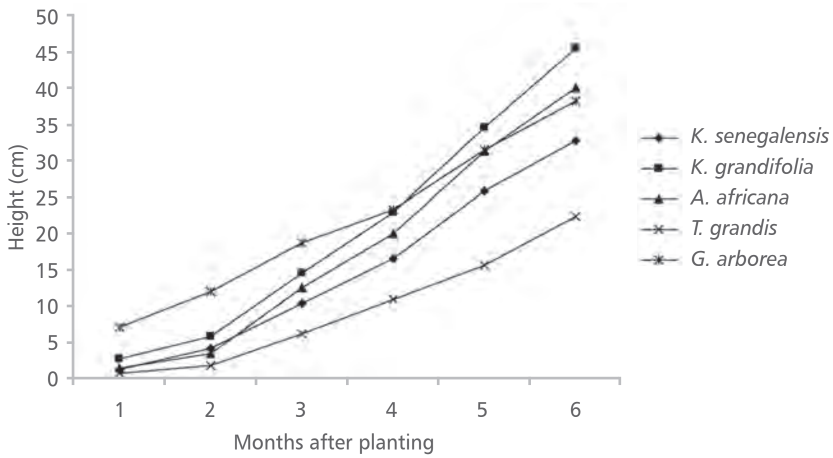

FIGURE 1. Height growth of the species after six months

TABLE 1. Increase in height, collar diameter and number of leaf of tree saplings

Species	Height increment (cm)	Collar diameter increment (cm)	Number of leaf (n)
K. senegalensis	32.64c	3.90a	21.4b
K. grandifolia	45.39a	4.14a	26.7a
A. africana	40.03b	3.94a	19.0b
T. grandis	22.36d	2.51b	13.8c
G. arborea	38.11b	4.23a	21.2b
p-value	0.000*	0.000*	0.000*

Means with similar superscript within the same column of any set of species are not significantly different at p=0.05
*=significant (p<0.05)

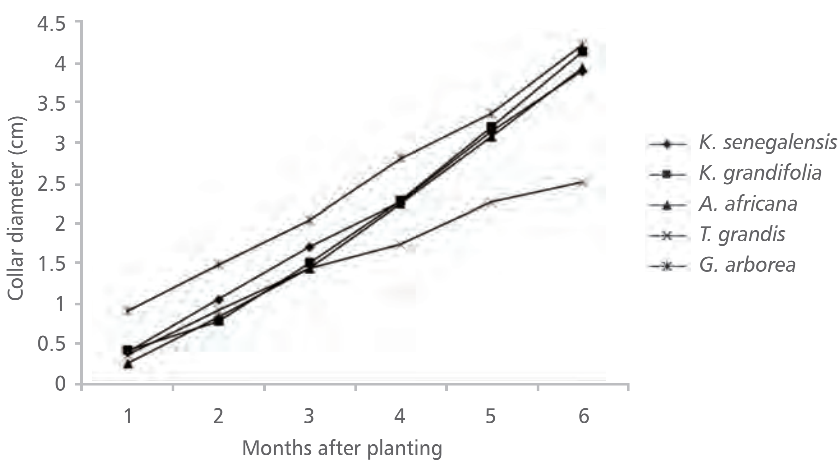

FIGURE 2. Collar diameter growth of the species after six months

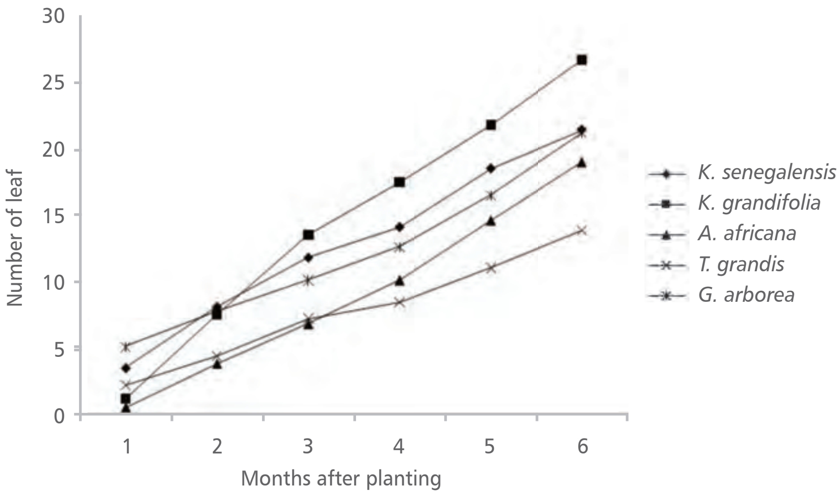

FIGURE 3. Number of leaf of the tree species after six months

DISCUSSION

The significant differences observed in the growth of the five tree species suggest that their level of adaptation to the same environmental conditions is more or less different. This may be ascribed to the combined effect of the environment and the inherent characteristics of the trees, which determines their physiognomy. The relatively better collar diameter growth rate observed in *G. arborea* than all other species at the initial stage may be due to its fast ability to transform photosynthate to growth at a seedlings' age [6, 13]. This finding is in consonance with Mohammed et al. [12], who discovered that some trees can be very slow in growth at their tender age, but the rate of growth increases as they transcend to saplings age.

Generally, the sampled exotic species flourished and grew more rapidly at the initial period of assessment of the seedlings. As reported by some authors [13-15], these species are more favored to be used for plantation planting materials than our indigenous trees. However, in later stages, the indigenous species proved to have a better height and diameter increment than exotic species. Consequently, the findings of this study are in contrast to those of Gardner [16] and Zuidema et al. [17], who emphasized that exotic species performed better in growth compared to native species. For instance, Sarrailh and Ayrault, [8] stated that, with respect to tree height growth, exotic species (*E. grandis* and *A. saligna*) performed better than indigenous species (*A. polyacantha* and *B. thonningii*) amongst all the species they experimented with and as such, concluded this has culminated with the fact that exotic species have been preferred because of their high growth rate. Interestingly, their study did not involve the sapling stage of the species but rather examined only the seedling stage. Conversely, this study agrees with Olukoye et al. [18], who recorded that exotic tree and shrub species showed a poorer performance in relation to indigenous species.

CONCLUSION

The study has been able to compare the growth rate of the exotic and the indigenous species up to the age of a year and half. The three indigenous species appeared promising. This is based on the fact that *K. grandifolia* grows better, both in height and diameter, at the saplings' age than the two most popularly known and propagated exotic species in Nigeria (i.e. *G. arborea* and *T.*

grandis). However, further research is needed to ascertain this finding. In as much as this study is a preliminary study, further research in this regards can therefore focus more on the simultaneous growth of these at an older age. When this is achieved, ecologist and other tree growers as well as the tree planters will be encouraged to utilize them for the reforestation and afforestation in order to improve our degraded forests rather than using the exotic species. Hence, the threatened conservation status of the indigenous species in the natural forest would be ameliorated.

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Preliminary communication

Soil Protection in the EU According to the Directive on Industrial Emissions (IED) and Croatian Practice

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Abstract

Background and Purpose: Soil protection against pollution in EU is mostly covered in a new Directive on industrial emissions (IED), adopted on November 24, 2010 as a follow up of the IPPC Directive. For all industrial facilities that fall under IED, the Directive obliges the establishment of a complex system of management of contaminated soil at the national level, in order to facilitate the implementation of the principle of "polluter pays" furthermore to reduce the risk of contamination of soil and groundwater.

Material and Methods: This paper presents an overview of soil management system that should be established in each EU country to fulfil IED requirements. It consists of a meta-analysis of IED requirements and current state and drawbacks of soil protection in Croatia including present state of legislation, responsibility of authorities, soil surveys and remediation activities.

Results and Conclusions: IED set the obligation on the industrial operator before the start of production to prepare a report on the initial state of soil as a necessary requirement for obtaining environmental permit. It set obligations for monitoring of soil and groundwater status in the location of industrial facility for a period of ten (soil) and five years (groundwater). After the cessation of production, and in the case of exceeding critical limits of pollution, the operator is obliged to perform remediation or restitution of land in the state as it was at the beginning of production. Management of contaminated soil according to IED requirements obliges the Croatian government to establish a complex multi-level system. At first it requires better definition of responsibilities between two ministries; Ministry of Environmental and Nature protection and Ministry of Agriculture. IED requires enactment of adequate legal basis (i.e. Soil protection act) and the establishment of operational instruments for the implementation of soil protection, such as a register of contaminated soils and the accreditation of soil remediation experts.

Keywords: Soil pollution, Directive on industrial emissions (IED), Soil protection, monitoring, remediation

INTRODUCTION

The responsibility to protect soils in Croatia arises primarily from the Environmental Protection Act [1], which established protection grounds: (i) Soil protection comprises retention of health and functions of the soil, prevention of soil damage, monitoring the quality of soil and restoration of damaged soils and land, (ii) contamination or damage to the soil are considered to have a detrimental impact on the environment, and the creation of acceptable limits of soil quality should be manifested in specific regulations. Penalties for long-lasting and significant deterioration of the quality of the soil through the input of pollutants, what thus leads to endangering of people's health, are stipulated in addition to the concept of "polluter pays", also in the Criminal Act of the Republic of Croatia [1]. However, to the present time, further development of the soil management, throughout the provision of acceptable limits, soil monitoring as well as follow up remediation of contaminated sites in Croatia is still not resolved as it should be according to the Environmental Protection Act [2].

Apart from the environmental protection act, soil protection in the Republic of Croatia has been mainly implemented through sectors such as agriculture and forestry, particularly through case study assessments [3, 4, 5]. Soil pollution is also mainly considered together with air pollution where international programs, such as forest ecosystem monitoring and ICP-Forest (http://icp-forests.net/), are implemented together with similar vegetation monitoring activities [6, 7, 8]. In respect with the state of development of respective legislative in Croatia, a significant shift has been made in the agricultural sector, inside the framework of Agricultural Land Act [9] and associated regulations; The Regulation on the protection of agricultural land from pollution [10], the Regulation on standards for determination of exceptionally valuable arable (P1) and valuable arable (P2) agricultural land [11], and the Ordinance on the methodology for the monitoring of agricultural land [12]. In 2010, national centres responsible for the implementation of continuous monitoring of agricultural and forest land were established. According to the Regulation on the methodology for the monitoring of agricultural land [12], the responsible authority for monitoring of the condition of agricultural soils is "Croatian Centre for Agriculture, Food and Rural Affairs - Department of Soil and Land Conservation" (now the Agency for Agricultural Land), while, according to the Regulations on monitoring of the state of damage of forest ecosystems, including soil [13], under the Forests Act [14], the responsible authority is the Croatian Forest Research Institute as an ICP-Forest National Focal Centre. Under the Forestry Act, however, soil protection is not explicitly specified in any of the related regulations [13].

From July 2013, the Republic of Croatia is a full member of the European Union, and it has committed itself to align with the EU acquis (acquis communautaire). This means that Croatia must accept the founding treaties and other materials derived from the contract and to align its legislation with the EU acquis. EU membership obliges Croatian authorities to adopt and harmonize the legislation concerning also the protection of the soil in the frameworks of environmental protection and sustainable development. Both in Croatia and the EU, soil is mostly encompassed inside various sectorial directives [15]. Up to the present stage, in the EU, there is no unified legislation comprised within a separate directive regarding soil. Long-standing initiatives related to soil protection in the EU has so far resulted in two key documents adopted in 2006; Thematic Strategy for Soil Protection [16], and a proposal for a framework directive on soil protection [17]. Although, since 2007, there have been undergoing discussions at the EU level between Member States, up to the present moment, no common agreement in terms of the "Soil directive" has been reached. After the Spanish presidency in 2010, soil issue was no longer placed on the agenda for further discussion. Despite that, the absence of a common "Soil directive" slightly diminishes the perception of importance of soils in the EU, soil protection is a rather important issue, functionally established in a series of sectorial directives. Soil is entangled inside the Habitats Directive [18] which defines the protection of natural habitat types.

Soil protection in agriculture is regulated with a cross-compliance policy [19, 20] that links a number of EU directives and provisions of subsidies for farmers with the obligation of applying the principles of good agricultural practice. However, one of the newest and particularly important acts for soil protection against contamination is presented in the Directive on industrial emissions (IED) [21], adopted on November 24, 2010 as a follow up of the IPPC Directive (Integrated Pollution Prevention and Control). For all industrial facilities that fall under the IED, the Directive obliges the establishment of a complex system of management of contaminated soil at the national level in order to facilitate the implementation of the principle of "polluter pays" and furthermore to reduce the risk of contamination of soil and groundwater.

This paper introduces the most important IED requirements for member states regarding the protection of soil against industrial pollution as well with the comprehensive soil management system that has to be established accordingly. This paper also provides an overview of gaps identified in the current system of governance of contaminated soils in Croatia.

MATERIAL AND METHODS

An overview of the Directive on Industrial Emissions (IED)

Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control - IPPC) builds and recast: the EU directive on waste from the titanium dioxide industry, the EU directive on limitation of emissions of volatile organic compounds (VOC) due to the use of organic solvents, the Directive on the incineration of waste, the Directive on the limitation of emissions of certain pollutants into the air from large combustion plants and the Directive on integrated pollution prevention and control (IPPC). It is based on the prevention and reduction of pollution at source by the principle of "polluter pays". Different approaches for controlling emissions into air, water and soil separately may encourage the shifting of pollution from one environmental medium to another rather than protecting the environment as a whole. The Directive provides an integrated approach for the prevention and control of emissions into air, water and soil, for waste management, for energy efficiency and for accident prevention. The Directive is going to clarify the provision, reduce unnecessary administrative burdens and implement the conclusions of the Commission related to the Thematic strategy on air pollution, the Thematic strategy for soil protection and on the Thematic strategy for the prevention and recycling of waste. It relies on the Sixth Environmental Action Programme of the EU from 2002.

Each installation should operate only if it holds a permit or, in the case of certain installations and activities using organic solvents, if it holds a permit or if it is registered. It is on the Member States to determine the approach for assigning responsibility to operators of installations provided that a compliance with this Directive is ensured. Member States may choose to grant the permit to one responsible operator for each installation or to specify the responsibility amongst several operators of different parts of an installation. In order to facilitate the granting of permits, Member States should be able to set requirements for certain categories of installations in general binding rules. It is important to prevent accidents and incidents and limit their consequences. Liability regarding the environmental consequences of accidents and incidents is a matter for the relevant national law and, where applicable, other relevant Union laws. In order to avoid duplication of regulation, the permit for an installation covered by Directive 2003/87/EC of the European Parliament establishing a scheme for greenhouse gas emission allowance trading within the Community should not include an emission limit value for direct emissions of the greenhouse gases.

This Directive does not prevent Member States from maintaining or introducing more stringent protective measures.

Operators should submit permit applications containing the information necessary for the competent authority to set permit conditions. Operators should be able to use the information resulting from the application of the Council Directive 85/337/EEC of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment and of the Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances when submitting permit applications. The permit should include all the measures necessary to achieve a high level of protection of the environment as a whole and to ensure that the installation is operated in accordance with the general principles governing the basic obligations of the operator. The permit should also include emission limit values for polluting substances, or equivalent parameters or technical measures, appropriate requirements to protect the soil and groundwater and monitoring requirements. Permit conditions should be set on the basis of best available techniques. In order to determine best available techniques and to limit imbalances in the Union regarding the level of emissions from industrial activities, reference documents for best available techniques (hereinafter BAT reference documents') should be drawn up, reviewed and, where necessary, updated through an exchange of information with stakeholders. The Commission should, through a committee procedure, establish guidance on the process of data collection, on the elaboration of BAT reference documents and on their quality assurance. The Commission should aim to update BAT reference documents no later than 8 years after the publication of the previous version.

The Commission should establish a forum that operates in a transparent manner. Practical arrangements for the exchange of information and the accessibility of BAT reference documents should be laid down, in particular to ensure that Member States and stakeholders provide data of sufficient quality and quantity. It is important to provide sufficient flexibility to competent authorities to set emission limit values that ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques. In order to take into account certain specific circumstances where the application of emission levels associated with the best available techniques would lead to disproportionately high costs compared to the environmental benefits, competent authorities should be able to set emission limit values deviating from those levels. Such deviations should be based on an assessment taking into account well-defined criteria. The emission limit values set out in this Directive should not be exceeded. In any event, no significant pollution should be caused and a high level of protection of the environment taken as a whole should be achieved.

RESULTS AND DISCUSSION

Obligations to Protect Soil and Groundwater from Contamination by IED

IED in Article 12 Section 1.e. stipulates that all Member States take measures in issuing new environmental permits as well as at the closing of industrial activities, to provide an assessment of baseline soil contamination (baseline report). When the activity involves the use, production or release of relevant hazardous substances and there is a possibility of contamination of soil and groundwater in the area of installation, the operator shall prepare and submit a report to the Authority on the initial state (baseline report) before starting the operation or before the license is renewed for the first time after 7 January 2013. Report on the initial state should contain all the necessary information from which it can determine the state of soil and groundwater with respect to contamination, in order to make a quantitative comparison with the state of soil and groundwater after definitive cessation of industrial activities.

Report on the initial state (baseline report) must contain at least:

(a) Information on the current usage of the site and the information, if any, on how land has been used in the past.
(b) Existing information on the measured quality and condition of the soil and the groundwater status that reflect the state when the report was assembled, alternatively, a new quantitative analytical measurements of soil and groundwater, for those substances, of which there is a potential risk of contamination from the manufacture or accompanying emissions should be attached.

If there are information on the state of soil and groundwater, made under the national legislation, and which meet the requirements of this Directive, they may be attached to the report in the initial state.

The European Commission will establish guidelines on the content of the baseline report.

- IED in Article 14 also establishes permit conditions for supporting activities such as protection of soil and groundwater through monitoring the impact of the management of industrial waste produced during operation of the installation.
- IED lays claim to "permanent monitoring" of soil and groundwater as defined in Article 16. Monitoring of groundwater status will be conducted at least once every five years while the monitoring of soil has to be done at least once every ten years.
- IED establishes measures for the soil to be taken after the closure of industrial plants in Articles 22.3 and 22.4.:

After the final closure of the manufacturing plant, the operator will make an assessment of the state of soil and groundwater contamination from pollutants used, produced or discharged from the system. Where the operation has caused significant pollution of soil and groundwater, which can be seen by comparing current state results with those of the report on the initial state (baseline report), the operator is obliged to take all relevant measures to rehabilitate the pollution and to return the land to the state before the start of production.

After the end of production, and where contamination presents a significant risk to human health and the environment, the operator shall take the necessary measures to eliminate or reduce pollution of soil and groundwater (remediation) so that such land ceases to pose a significant risk.

Management of Contaminated Soil According to IED, the Case Study of Flanders

The establishment of an efficient system for the protection of soil and groundwater from contamination by IED, requires the establishment of a functional organizational framework at the state level, which consists of the legal framework that defines in detail the protection of soil and other instruments for the implementation of policies such as the register of contaminated soils; soil certificates; soil standards; assurances for financing; accreditation of soil experts [22]. As a functional example of the establishment of such effective and developed system, one can examine existing Flemish management system for contaminated soil from which the established solutions are partially transferable. The disclosure of Flemish system is briefly outlined below.

Flemish system for management of contaminated soil is defined in the regulations and the Decree on soil remediation and protection [23], adopted at 14th December 2007, aimed on protecting the soil from contamination and damage. The goals of protection strive towards improving the condition of soil close to the natural, unpolluted environment. The Decree regulates the obligation of removing the "historical" pollution over the period of the past 40 years as well as prevention and

FIGURE 1. Explored contaminated sites in Flanders from the Land register

remediation of new soil contamination. There are several instruments for the implementation of the mentioned policy, and one of them is Soil Information Register, containing quantitative and analytical parameters of soil excavated from contaminated sites in Flanders. The Soil Information Register contains the so called "Soil certificate", available for each of the specified plots with all necessary information about the land parcel. The entire system is carried out by the Waste Agency of Flanders (OVAM). Inventory of potentially polluted land is carried out at the lower administrative levels such as counties (Figure 1).

New contaminated sites imply that they have been contaminated after 28 October 1995 and that they should be remediated if the contamination exceeds the remediation standards set by law. For the historical pollution that has occurred before 29 October 1995 there are remediation obligations if there is a serious health and environmental risk, all in accordance to certain priorities. The obligation to implement and finance the remediation is on the operator, and in the situation when he is not known, the user of land. In a case when the operator does not possess sufficient resources, it can apply for support from the Flemish government. Standards for remediation (limit and target values) are set by the Flemish government, and they must be below the values that represent a risk to health and to the environment. If it is determined that soil contamination exceeds the given thresholds, a more detailed study of the soil is immediately carried out. To carry out exploration activities on the site, the Flemish government empowers individuals and legal entities called "experts for soil remediation" (currently in Flanders there are 72 legal persons or companies accredited for the soil survey). Experts for remediation conduct a preliminary investigation of soil and groundwater, a more detailed investigation, remediation, and preparation of the final remediation report. By 2013 Flanders has issued over 3 million soil certificates, over 32 000 preliminary soil testing and over 9500 detailed examination have been carried out. More than 4000 remediation projects have been approved, 3500 were initiated and around 2200 were completed.

The Current State of the Management of Contaminated Soils in Croatia

Implementation of the management of contaminated soil according to IED, requires the establishment of a functional operational, multi-level system at the country scale (Figure 2).

JURISDICTION (MINISTRY)

↓

LEGISLATION

↓

REGISTER OF CONTAMINATED SITES

↓

CERTIFIED SOIL EXPERTS

FIGURE 2. Hierarchical components of the soil management system

In the above presented hierarchical structure, the first requirement in the establishment of soil management system presents a clear definition of concerning jurisdictions between ministries. In the current practice in Croatia, for issues related to the soil legislation, the institution in charge is the Ministry of Agriculture where the necessary capacity to implement the obligations has been partially developed. The Ministry of Agriculture through the Agricultural Land Agency is responsible for the operational implementation of the control of soil condition, but mainly on agricultural land (i.e. soil contamination in the urban areas, and nearby industrial facilities, on the non-agricultural land is beyond the scope of this ministry). On the other hand the responsible entity for the implementation of general environmental strategy, policies of sustainable development together with the protection of environmental components such as air, soil, water, sea, biodiversity, environmental directives such as IEDs, according to the Law on Organization and Jurisdiction of ministries and other central government bodies [24] is the Ministry of Environmental and Nature Protection, together with its operating body, the Environmental Protection Agency. At the present neither the Ministry of Environmental and Nature Protection nor the Environmental Protection Agency have developed a sufficient capacity for self- performing and leading of the operational implementation of contaminated soil management by an IED. Also, due to the relatively strong fragmentation of environmental activities between ministries in Croatia the responsible entity for monitoring of groundwater quality at urban sites (what is also required by IED) is within the scope of the Ministry of Health (Public Health) and Croatian waters.

According to IED (Article 22), activities that involve use, production or emissions of hazardous substances that can contaminate soil and groundwater at the site, require the preparation and submitting of a report on the initial state (baseline report) before starting of the operation (industrial process) or before renewal of the environmental permit. However, until today the Croatian legislation concerning soil has not yet defined what presents "soil contamination", what are the pollutants that should be concerned in respect to IED, and also there are no critical limits set. The legislation has not yet defined values that represent "significant pollution" or "significant risk" which exceeds the requirements for the remediation of soil. Although the new law on environmental protection tackles a lot of subjects inside IED, issues associated with contaminated soils are mostly neglected and insufficiently considered so there is a strong need for urgent development of the new legislative framework that will accurately define the obligation and procedures for the management of contaminated soil.

With respect to the Soil pollution register, the Environmental Protection Agency has prepared the GEOL database in 2006 as part of the Croatian Soil Information System (HIST). GEOL is geo-referenced (GIS) database, which includes data and information on potential and identified contaminated sites, pollutants on confirmed contaminated sites, and the status of implementation of remediation of contaminated sites. A linkage of the GEOL database with the database of Landfill Inventory and the data in the

Register of installations in which dangerous substances are present (RPOT) has been performed. Given the current state, the CEA has made a significant step towards building a comprehensive IT - spatial platform, which provides a good basis for further development of management system of contaminated sites in Croatia. Next steps require continuous replenishment of established database structure with quantitative parameters of soil, depending on the source of contamination on all relevant locations for IED what is likely to represent a time consuming and financially demanding process.

Ambiguities in the Current Soil Management Practice in Croatia (Examples from Urban Zones, Agriculture, Forestry and Natura2000)

The City of Zagreb (Industrial and Urban Pollution)

The Environmental Protection Report of the city of Zagreb (2009) highlighted the problem of inputs of certain pollutants into Zagreb aquifer due to the very probable excessive pollution of soils in some of the locations in the city area [25]. Zagreb aquifer is the main source of drinking water supply for metropolitan inhabitants. Undoubtedly, for the protection of human health, monitoring of the drinking water quality by authorized public health laboratories is carried out. However, according to acquired results, Zagreb aquifer is a very vulnerable environmental system, highly sensitive to contamination. In the metropolitan area, on a number of wells pollution has been detected which indicates contamination of soils (Figure 3). The most common pollution is caused by heavy metals such as lead as shown in the analysis of groundwater in the area of Zapruđe, Prečko, Kosnice and Ivanja Reka. Contamination by manganese (Petruševec, Sašnjak and Kosnica) and mercury (Kosnica) is also very common in groundwater. In addition to pollution by heavy metals, a specific problem represents atrazine, which have been found in groundwater in the agricultural area near Buzin. Due to excessive inputs of pollutants into groundwater, within 10 years, the city of Zagreb remained without water supply wells that provided around 114.5 million litters of drinking water per day (what is equal to the needs of the city of 350,000 inhabitants).

The case of Zagreb aquifer presents sterling example of the lack of a systematic approach for the management of contaminated soil, which leads to the pollution of groundwater and ultimately resulting in the closure of water wells. Systematic approach, which would reduce the long-term pressure and the risk of contamination can be sought by transposing and implementing good environmental practice contained in IED through the following steps: a) increased engagement of the city administration to identify contaminated sites and associated pollutants; b) determining the status of soil contamination by authorized soil experts; c) establishing threshold values for soil that do not pose a significant risk to health and the environment (at the state ministerial level); d) the gradual conduction of remediation on established risk sites; e) the adoption of comprehensive legislation that will define all previous measures.

Zadar County (Agricultural Production)

The state of soil pollution of Zadar County, which is mandatory for production of the County Environmental Status Report (2012), was assessed using geochemical atlas of Croatia [26]. The obtained results confirmed existence of elevated concentrations of arsenic, cadmium, chromium and manganese (Figure 4), the pollutants which are mostly highly toxic to humans, plants and animals. Elevated concentrations of arsenic, chromium and manganese in the area are formed by nature, they are related to geological bauxite deposits and their weathering, while the most possible origin of cadmium are local sources of pollution. According to the existing legislation (Regulation on the protection of agricultural land from pollution [10] and valid critical limits (maximum allowable concentrations), large areas in the County can be classified

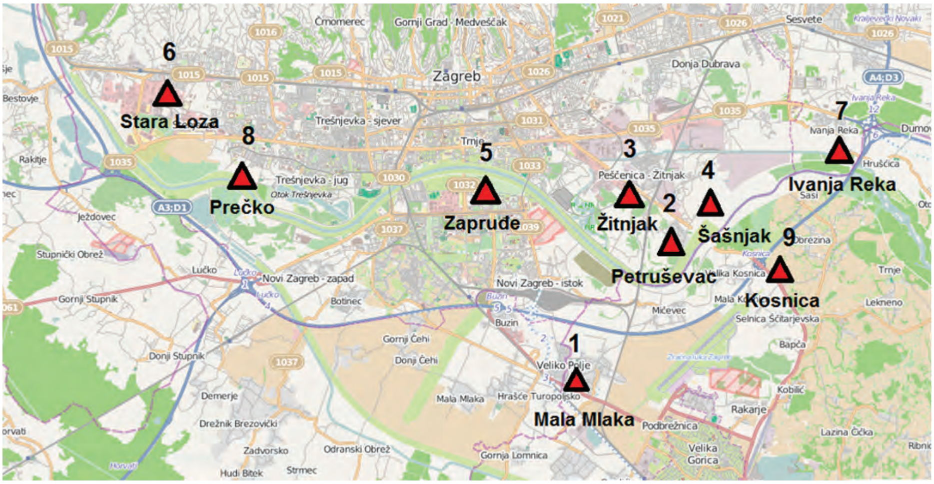

FIGURE 3. Locations of polluted water supply wells in the city of Zagreb (1. High and constant concentrations of atrazine, chromium, lead, cadmium and copper; 2. High concentrations of manganese; 3. High and constant concentrations of organic solvents; 4. High manganese concentrations; 5. Periodically high concentrations of lead; 6. High concentrations of lead, iron, manganese and trichloroethane solvent; 7. Higher concentration of nitrates, lead and organic solvents; 8. Excess of bacteria, cadmium and lead; 9. High concentrations of iron, manganese, zinc, lead and mercury)

as "contaminated" due to the high content of these elements in the soil. It is particularly important to emphasize high concentration of chromium in the wider area of Ravni kotari, which are very famous for their intensive agriculture. According to current regulations and established critical limits, soil in the vicinity is classified as "contaminated" and it is questionable if these areas can be used for "Ecological agricultural production" and fulfil the requirements for obtaining subsidies for ecological farming. However, since these high concentrations are mainly of natural origin, in the area historically committed to agriculture, it is questionable how much in reality these elevated concentrations of chromium represent a "significant risk" to health and the environment, and whether it is necessary to constrain subsidies for food production because of that historical "pollution" and vagueness of existing legislation. In drafting of the new regulations concerning soil contamination, one must take into account the natural load of polluting substances in the soil as well as their realistic environmental risk.

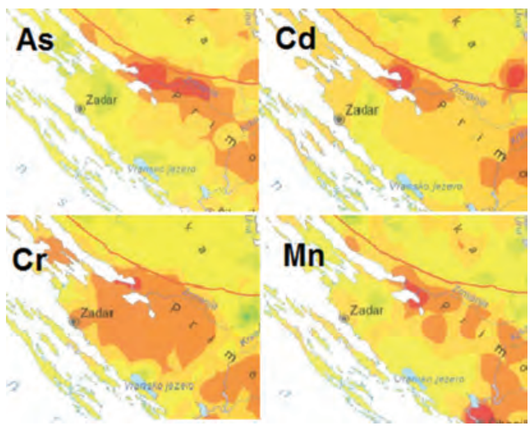

FIGURE 4. The load of arsenic, cadmium, chromium and manganese in the area of Zadar County [20]

Vukovar – Srijem County (Spačva forest - Forestry, Natura2000)

Spačva forest in Vukovar-Srijem County presents the largest complex of lowland oak (Quercus robur) forests in Croatia and it is partly included in Natura 2000 network. Particularly valuable habitats are in the south-western part of Spačva which consists of the protected riparian mixed forests of Quercus robur, Ulmus laevis, Ulmus minor, Fraxinus angustifolia, alluvial forests (Alno-Padion, Alnion incanae, Salicion alba), oak-hornbeam forests and natural eutrophic waters with Hydrocharition or Magnopotamion vegetation. However, a large part of these protected habitats are located in the areas with polluted soil with a high content of chromium and nickel (Figure 5), due to a historical sedimentation by flooding. Although in the above case it is not realistic to perform any kind of remediation measures, the soil management practice and legislation should at least consider the risk on the environment and habitats which potentially could presents these elevated concentrations in soils. Separate "physical" protection of naturally valuable areas against man made influence have only full meaning if the components of environment such as soil are also considered and protected by respective regulations. One cannot establish physical barriers around naturally protected areas, there will always be the pressure of emissions of pollutants from the surroundings and therefore the proper implementation of the Habitat directive and nature protection should aim on development of regulation and management system also related to the protection of soils and reduction of environmental risk to air, water and soils at the Country level.

CONCLUSION

Soil protection in the EU is carried out by various sectorial directives where soil is not a core subject. Soil protection is particularly orientated on preventing the contamination of surface and groundwater.

- Some of the Directives which partly and indirectly consider soil protection Water framework directive (Directive 2000/60/EC concerning Water & Directive 2006/118/EG concerning Groundwater) with the aim of obtaining good water status until 2015 and improving of groundwater quality. This directives aims on production watershed management plans with identification of point sources of contamination.
- The EU Directive on environmental liability (Directive 2004/35/CE concerning environmental liability) aims to prevent and remedy environmental damage, and in particular soil destruction. This Directive regulates how investors and performers of various harmful activities in the environment must take the necessary measures to prevent adverse impacts on the soil.
- The protection of soil from pollution is regulated by the Directive on industrial emissions (Directive 2010/75/CE concerning Industrial Emissions, IED). IED Directive sets the obligation on the industrial operator before the start of production to prepare a report on the initial state of soil as a necessary requirement for obtaining the environmental permit. It sets obligations for the monitoring of soil and the groundwater status in the

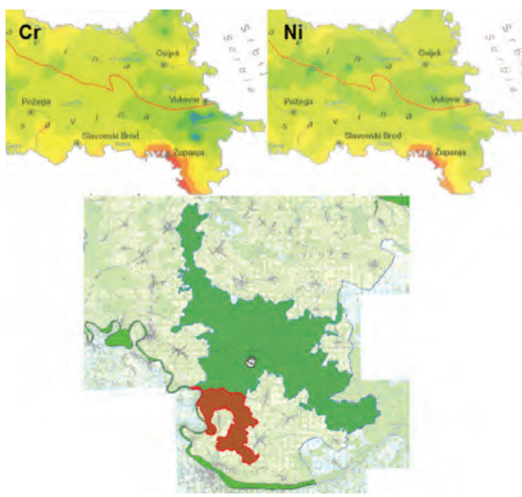

FIGURE 5. High concentrations of chromium and nickel [20] in the Natura 2000 protected area of Spačva forest

location of an industrial facility for a period of ten (soil) and five years (groundwater). After the cessation of production, and in the case of exceeding critical limits of pollution, the operator is obliged to perform remediation or restitution of land in the state as it was at the beginning of production.

Management of contaminated soil according to IED requirements oblige the Croatian government to establish a complex system at multiple levels. First, it requires better definition of responsibilities between ministries; in particular, between theMinistry dealing with environmental protection and sustainable development and the Ministry dealing with agriculture. IED requires enactment of adequate legal basis (i.e. Soil protection act) and the establishment of operational instruments for the implementation of soil protection, such as register of contaminated soil and the accreditation of soil remediation experts.

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Preliminary communication

Assessment of Forest Damage in Croatia Caused by Natural Hazards in 2014

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Abstract

Background and Purpose: Recent natural disasters (ice-breaks, torrents, floods) that affected five Croatian counties caused significant damage on forest stands and forest infrastructure. Since in Croatia there is no common methodology for fast and reliable assessment of forest damage, the aim of this paper is to develop and present methodology for rapid damage assessment and to prescribe urgent recovery measures, as well as to provide first preliminary results of the total damage to forests.

Materials and Methods: An attempt was made to develop the methodology which would rely on existing legislations, regulations, instructions and experiences for forest damage assessment as much as possible. Estimation of forest damage was based on field observations, spatial data of forest management units and data from the existing Forest management plans.

Results: According to conducted assessment, forests of Primorsko-goranska County are the most affected by the overall damage caused by ice-storm. Major damages occurred both on the forest and on forest roads. Ice-storm also caused serious damages on forests and on forest roads in Ličko-senjska County and Karlovačka County, while floods and torrents caused damages on forest roads in Zagrebačka County, Sisačko-moslavačka County and Karlovačka County. Money-wise, the total forest damage amounts 942 252 183 €.

Conclusions: Methodology for rapid damage assessment presented in this paper resulted on first preliminary estimate of range, intensity and cost of forest damage caused by recent natural disturbances. More precise data on forest damage will be known after the implementation of the proposed emergency recovery measures. Also, certain improvements of methodology in terms of precision and collection of data may be achieved by incorporating remote sensing methods.

Keywords: ice break, torrents, floods, damage assessment methods, forest, natural disaster

INTRODUCTION

Natural hazards can significantly affect the sustainability of forest ecosystems [1]. Besides the influence on structure and functionality of a forest ecosystem, natural hazards often cause economic loss, especially in managed forests [2, 3]. Studies on forest damage caused by natural disturbances such as ice storms, torrents or floods are infrequent [4], especially in the region of the South-east Europe. However, the negative impact of natural hazards on forests should not be ignored. Schelhaas et al. [5] showed the increasing trend in frequency and severity in the last decades of the major disturbance types in Europe.

In the period between 31 January and 6 February 2014 significant damage of forest ecosystems caused by several natural hazards occurred on the area of five Croatian counties. In the Primorsko-goranska County major forest damage occurred due to freezing rain (ice-breaks) in a form of damage of forest stands, forest roads and forest skid-trails. Extreme rain supported by huge water waves from Slovenia resulted in excessive floods, which caused significant damage on forest roads, forest skid-trails and other forest infrastructure in areas of the Zagrebačka County and Sisačko-moslavačka County. Damage in Karlovačka County and Ličko-senjska County was caused by the same stress factors but of lesser intensity. In all affected counties a state of natural disaster was proclaimed. In order to apply to the EU Solidarity Fund, damage assessment had to be done in a very short period.

In Croatia, there is no methodology for fast and reliable assessment of forest damage. Only several studies of earlier date [6-8] dealt with the assessment of forest damage caused by ice-break, mainly after greater damages occurred. Therefore, recent natural disasters raised the need for a methodology that would consolidate existing legislations [9-11], regulations [12-14], instructions and experiences [6-8, 15-19] and propose the use of advanced technology for the assessment of range and intensity of forest damage.

This paper aimed to present the developed common methodology for rapid damage assessment and to prescribe urgent recovery measures, as well as to estimate the total damage of forests in the Republic of Croatia that were caused by natural hazards. Specific measures and procedures applied in this methodology including the procedure for the interpretation of results are shortly described. The cost of damage on forests, forest roads and skid-trails, the cost of recovery, afforestation and protection of newly established stands and the cost of losing forest ecosystem services were calculated, as well as the cost of emergency interventions by Croatian forests Ltd. while enabling public traffic and public access to damaged areas. Furthermore, long-term consequences for forest ecosystems and forestry as economic activity were discussed.

MATERIALS AND METHODS

Study Area

The area of five Croatian Counties affected by natural disturbances is shown in Figure 1.

Within each County there is one or more Forest Administrations (FA) which were differently affected by ice-breaks, torrents or floods. FAs are organizational units of Croatian forests Ltd. responsible for the overall (state-owned forests) or partial management (state-owned forests within protected areas – natural parks, privately-owned forests) of forests located within their boundaries. On the area of the counties affected by natural disturbances the following FAs are located: FA Delnice (Primorsko-goranska County), FA Senj (Ličko-senjska County), FA Zagreb (Zagrebačka County), FA Sisak (Sisačko-moslavačka County), FA Karlovac and FA Ogulin (Karlovačka County). Concerning damage on forests caused by ice break the FA Delnice was mainly affected together with National Park Risnjak (Figure 1 – hatched area).

Existing Regulations for Assessment of Forest Damage

An attempt was made to develop methodology which will rely on the existing regulations for forest damage assessment [9, 10] as much as possible.

The Methodology for Damage Assessment Caused by Natural Disasters [9] prescribes the

FIGURE 1. The area of 5 Croatian Counties affected by natural hazards including the location of Forest Administrations' (FA) headquarters and National Park (NP) Risnjak. Hatched area in the Primorsko-goranska County (NP Risnjak, FA Delnice) presents the most damaged forest area by ice-break.

procedure of damage assessment for damage caused by ice breaks and floods in the Republic of Croatia. The purpose of damage assessment is the assessment of type and scale of damage in units of local government and self-government and the Republic of Croatia in general according to the time and cause of damage, as well as according to the cost of damage for the local population. Calculated costs are expressed in monetary value in terms of the amount needed to repair damaged goods or in some cases to buy new ones. Total damage costs also include costs caused by natural disaster that would not occur otherwise, such as costs of damage risk prevention, work of committees, various refunds etc. According to the Law on Protection from Natural Disasters [10] the refund is allocated only for the mitigation of consequences caused by natural disaster in terms of direct damage on goods, while indirect costs are not taken into account.

Determination of Damaged Area and Damage Intensity

Usually, the main problem after the occurrence of forest damage is physical access to the affected area. In terms of ice breaks, an initial assessment and emergency interventions could be done during the duration of natural disaster. However, a full assessment is possible only after the ice melts down. During floods limited access is also possible by boat, but also the full assessment is possible only after the water withdraws. Forest damages caused by ice breaks or floods depend on the amount of ice or water and the time of retention in the forest stand.

In case of limited or completely restricted access to forest, remote sensing methods may have advantage over terrestrial methods which will be discussed later in the separate subsection (Incorporation of Remote Sensing Methods). However, due to certain circumstances, such as very short period for the delivery of the report on damage assessment which was considerably shorter than the expected delivery time of satellite images, as well as, bad weather conditions (fog, low clouds) for images acquisition, the initial assessment of damaged area and intensity was conducted by using terrestrial methods.

Thanks to precise division on forest compartments, i.e. spatial organization of forests management units in Croatian forests Ltd. and data from relevant Forest management plans the field work and assessment of damages was possible without direct measurements. The work in the field started even during ice-break by cleaning the area from fallen trees and other obstacles to make access to endangered area which enabled marking of damages and assessment of affected area and intensity of damage in the same time.

Forest area affected by the natural disturbances was delineated based on spatial division of forests at least on the compartment level when access was possible. Besides the overall affected area which was determined for orientation purposes and for assessment of loss on forest ecosystem services values, the estimate of damage intensity at the stand (compartment) level was conducted.

The damage intensity of forest stands was assessed in accordance with the Methodology for Damage Assessment Caused by Natural Disasters [9]. For each damaged stand (compartment), a degree of the damage (P) was estimated by evaluating the share of damaged trees in the stand. The value of P was determined by a committee after a visit to the damaged area and its value ranged between 0 and 1.0 with precision of 0.1. The tree was considered damaged when its upper third of the crown, considered as the most active part of the crown on which depends the possibility of survival of the whole tree, was damaged more than 50%. If the vital part of the crown was damaged less than 50%, the tree was not recorded as damaged. The broken, uprooted trees (Figure 2), and trees with majority of the crown broken were considered as totally damaged (destroyed) trees.

FIGURE 2. Uprooted and fallen trees

According to the estimated degree of damage (P), forest stands were classified into two groups:

1. Damaged forest stands - stands in which share of damaged trees is lower than 70% ($P<0.7$). Stands in which the timber is damaged in a way that its economic value is reduced, that the costs of felling, bucking and extraction are enlarged, yet certain potential for utilization of logged timber remains comprised.
2. Destroyed (totally damaged) forest stands - stands in which the share of damaged trees is higher than 70% ($P>0.7$). Stands that require recovery. The assumption is that timber from these areas will be logged and extracted without any expectation of its further use except for firewood (woodchip) (Figure 3).

The spatial extent of damage due to floods was initially approximated according to the flooded area, which was hardly accessible or inaccessible. After water withdrawal a more precise data were identified on the damages made by floods or torrents which appeared due to water arrival or withdrawal. In this case the damages were recorded only on infrastructure i.e. on forest skid-trails, classified and unclassified forest roads, due to torrents. This resulted either in the deposition of larger quantities of material on forest roads which made them hardly accessible or inaccessible, or in removal of part of the forest roads and the construction material which led to their damaging.

FIGURE 3. Completely destroyed forest stand

In such a way the determined damaged areas served as a basis for further calculation of damage costs, as well as for defining the priority of forest areas for recovery.

Estimate of the total amount of damage

Estimate of the total amount of damage (loss of value) on timber volume

When estimating the damage of natural disasters in the forests, the areas under deciduous and coniferous forests per ha are identified, and then the volume of timber in m^3 per timber assortments (damaged or destroyed) in forest stands is estimated [9].

The loss of value of timber volume was obtained as a difference between the values of forest stands before and after the damage occurred. The value of forest stands before the damage occurred was estimated depending on the age and stage of development of the stands in accordance with Regulations on forest management (Chapter VIII, Determination of fees for transferred and limited rights to forest and forest land) [12].

The value of timber assortments (technical and fuel wood) for damaged forest stands was calculated according to the average prices achieved in the previous year (source: Croatian forests Ltd.). The amount of damage was calculated using the form EN-5A ("The damage from natural disasters in the damaged forests") so that the total value of undamaged timber (before natural disturbances) multiplied by the degree of the damage (P).

For totally destroyed forests the value of damage was calculated using the form EN-5B ("The damage from natural disasters in the destroyed forests"). The damage is equal to the total value of damaged forest by assortments (technical and fuel wood) reduced in accordance with the percentage of the use of timber.

In order to calculate the total damage of timber, increased costs of harvesting of destroyed trees as well as loss of timber increment were added to the loss of value of timber volume. Increased costs of harvesting, i.e. costs of felling, bucking and extraction of destroyed trees to the roadside were calculated based on the determined priority forest areas for recovery. Priority forest areas for recovery by felling are determined as the quarter of the totally damaged area prescribed for urgent recovery by felling, bucking and extraction of all the trees regardless of whether they are broken or uprooted. Increased costs of harvesting were calculated by multiplying destroyed timber volume with the average cost of harvesting of 16 €/m^3 (source: Croatian forests Ltd.). For the calculation of loss of timber increment, the average increment of the affected area of 5.9 m^3/ha was used [20]. This was multiplied with the total destroyed area, so an overall increment value on this area was multiplied with the average value of 41 €/m^3 and multiplied with 30 i.e. the number of years in which we expect that new stands will reach its stability and ability to fulfil all its functions after recovery.

Costs of recovery (sowing or planting of seedlings)

Due to the risk of erosion on the identified priority areas for recovery, sowing or planting of seedlings need to be done in a certain timeframe which means in the same vegetation period or, at the latest, at the beginning of the next growing season [11].

Areas scheduled for the recovery by replanting were determined in the same proportion for both state and private forests, and the costs of recovery were planned in the same amount according to the valid scale of charges and in accordance with existing standards, using the workforce of the Croatian forests Ltd and their external services.

The following activities were included in the calculation costs of: (a) soil preparation, (b) planting of new young stands with an estimate of the required planting material, (c) tending and protection of new young stand, and (d) additional revision of Forest management plans (Table 4). Required working days and quantities of planting material were taken from the existing norms of Croatian forests Ltd.

Determination of damages on forest roads and forest skid-trails

The damages on forest roads and forest skid-trails were classified as follows:

1. Damages on forest roads were classified in two groups:
    a. Damages occurred as a consequence of down timber and breakage of trees fallen on the roads causing direct damage i.e. the roads are closed for traffic which requires clearing of roads in order to prepare conditions for free access and recovery of the affected areas.
    b. Damages occurred on roads themselves which are visible as landslides, damaged system of longi-tudinal and transversal drainage and damages on the road cross-section, its upper and lower stratum/layer, affected after the ice melt or water withdrawal (Figure 4, left).
2. Damages on forest skid-trails which encompass damages which occurred as a consequence of down timber and breakages, and the impact of water, require recovery in order to allow free traffic communication and access to the affected areas for the purposes of recovery (Figure 4, right).
3. Construction of new skid-trails in order to allow the access to the forest areas which were severely damaged by natural disturbances, in order to conduct further necessary measures of recovery.

In order to ensure functionality of the local population in the affected areas emergency measures in terms of establishment of public traffic on important roads and public access to facilities were undertaken by Croatian forests Ltd. Therefore, the costs of the undertaken emergency measures were also estimated.

Costs of damage (loss of value) of forests ecosystem services (FES)

Besides the marked-validated forest products (timber products, non-wood products), forests

FIGURE 4. Left: Damages on forest road caused by landslide. Right: Damages on forest skid-trail

provide both material (e.g. tourism, hunting, etc.) and intangible (e.g. positive impact on forest health) benefits, known as forest ecosystem services (FES), in which people can enjoy [21-23].

The value of forests ecosystem services (FES) is defined by the Law on Forests [11], Regulations on forest management [12], Regulations on the method of accounting, forms and deadlines for payment of fees for the forests ecosystem services (FES) [13] and Regulation on the fee transferred and limited rights on forest and forest land [14].

Although natural disasters are not listed among the reasons for which the fee is calculated, alogic of Regulation [14] was applied in the estimate of the total damage to the forests to which the loss of FES will be added. According to the Regulations on forest management [12], for each forest on the compartment level the value of FES was estimated according to: protection of soil, roads and other structures from erosion, torrents and floods, the impact on the water regime of the hydroelectric system, the impact on soil fertility and agricultural production, the impact on the climate, protection and improvement of the environment, creating oxygen and purifying the atmosphere, recreational, tourist and health functions, and the impact on fauna and wildlife.

Estimate of the loss of FES was done in accordance with the estimated degrees of damage and the contribution of the damage on the level of management unit using the average value identified in the forms O-16 of the valid Forest management plans. In accordance with the prevailing intensity of damage the FES value was reduced by 40% (average estimated reduction in the value of forests for all stands is 40%), for less damaged stands the value was reduced by 20% while for destroyed stands the total value of FES was calculated as damage.

Calculation of the total damage of forests

Calculation of the total damage of forests and forest infrastructure caused by recent natural disasters was done by summarizing the estimated costs of all damages. Furthermore, the calculation of the cost of conducted emergency measures from the side of Croatian forests Ltd. professionals during the assistance for the establishment of public traffic on important roads and public access to facilities was done.

RESULTS

Forest area affected by natural hazards

In total, 56 021.68 ha of forests were affected by damages all in the Primorsko-goranska County (FA Delnice), Karlovačka County (FA Ogulin) and the Ličko-senjska County (FA Senj). Based on the degree of damage (P) estimated on compartment (stand) level, it was found that 19 245.79 ha of forests have been seriously damaged, while 9 808.22 ha of forests have been totally destroyed (Table 1).

Degrees of damage are shown on maps of damaged (Supplementary material 1, Supplementary material 2) and destroyed (Supplementary material 3, Supplementary material 4) forests for broadleaved and coniferous species separately. These maps illustrate the seriousness of the damage and define the priority of forest areas for recovery (sanation). They are also good indicators of spatial distribution of this disaster and its various degrees of damage.

TABLE 1. Forest area affected by natural hazards (FA Delnice, FA Senj, FA Ogulin)

Ownership	Overall affected area (ha)	Damaged forest stands (ha)	Destroyed forest stands (ha)
State-owned	45 821.90	9 522.36	7 377.36
Privately-owned	10 199.78	9 723.43	2 430.86
Total	56 021.68	19 245.79	9 808.22

Total amount of damage

Damage on timber volume (loss of value)

The loss of timber volume of damaged and destroyed stands for FA Delnice, FA Senj and FA Ogulin was calculated according to the described methodology, i.e. by subtracting the value of damaged or destroyed forest stands from the value of forest stands before the damage.

The loss of values of damaged and destroyed forests was calculated as the sum of the loss of reduced values of damaged timber (Table 2. 1A) and the loss of the value of destroyed timber (Table 2. 1B) and it amounted to 67 528 498 €. The loss of the value of destroyed timber (Table 2. 1B) was calculated as a difference between the destroyed and damaged timber, which is then multiplied by a reduced value of 10 €/m^3.

Based on the determined priority forest areas that need urgent recovery by felling, bucking and extraction (9 600.59 ha), increased costs of harvesting were calculated. Destroyed timber volume (1 644 946 m^3) from the priority forest areas was multiplied with an average harvesting cost of 16 €/m^3 which resulted with increased harvesting costs of 26 259 016 €.

TABLE 2. Loss of values of damaged and destroyed forests (FA Delnice, FA Senj, FA Ogulin)

1A. Loss of reduced values of damaged wood volume				
Ownership	**Area** (ha)	**Technical wood**	**Fuel wood**	**Total**
		Damaged wood volume (m^3)		
State-owned	45 821.90	2 170 686	1 241 299	3 411 985
Privately-owned	10 199.78	325 471	535 026	860 497
Total	56 021.68	2 496 157	1 776 325	4 272 482
	Area (ha)	**Destroyed wood volume** (m^3)		
State-owned	7 169.74	743 615	419 522	1 163 137
Privately-owned	2 430.86	180 956	300 853	481 809
Total	9 600.59	924 570	720 376	1 644 946
		Wood volume with reduce value (m^3)		
State-owned		1 427 589	822 464	2 250 053
Privately-owned		144 515	234 173	378 688
Total		1 572 104	1 056 637	2 628 741
Total loss (€)				26 287 409

1B. Loss of value of destroyed wood volume			
Ownership	**Area** (ha)	**Destroyed (technical and fuel) wood volume**	
		(m^3)	(€)
State-owned	2 160.26	1 163 137	31 923 551
Privately-owned	9 723.43	481 809	9 317 539
Total	11 883.69	1 644 946	**41 241 089**

By multiplying the total destroyed area (9 600.59 ha) with the average increment of the affected area (5.9 m^3/ha) an overall increment of the destroyed area (70 113.77 m^3) was obtained. An overall increment was then multiplied with an average value of 41.32 €/m^3 and with 30 (the number of years in which we can expect a complete recovery of the affected areas) and it resulted with the loss of timber increment in the amount of 70 205 691 €.

Finally, the total damage of timber is the sum of all three components (loss of values of damaged and destroyed forests, increased costs of harvesting, loss of timber increment) amounted to 163 993 205 €.

Damage on forest roads and forest skid-trails

The total estimated damage on forest roads and forest skid-trails is summarized in Table 3.

FA Delnice is the most affected area by the overall damage caused by ice-break. Damages include forests and forest roads. A total of 2 703 km of existing skid-trails need to be repaired. It was also estimated that it is necessary to build 23.18 km of new skid-trails in order to allow access and recovery of damaged and destroyed forest stands. In other affected areas (FA Zagreb, FA Sisak, FA Karlovac, FA Ogulin) damage on forest roads and forest skid-trails mostly occurred as a result of the impact of huge amount of water which damaged the roads or simply deposited materials onto them, and which should consequently be removed and the top layer of the road repaired.

Furthermore, the cost of undertaking of emergency measures for establishing public roads amounted to 61 592 € and to 11 846 € for FA Delnice and FA Ogulin, respectively.

Cost of recovery (sowing and planting) for destroyed stands

Total cost of recovery was calculated based on 9 600 ha of identified priority areas and it amounted to 65 449 263 € (Table 4).

Cost of damage (loss of value) of forest ecosystem services (FES)

Calculation of costs of damage, i.e. calculation of the loss of value of FES is shown in Table 5. Average FES values in the management units affected by disaster are 22.5 points (HRK/ha/year) and 19.5 points for state-owned and privately-owned forests, respectively. These values were reduced by 40% for highly damaged forest stands and by 20% for less damaged stands (Annex 1, Table FES-1) [14]. The calculated compensation values for each damage class (destroyed, highly damaged and less damaged forest stands) and ownership type (state owned and privately owned forest stands) were then multiplied with the corresponding forest area.

The total cost of losing forest ecosystem services (FES) amounted to 709 619 178 €.

TABLE 3. Summarized costs of damages on forest roads and forest skid-trails

Forest Administration	Type of damage			
	Damages on forest roads (€)	Damages on forest skid-trails (€)	Construction of new skid-trails (€)	Total (€)
Delnice	445 956	1 199 278	190 060	1 835 294
Karlovac	390 415			390 415
Sisak	180 399			180 399
Zagreb	695 511			695 511
Ogulin	15 480			15 480
Total	**1 727 761**	**1 199 278**	**190 060**	**3 117 099**

TABLE 4. Total cost of recovery for destroyed stands – identified priority areas encompass 9 600 ha

Activity	Rate	Employment (%) Croatian Forests	Employment (%) External Services	Quantity	Cost (€·ha^{-1})
Preparation of soil	10 wd/ha	30	70	Manual-machine work	**585.00**
Planting material	8 000 pc/ha	100		Broadleaved, 2+0	2 652.63
Planting material	1 000 pc/ha	100		Conifers, 1+0	368.42
Planting of stock-seedlings	49 wd/ha	30	70	8 000 pc (Beech)	1 977.11
Planting of stock-seedlings	12.79 wd/ha	30	70	8 000 pc (Conifers)	519.87
Transport of planting material	1 machine	30	70	day	177.90
Total cost of planting of new young stand					**5 695.92**
Cost of tending and protection of young stand	1) 8 wd/ha 2) 5 wd/ha	30	70	ha	**523.42**
Cost of additional revision of Forest Management Plan		100			**13.29**
Total cost (€·ha^{-1})					**6 817.63**
Total cost (€)					**65 449 263**

TABLE 5. Cost of damage of forest ecosystem services (FES)

Ownership	Average FES value (points)	Compensation (HRK)	Area (ha)	Damage cost (HRK)	Damage cost (€)
Destroyed forest stands					
State-owned	22.5	255 000	7 377	1 881 135 000	247 517 763
Privately-owned	19.5	190 000	2 430	461 700 000	60 750 000
Highly damaged forest stands					
State-owned	9.0	55 000	9 522	523 710 000	68 909 211
Privately-owned	7.8	51 000	9 723	495 873 000	65 246 447
Less damaged forest stands					
State-owned	4.5	36 750	45 821	1 683 921 750	221 568 651
Privately-owned	3.9	34 000	10 199	346 766 000	45 627 105
Total - State-owned				4 088 766 750	537 995 625
Total - Privately-owned				1 304 339 000	171 623 553
Total				**5 393 105 750**	**709 619 178**

Total damage of forests and forest infrastructure

Total damage to forest stands and forest infrastructure calculated by summarizing all estimated costs amounted to 942 178 745 €.

If the costs of the undertaken emergency measures on public traffic (73 438 €) is added to the cost of total damage, the overall amount is then increased to 942 252 183 €.

DISCUSSION AND CONCLUSIONS

The methodology of rapid damage assessment presented in this paper resulted on the first, preliminary estimate of the range, intensity and cost of forest damage caused by recent natural disasters that occurred at the beginning of 2014 in five Croatian counties. The estimate of forest damage based on field observation, spatial data of forest management units and data from the existing Forest management plans was done in accordance with the existing regulations [9-14].

According to the conducted assessment, forests of FA Delnice (Primorsko-goranska County) are the most affected by the overall damage caused by ice-storm. Major damages occurred both on the forest and on forest roads. Ice-storm also caused serious damages of forests and forest roads of FA Senj (Ličko-senjska County) and FA Ogulin (Karlovačka County), while floods and torrents caused damages on forest roads in FA Zagreb (Zagreb County), FA Sisak (Sisačko-moslavačka County) and FA Karlovac (Karlovačka County).

In the total amount of damage expressed in money (942 252 183 €), the loss of value of FES makes the biggest part (75%). The loss of value of timber from damaged and destroyed stands and the cost of recovery of forest stands amounts to 17% and to 7% of the total estimated damage, respectively. Other costs in the amount less than 1% of the overall damage include costs of reconstruction of damaged forest roads and forest skid-trails, as well as, construction of new ones.

More precise data on forest damage will be known after the implementation of emergency recovery measures. Also, certain improvements of methodology used in this case in terms of precision and collection of data may be achieved by incorporating remote sensing methods.

Incorporation of Remote Sensing Methods

In case of a limited or completely restricted access to forest, remote sensing methods may have advantage over terrestrial methods. Remote sensing methods allow fast and reliable assessment of the affected area [19, 24-26] and give precise information on the range and intensity of the damage caused to forest or forest infrastructure.

Continuous technological development strongly affects the development of remote sensing methods and widens the area of application of these methods. Digital aerial photogrammetric cameras facilitate capturing of digital aerial images of very high spatial resolutions (usually with pixels size from 10-30 cm) and the radiometric resolution [27-29]. Satellite images have an increasing application in forestry not only due to its spatial resolution (less than 50 cm) but also due to lower costs when compared to aerial images. This is of special importance when large areas have to be taken into account [30]. Furthermore, the main features of satellite images are its spectral resolution (higher number of spectral channels compared to aerial images) and the high temporal resolution (frequency of taking images of the same area). Some satellites (e.g. WorldView 2) make a daily survey of a specific point on the Earth's surface. Aerial and satellite images enable quality visual interpretation on the tree scale taking into consideration their features. Remote sensing methods are hence a superior choice for the assessment of damage distribution, intensity and monitoring of success of recovery.

However, in this case, due to a very short period for the delivery of the report on damage assessment which was considerably shorter than the expected delivery time of satellite images (30-50 days), the initial assessment of the damaged area and intensity was conducted by using terrestrial methods. Also, most of the days after recent nature disasters had bad weather conditions (fog, low clouds), and consequently, using the remote sensing data (satellite images) was questionable. Nevertheless, remote sensing methodology for the assessment of damaged area and intensity in this case is still highly recommended. The delayed remote sensing survey (after the occurrence of natural disasters) in spring time when the vegetation starts to grow is even better since it is possible to determine physiological damage of trees and be more specific in the proposed measures for recovery (sanation). These remote sensing images may than serve as a basis for monitoring of the progress of recovery.

Severity and Long-Term Consequences for Forestry

In view of the positive effects of forests on climate, oxygen production, air purification, regulation of water table, prevention of erosion and landslides, population health, and the whole biosphere, the value of forests being reduced or completely nullified by large natural disasters is invaluable. Because of this, the seriousness and the longevity of effects on forest ecosystems, biodiversity and economy in this case, forestry has to be especially emphasized.

Overthrown trees and breakages of stem or branches and parts of crown, e.g. tree tops in conifers as the result of ice, in some areas have caused total blockage of roads and skid-trails, making large parts of forests inaccessible, and leaving a large number of forest roads damaged after the withdrawal of ice and water.

The damages in forests, be it individual trees or entire stands, in different degrees and coverage at the scale of management units, have one common denominator – the change in health status, structure, quality and value of stands requiring extraordinary measures and a whole new approach when it comes to either resolving urgent restorations, or future management with the goal of mitigation of long term after effects.

If the restoration, mitigation and regeneration measures are not taken immediately, is going to have serious and long reaching consequences, but even with all measures that have been, or will be taken in the next couple of months, the damage and after effects will continue to emerge through a longer time period. Generally, we can say that the regeneration of a forest stand lasts on average about 30 years, so we have to assess the negative impact of increment reduction and non-wood value of forests for that time span.

Along with the degradation of the overall status of forest stands, we have to expect a significant effect on the economy linked to this resource, as due to increased volume of wood on the market the prices will likely fall. Also, the wood coming to the market in the course of restoration will not achieve the expected price not only due to increased volume of wood on the market, but also due to the lesser quality of the wood itself. The choice of wood assortments will also be disturbed and those of lesser quality and price will prevail, taking a toll on the financial result of the company.

Due to the urgency of managing a large number of operations in a short time, the price of their accomplishment may rise, additionally lowering the income from wood. Additionally, in a longer timeframe, the costs of forest tending and regeneration will increase, and we should expect more tree dieback after a few years due to the increased activity of secondary pests and diseases and the changed ecological and stand conditions.

All this points due to the serioussness of the established situation, for which the costs of damage will be added for years to come, with regeneration, nursing and protection measures adding to the management costs. The newly developed situation puts in front of the forest practice and science a large challenge – how to, in the shortest time possible, restore the stability and grandeur of these forests, requiring the adaptation of forest management with new silvicultural and management methods for the future.

Emergency Recovery Measures

For the urgent recovery measures by logging and regeneration one quarter of destroyed forest stands were proposed according to the emergency assessment made by experts on the terrain.

The rest of damaged forest areas need to be recovered by using enhanced, and revised regular trees-marking, other measures of cutting, exploitation and cleaning of forest stands with smaller diameters, which have been damaged the most.

Damaged stands, as in our example of beech stand, in order to protect the forest soils on the steep slopes and thin and skeletal soils, require rapid recovery due to the possibility of erosion on that torrential area where there is a high possibility of soil washouts due to large amounts of precipitation.

Tree-marking and measurement, as well as, record of all the damaged trees need to be done at the destroyed stands, and those trees having a chance to recover shall be left, and marked trees must be removed from the stand. Because of the steep and inaccessible terrain at these stands, the new forest roads and forest skid-trails that will enable removing all felled timber with at least damage to future young stands as possible have to be designed and constructed.

After the exploitation of the timber, an assessment of rejuvenation on forest compartment area has to done, or, in other words, the assessment of the seedlings, yearlings and saplings which can be counted on as a future stand. The other parts of damaged forests have to be planted by deciduous seedlings (8000 pcs (units)/ha) and conifers seedlings (1000 pcs (units)/ha), in other words (or,) taught by this kind of experience, to establish mixed forest stands that would have greater stability and have better possibility of survival given these and similar situations.

All emergency measures, as well as those that will come after them have been described in previous chapters and in rough form consist of, intensified work on measurement, tree-marking and exploitation, part-revisions of forest management plans as a results of significant changes in the stands which are looking for a change of management plans for the future management, more intensive activities on the reconstruction of damaged roads, especially forest roads and skid-trails and construction of the new required for the urgent recovery activities. Urgent recovery by using tree felling and the regeneration of damaged stands with the establishment of new ones with implementation of all the preparatory and protective (measures) as well as silvicultural measures during the establishment of young forest stand.

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Supplementary materials

Supplementary material 1. Map of broadleaved forests damaged by ice-break (http://www.seefor.eu/supp_material/vuletic_et_al_1.pdf)

Supplementary material 2. Map of coniferous forests damaged by ice-break (http://www.seefor.eu/supp_material/vuletic_et_al_2.pdf)

Supplementary material 3. Map of broadleaved forests destroyed by ice-break (http://www.seefor.eu/supp_material/vuletic_et_al_3.pdf)

Supplementary material 4. Map of coniferous forests destroyed by ice-break (http://www.seefor.eu/supp_material/vuletic_et_al_4.pdf)

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