Clean Up Georgia – Increasing Public Awareness and Involvement in Solid Waste Management Improvement (Phase II)

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FOREST HABITAT RESTORATION IN GEORGIA, CAUCASUS ECOREGION

GSNE "Orchis"

SWEDEN

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Executive Summary

Forest Habitats in Georgia

Georgia—as a part of the Caucasus ecoregion—is among the planet's 34 most diverse and endangered hotspots designated as conservation priorities because the Caucasus is a region of remarkably rich vegetation with a very high level of endemism. There are about 400 wood species in forests, including trees (153), high shrubs (202), low shrubs (29), and lianas (11). The forest in Georgia contains relict tree species remaining from ancient times when there was no glaciation in the Western Caucasus and forest degradation was not influenced by climate. The refuge of Colchic forest habitat type contains relict species of the Tertiary Period: fern, ***Hymenophyllum tunbrigense,*** arboreal plants—***Fagus orientalis, Castanea sativa, Zelkova carpinifolia, Pterocarya fraxinifolia, Diospyros lotus, Taxus baccata,*** etc. It needs protection and forest restoration.

Natura2000 habitat directives based on the CORINE biotopes classification system identified 24 forest habitat types in Georgia. Eighteen habitat types belong to the European temperate forests and six to Mediterranean deciduous forests. Beech forest group is represented by seven habitat types. Two of them: (1) Beech forest with Colchic understory ***(Fageta fruticosa colchica)*** and (2) Beech forest without understory ***(Fageta sine fruticosa)*** are only found in Georgia. Four other habitats differ from European ones: (1) Dark-coniferous forest (***Piceeta orientale-Abieta nordmanniana)***; (2) Pine forest ***(Pinus kochiana)***; (3) Yew forest ***(Taxus baccata)***; (4) Hornbeam forest ***(Carpinus caucasica)***. Five habitat types of Mediterranean deciduous forests are typical only for the Caucasus: (1) Chestnut forest ***(Castanea sativa)***; (2) Zelkova forest ***(Zelkova carpinifolia)***; (3) Boxwood forest ***(Buxus colchica)***; (4) Kolkheti broad-leaved mixed forest; (5) Arid open woodland; (6) Sub-alpine birch krummholz.

Conservation activity should be related to sensitive forest habitats of Georgia: (1) Beech forest with Colchic understory ***(Fageta fruticosa colchica)***; (2) Kolkheti broad-leaved mixed forest; (3) Bog woodland ***Tilio-Acerion*** forest of slopes, screes and ravines; (4) Alluvial forest; (5) Alluvial forest with alder trees – ***Alnus glutinosa*** and ash trees – ***Fraxinus excelsior (Alno-Pandion, Alnion incanae, Salicion albae)***; (6) Riparian mixed forest; (7) Yew forest ***(Taxus baccata)***; (8) Zelkova forest ***(Zelkova carpinifolia)***; (9) Boxwood forest ***(Buxus colchica)***; (10) Sub-alpine birch krummholz.

Forest Degradation Problem in Georgia

The problem of forest degradation in Georgia is associated with a loss of forest structure, productivity, and diversity of native species. Degradation decreases forest quality that eventually leads to deforestation. Forests in Georgia have been historically set on fire by occupants during wartime, while intensive industrial cutting activities were carried out during the Soviet era, 1930–1950. After this period—between 1950 and 1990—forests were managed principally with objectives for protection and recreation with timber and timber products being imported from Siberia, Russia. Since the declaration of independence in 1990, Georgia's forests have been particularly hard-hit with widespread illegal timber harvesting and uncontrolled fuel-wood exploitation. Moreover, climate change was detected in the Caucasus region. As a result, forests were mostly heavily damaged by overcutting, forest fires, tree diseases as well as hard grazing cows, sheep, etc.

Global warming leading to changes in forest protection has already started in the South Caucasus region causing temperature increase, glacier shrinkage, sea level rise, reduction, and redistribution of river flows, decreased snowfall, and an upward shift of the snowline. Climate change affects many degradation processes in forest habitats: sunlight, water, nutrient cycle, soil erosion, and organisms.

Forest Restoration Programs

Global interest in forest restoration was partly triggered by environmental concerns related to plantation forestry. Rural people complained that the exotic species planted did not provide either fodder for their animals or non-timber product supplies necessary for their daily sustenance. Plantations are often established using industrial techniques often resulting in uniform stands that are relatively low in both biodiversity and other environmental and social values. However, considerable work has been done on more environmentally friendly approaches towards tree establishment. In any use of commercial plantations to contribute to landscape restoration objectives, it is essential to ensure that the plantations are managed to the highest possible standards. In many forests, commercial plantations will have a potential role in restoration. Much will depend on where in the forest they are located and how they are managed. Plantations do not always have to be of a single species. It is not always necessary to keep the land under the trees bare; weeds and spontaneously colonizing local trees can be encouraged.

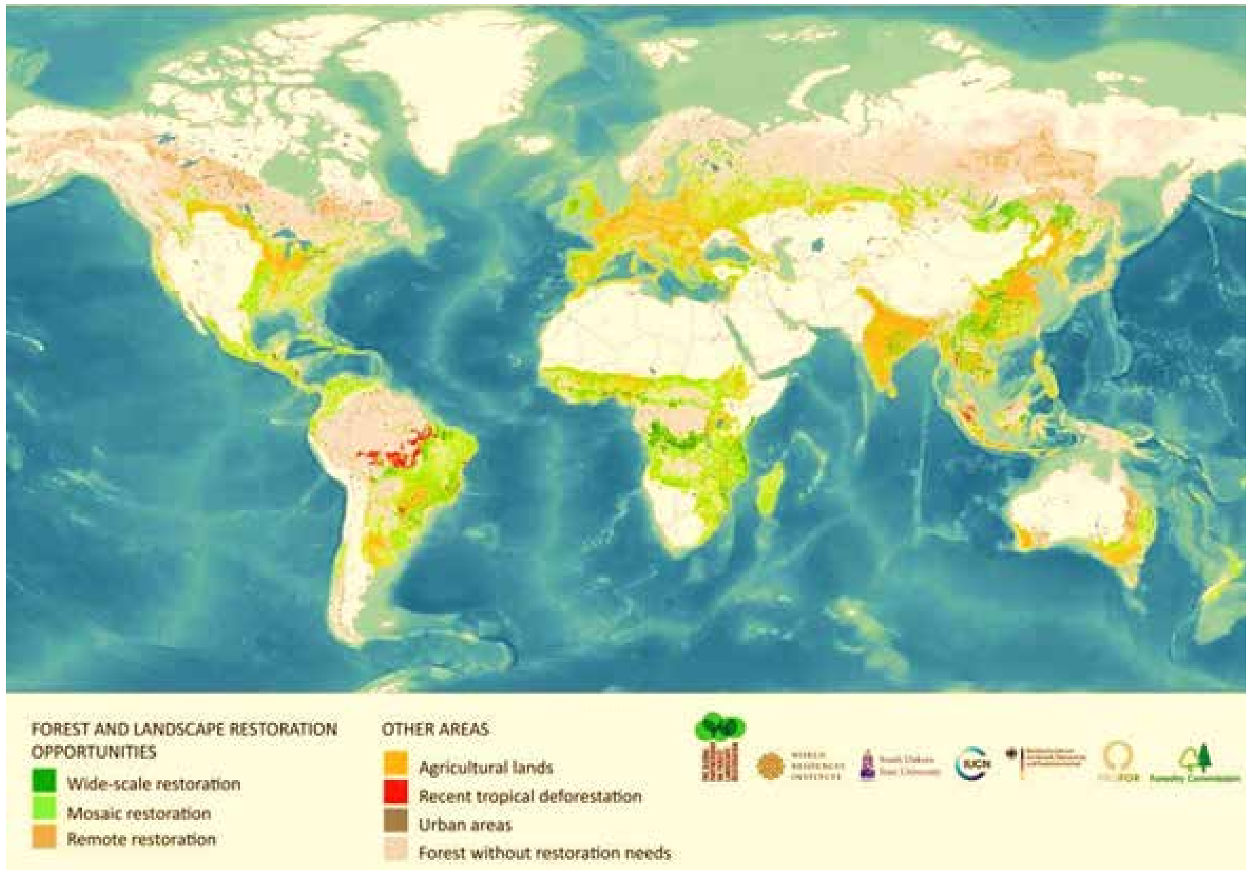
The first step toward restoring quality of forests is to determine what is missing. Many different definitions of naturalness exist at a site level, although most of these do not identify the different components involved. Most aspects of quality restoration can be achieved by removing the pressures that are currently reducing quality, such as overgrazing, changes in fire regime (either unnaturally high or low incidence of fire), poaching, and over collection. Thus, it is important to carry out the forest restoration in the direction of natural habitat types. The plantations should not to contain singletree, invasive, or exotic species. It is desirable to plant all natural species composed in the diversity combination of natural habitat types and to create a fully restored natural habitat. Georgian forests represent a refuge containing relict species conservation of which is essential, and its degradation is unacceptable.

1. Introduction

Forest degradation affects global climate change as well as continental conditions on the earth, which is a problem for human society. Climate change of anthropogenic origin is predicted to lead to mass extinction of plant and animal species in forest regions of the world, and thus become one of the greatest threats to biodiversity **(Walther et al., 2002).** Forests produce large portion of the earth's oxygen and sequester a substantial portion of its carbon, and thus play a major role in regulating climate change. Deforestation and other land-use changes cause climate change, which is a hotcake issue in the present day, especially due to the accumulation of greenhouse gases (GHG)—principally carbon dioxide (CO_2)—in the atmosphere because of emissions caused by industrial activities and combustion of fossil fuels for non-industrial activities **(Nordell 2003; Houghton 2005; Fearnside 2006).**

Different forestry options for different land categories should be targeted not only for sequestrating the carbon but also for meeting the biomass needs of local communities and industries; conserving soil, moisture, and biodiversity; and generating employment for communities through the supply of non-timber forest products (**NTFP**). The cumulative effects of the release of carbon once sequestered in biomass and soil organic matter are likely to contribute to long-term changes in the global climate. These biophysical changes have both social and economic impacts, with the most immediate effects being felt by communities that depend on forests for part or their entire livelihood. Forest resources provide food, medicines, and firewood, resources that now have to be obtained from forests that are more distant. And as forest areas are reduced, pressure on the remaining forests increases even more. There can be four approaches increasing the carbon pool in the forests: (a) conservation of forests and carbon sinks; (b) reforestation in previously forested barren lands and afforestation in newly accredited lands; (c) enrichment of the existing "poor tree cover" forestlands with reforestation; and (d) enforcement of the forestry acts and regulations. All of these approaches are expected to achieve the objectives of forest resources development and abatement of GHG emissions **(Miah et al., 2011)**.

Forests preserve biodiversity and provide habitats for much of the world's plants, animals, and microorganisms. Forests are an important land use throughout the world. Forests covered 3,952,925,000 ha in the world in 2005, which is approximately 30% of the earth's total land surface area **(FAO, 2005)**. Forest loss and degradation is a worldwide problem, with net annual estimates of forest loss being 9.4 million hectares throughout the 1990s **(Map 1)**. Widespread deforestation and declining condition of the world's forests has resulted in environmentally, economically and aesthetically impoverished habitats. To some extent, the effects of deforestation and loss in forest quality have been offset through natural regeneration of forest and the establishment of plantations. However, much of the regenerated forest consists of a few species designed to yield one or two products rather than seeking to produce a broader range of forest goods and services that will also contribute to the well-being of local communities **(Gane, 2007)**.



Map 1. World forest restoration properties on different continents.

In many temperate countries, agricultural practices are intensifying. Small family-owned farms are being replaced by larger industrial operations owned by corporations, while forest remnants and hedgerows are being removed to allow for larger-scale operations. Ironically, the area of abandoned lands in Georgia has also increased since the 1990s. In some cases, previous forms of agriculture were unsustainable and farmlands were abandoned when productivity declined. In other cases—particularly in Georgia—social and economic changes (including reductions in agricultural subsidies) have led to the abandonment of previously productive agricultural lands. Ecological factors leading to land abandonment are in many cases ultimately the result of mismanagement at a landscape level (e.g., unadapted agriculture and overgrazing), and include productivity loss or the land exceeding cattle carrying capacity. Socioeco nomic factors leading to land abandonment include a loss in farmland productivity, diversion of labour toward the industrial and service sectors, reduced subsidies for many crops and regions, and subsidised set-aside programmes (**Benayas, 2005**).

Worldwide, wood from forests is a major economic commodity, serving as the raw material for building materials, paper, packaging, and fuelwood. Export of woods remains the single largest use in Georgia. The aims of forest restoration have therefore always transcended conservation to embrace development. For foresters, restoration traditionally meant establishing

trees for a number of functions (wood or pulp production, soil protection). For many conservationists, restoration is either about restoring original forest cover in degraded areas or about planting corridors of forest to link protected areas. For many interested in social development, the emphasis will instead be on establishing trees that are useful for fuelwood, or fruits, or as windbreaks and livestock enclosures (**Dudley et al., 2005**). Through ecoregion conservation, WWF has learned that large-scale works are complex, costly, and time-intensive. However, it is also a more sustainable way of addressing conservation than through small, often unrelated projects.

World Wide Fund (WWF) – The Conservation Organization and IUCN – The World Conservation Union have been working with a range of other partners since 1999 to promote an approach called "Forest Landscape Restoration" (**Lamb, Gilmour, 2003**). Their aim, through both practical projects and the provision of credible policy advice, is to promote ecological integrity and enhance human well-being in deforested or degraded forest landscapes (**Fig. 1**).

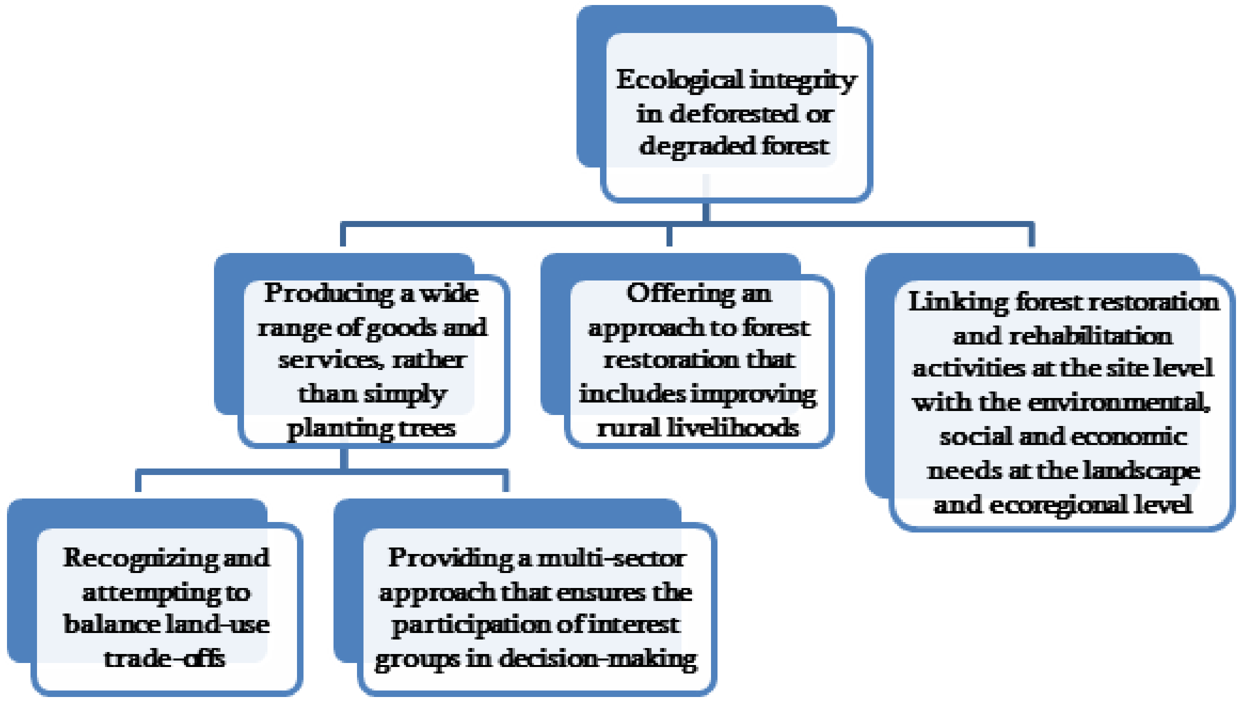


Figure 1. WWF and IUCN approach called "Forest Landscape Restoration" (Lamb, Gilmour, 2003).

Forests are vital to the world's ecological, social, and economic health. People have been actively using forests since long before the beginning of history. Ecological restoration is defined as the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. It is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability. Climate change increases the need for restoration, both to help forest systems to manage existing changes and to buffer them against likely changes in the future by increasing areas of natural, healthy forest systems. Adaptation to climate change via selection of resilient species depends on genetic variation. Efforts to maintain genetic diversity should be applied, particularly in degraded forests or within populations of commercially important trees.

In order to assess biodiversity response under climate change, **Hannah et al. (2002)** emphasized the need to apply simulation models operating on a regional scale. Moreover, species respond differently to climate change because of different adaptations to their environment **(Erasmus et al., 2002)**. However, even though recent simulation tools have occasionally been applied for climate-sensitive animal species **(Wang et al., 2002)**, spatial plant population models are extremely scarce **(Kickert et al., 1999)**. Consequently, single-species models with a regional focus are essential to fully understand the manifold impact of global climate change.

A number of scientific, governmental institutions and nongovernmental organisations **(NGOs)** are acquiring expertise in the area of climate change impacts and adaptation/resilience. It will be fruitful to seek partnerships with these institutions at the beginning of any restoration project to analyse climate impacts and proposed restoration activities. The government agencies with responsibility for human health, animal health, plant health, and other relevant fields need to ensure that they are all working toward the same broad objective of sustainable development in accordance to national and international legislation. Thus, the forest restoration process should be related to climate change and ecological propagation principles.

2. Degraded Forest Restoration Strategy for the Ecoregion

Forest restoration is grounded in ecoregion conservation and is defined as a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forests. Such an approach helps achieve a balance between human needs and those of biodiversity by restoring a range of forest functions within a forest and accepting the trade-offs that result. To some extent, the effects of deforestation and loss in forest quality have been offset through natural regeneration of forest and the establishment of plantations.

Ecoregion conservation is a large-scale, long-term, and flexible concept whose purpose is to meet the four goals of biodiversity conservation: representation, maintenance of evolutionary processes, maintenance of viable populations, and resilience. In degraded landscapes and ecoregions, restoration goals and strategies will be critical to the success of an ecoregion vision. However, as restoration can be energy intensive, its role must be defined in the context of quantifiable goals related to the four larger goals of biodiversity conservation.

The Caucasus is characterized by high endemism. Flora of Georgia is very rich in economically valuable plant species many of which are endemic, threatened, or endangered. The Caucasus has been the centre of evolution for many unique life forms and is a natural museum for rich genetic resources, much of which has been lost due to loss of forest coverage and over-exploitation of certain species of plants for trade and local use. Local population is using fruit and other edible trees and shrubs traditionally and is collecting fruits in nature. Overuse of resources is usually associated with the loss of biodiversity. A number of threats emanate from the overexploitation of natural resources for fuel, fodder, manure, grazing and collecting of ornamental and edible plants. Human society is highly dependent on genetic resources, including those from wild and semi-domesticated sources, for the productivity of its agriculture. Biodiversity is present in all systems, including urban systems, and it plays a significant role everywhere. Thus, biodiversity concerns should be present in the management of all places, and more particularly so in those where human interventions are more severe.

2.1. The Caucasus Ecoregion

The Caucasus ecoregion (580,000 km^2) covers countries—Armenia, Azerbaijan, and Georgia—as well as the territories of the Russian Federation – the North Caucasus, the north-eastern part of Turkey, and the north-western part of Iran **(Map 2)**. This ecoregion is identified by the WWF for Nature as a Global 200 Ecoregion, based on selection criteria such as species richness, levels of endemism, taxonomic uniqueness, unusual evolutionary phenomena, and global rarity of major habitat types.

An ecoregion is defined as a large area of land or water that contains a geographically distinct assemblage of natural communities that share a large majority of their species and ecological dynamics, share similar environmental conditions, and interact ecologically in ways that are critical for their long-term persistence. The Caucasus ecoregion is among the planet's

Map 2. The Caucasus Ecoregion (WWF map).

34 most diverse and endangered hotspots designated as conservation priorities because the Caucasus is a region of remarkably rich vegetation with a very high level of endemism **(Nakhutsrishvili, 2013)**. Georgia has an extremely varied topography and climate that produce a mosaic of habitat types ranging from sea level up to alpine vegetation near the snowline; and, from warm, humid Colchic lowlands at the Black Sea to dry, continental areas in the Eastern Georgia covered by forests of different kinds, steppes, and semi-deserts. 4,400 species of vascular plants, including 380 endemic species, occur in Georgia **(Grossheim et al., 1928)**.

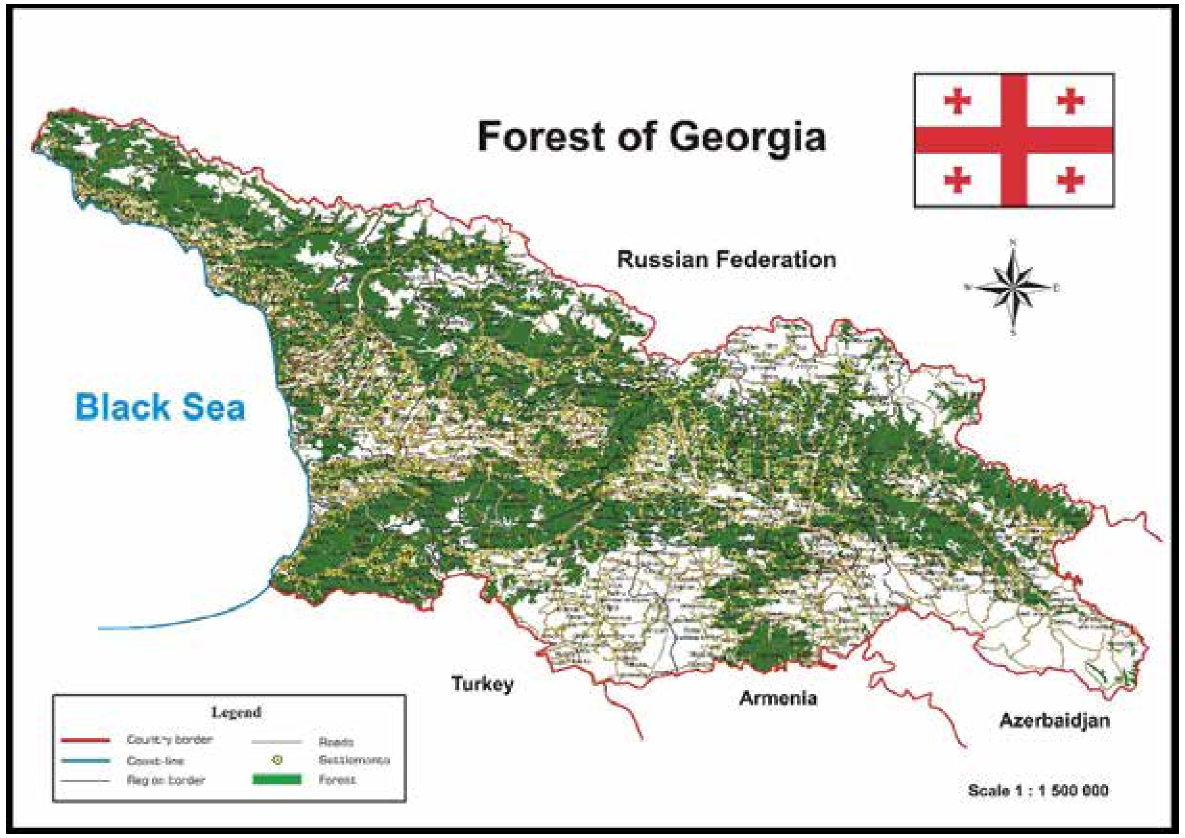
Georgian territory covers parts of the Greater Caucasus mountain range, Transcaucasian depression and the Lesser Caucasus Mountains, which run parallel to the greater range, at a distance averaging about 100 kilometres south, between 40º and 47º latitude east, and 42º and 44º longitude north. Two thirds of the country is mountainous with an average height of 1,200 m.a.s.l., with highest peaks of Mount Shkhara (5,184 m.a.s.l.; **Fig. 2**) at the Western Greater Caucasus and Mount Didi Abuli (3,301 m.a.s.l.) in the Lesser Caucasus.

Figure 2. The gorge of the Enguri River starting at Mt Shkhara Glacier in Svaneti region of the Western Greater Caucasus. Photo by Maia Akhalkatsi.

2.2. Forest Conservation in Georgia

Forests cover 43.18% of Georgian territory (69,700 km^2), 70% of which are mountain forests spread from the lower mountain belt up to the treeline ecotone **(Map 3)**. About 98% of forests are located on mountain slopes **(Gulisashvili et al., 1975).** Georgia is made up of two separate mountain systems: the Greater Caucasus lying between the Black and Caspian Seas; and the Lesser Caucasus, which runs parallel to the greater range. According to **Dolukhanov (2010)**, the Caucasus forest belt can be subdivided into three major elevation zones: broad-leaved forests (50–900 m), coniferous forests (900–1700 m), and high mountain subalpine forests (1700–2000 m) and krummholz forest in treeline ecotone (2000–2800 m).

Total timber stock in Georgia is 418.6 million m^3. Average stock of forest resources per unit area is approximately 300 m^3/ha. The timber stock is 1600–2800 m^3/ha at certain places and the annual growth rate is 10–15 m^3/ha. Virgin forests occupy about 500–600 thousand ha **(Ketskhoveli, 1959).** The Caucasus forests have one of the highest levels of endemism in the



Map 3. Forests of Georgia.

temperate world **(Nakhutsrishvili, 2013).** The overstory is frequently dominated by beech, hornbeam, chestnut, oak, and fir. There are about 400 wood species in forests, including trees (153), high shrubs (202), low shrubs (29), and lianas (11) **(Gigauri, 2000)**.

Conifers are 11 species belonging to three families: Pinaceae (4), Taxaceae (1), and Cupressaceae (6). 81% of total forest area is occupied by broadleaved forests of beech, Georgian and High Mountain oak, hornbeam, chestnut, ash, maple, etc. **(Kvachakidze, 2001).** 19% is coniferous forest composed by Caucasian fir (8.5%), Oriental spruce (5.8%), Caucasian and Bichvinta pines (4.7%), yew and juniper species. They are mainly located on steep slopes of the Greater and Lesser Caucasus, where access is restricted. The loss of diversity and changes in species composition in forests is mainly a result of anthropogenic influence.

Natura2000 habitat directives are based on the CORINE biotope classification system **(CORINE biotope classification, 1988, 1991)** determining codes and natural habitat types of Europe, particularly involving the division of the latter into sub-types. In order to join this system, it was necessary to conduct an inventory and develop new schema of habitat types according to Natura2000 standards in Georgia **(Akhalkatsi, Tarkhnishvili, 2012).** According to the Interpretation Manual of European Union Habitats – EUR27, habitat classification is based on plant community types **(Grossheim et al., 1928; Dolukhanov, 2010; Nakhutsrishvili, 2013; etc.).** However, the different methodology used by European and Soviet schools caused differences in nomenclature. Natura2000 habitat directives based on the CORINE biotope

classification system developed legislative basis for the conservation of natural habitats in the EU. The main difference from the European habitats is the existence of different dominant species of the plant community. Species composition at the generic level is very similar; but at the species level, the Caucasus differs from European vegetation. There are species, which are related to European ones but are endemic to the Caucasus: *Abies nordmanniana, Picea orientalis, Pinus kochiana, Fagus orientalis, Quercus iberica, Betula litwinowii,* etc.

Twenty-four forest habitat types were identified in Georgia **(Table 1)**. Eighteen of them belong to the biogeographical region – forests of temperate Europe. Six habitat types belong to Mediterranean deciduous forests. Beech forest group is represented by seven habitat types. Two of them: (1) Beech forest with Colchic understory *(Fageta fruticosa colchica;* **Fig. 3***)* and (2) Beech forest without understory *(Fageta sine fruticosa)* are only found in Georgia. Four other habitats differ from European ones **(Table 1)**: (1) Dark-coniferous forest *(Piceeta orientale-Abieta nordmanniana)*; (2) Pine forest *(Pinus kochiana)*; (3) Yew forest *(Taxus baccata),* and (4) Hornbeam forest *(Carpinus caucasica).* Five Forest habitat types of Mediterranean deciduous forests are typical only for the Caucasus.

Figure 3. Beech forest with Colchic understory. Photo by Maia Akhalkatsi.

Table 1. List of forest habitat types in Georgia. The code is based on the Interpretation Manual of European Union Habitats – EUR27. The Palaearctic classification (Pall. Class.) corresponds to the CORINE biotope classification (1988, 1991). "None" is indicated for 11 habitat types, which are absent in the list of habitat types of Europe. Sub-types and plant community types are determined for some habitats.

N	Code	Pall. Class.	Habitat types	Sub-types	Community types
I	*91.*		*Forests of temperate Europe*		
1	9110GE	41.11	*Luzulo-Fagetum* beech forests	0	1
2	9120GE	41.12	Beech forests with *Ilex* and sometimes also *Taxus* in the shrub layer *(Fageta taxceto-ilicitosa)*	4	4
3	9130GE	41.13	*Asperulo-Fagetum* beech forests	2	2
4	9140GE	41.15	Subalpine beech woods with *Acer* spp.	0	1
5	9150GE	41.16	Limestone beech forests *(Cephalanthero-Fagion)*	3	3
6	91FCGE	none	Beech forests with Colchic understory *(Fageta fruticosa colchica)*	6	14
7	91SFGE	none	Beech forests without understory *(Fageta sine fruticosa)*	5	8
8	9160GE	41.24	Oak or oak-hornbeam forests *(Quercitum -Carpinion betuli)*	6	13
9	9180GE *	41.4	*Tilio-Acerion* forests of slopes, screes and ravines	0	1
10	91D0 *	44.A1/4	Bog woodlands	0	1
11	91E0 *		Alluvial forests	0	1
12	91E0*	44. 2/3, 44.13	Alluvial forests with alder trees – *Alnus glutinosa* and ash trees – *Fraxinus excelsior*	2	2
13	91F0GE	44.4	Riparian mixed forests	0	1
14	91I0	41.7A	*Xero-thermophyte* oak forests	0	1
15	91PAGE	none	Dark-coniferous forests *(Piceeta orientale-Abieta nordmanniana)*	2	14
16	91PKGE	none	Pine forests *(Pinus kochiana)*	4	17
17	91TBGE	none	Yew forests *(Taxus baccata)*		
18	91CBGE	none	Hornbeam forests *(Carpinus caucasica)*	2	8
II.	*92.*		*Mediterranean deciduous forests*		
1	9260CSGE	41.9	Chestnut forests	7	7
2	92ZCGE	none	Zelkova forests *(Zelkova carpinifolia)*	2	11
3	92BCGE	none	Boxwood forests *(Buxus colchica)*	0	1
4	9BCGE	none	Kolkheti broad-leaved mixed forests	8	8
5	9AOWGE	none	Arid open woodlands	4	4
6	9BFGE	none	Sub-alpine birch krummholz	0	1

In situ conservation in nature reserves. Nature reserves in Georgia have a long history. The reserves were called "Korugi" in the past. In "The Book of Law of Vakhtang VI" (1709), Korugi is described as a reserve—"a place for hunting"—where it is forbidden to cut trees and to walk. The area was protected by so-called Korugimen. Nowadays, there are 20 nature reserves in Georgia—administratively divided into 14 state reserves—and 5 hunting farms: Korugi (Sagarejo), Iori (Signagi), Chachuna (Dedoplistskaro), Katsoburi (Abasha), and Gardabani. Total area is 511,123 ha, which is 7% of total territory of the country. Reserves are formed within the framework of the State Forest Fund.

Ex situ conservation. In the past, there were several forest tree nurseries in Georgia. The central nursery was located in Sartichala, near Tbilisi. Nowadays, academic institutes no longer function, while seedlings grew into mature trees. Tree nurseries act as private firms now. There are also several seed banks and living collections in Georgia, which are located within botanical gardens in Tbilisi, Batumi, Bakuriani, and Sukhumi.

Laws. The 1996 Law on Protected Areas by IUCN adopted categories of protected areas in line with international criteria. The Forest Code of Georgia was adopted in 1999. In 2008, new regulations regarding logging management and forest leasing were introduced. The new Forest Code also introduced a new term—"forest area"—which encompasses everything within a designated territory, including fields, lakes, animals, fish, etc. All forested lands in Georgia—except national parks and protected areas—will be divided into pieces, which according to the Minister should be large enough to attract investors, and those pieces of lands will be leased. The new Forest Code of Georgia will be based on that of Austria. The Forest Code defines additional categories of protected forests, including those with special soil and watershed regulation functions, floodplain, and subalpine strip forests.

Following are the goals of the Forest Code of Georgia:

a) Protecting human rights and law enforcement in the field of forest relations;

b) Conducting forest tending, protection, and restoration with the purpose of conserving and improving climate-regulating, recreational, and other useful natural properties of forests;

c) Conserving and protecting unique natural and cultural environment and its specific components – flora and fauna inclusive, biodiversity, landscape, cultural and natural monuments located in forests, and the endangered plant species; regulating harmonized interrelations between these components;

d) Setting rights and obligations of forest users;

e) Meeting environmental, economic, social, and cultural needs of population by providing access to the forest resources in the scope compatible with scientifically defined allowable norms;

f) Defining main principles of forest management.

Conservation and sustainable use of forest resources in Georgia needs further development of the following priority objectives: putting the Forest Code into practice; reforming silviculture and forest management systems; restoring tree nurseries; establishing a seed bank; performing an inventory and conservation of tree genetic resources; maintaining health and vitality of plant and animal species; encouraging public involvement in species conservation and planning sustainable use; and accelerating researches on genetic diversity and tree breeding.

2.3. Forest Loss and Degradation of Biodiversity

Deforestation and habitat fragmentation is a growing problem throughout the Caucasus. Governmental forest areas of Georgia cover 3005.3 thousand ha, while only 2294.6 thousand ha are used solely for forestry. Degraded forest area is 23.65% of the total forest area, which was confirmed as a result of logging activities during the 1990s. Assessment of current forest conditions is a necessary precursor to restoration. During ecological assessments, issues related to biodiversity, level of naturalness, and ecological integrity in general should be considered. Although significant areas of natural habitats remain, recent declines in available habitats threaten the persistence of Georgia in the South Caucasus.

Nowadays, 97% of Georgian forestland is situated on mountain slopes; the remaining 3% is within low-lying areas and floodplain forests in the Kolkheti region and the Western Georgia. Georgian mountain forest resources are estimated at 451.7 million m^3, which accounts for 0.13% of the world's total resources. Average forest density in the world is 100 m^3 per ha, while in Georgia it equals to 163 m^3 per ha. Forest density is related to the angle of inclination of slopes **(Table 2).** Georgia defines forests according to their age. Mature trees dominate with 33.4% (852.3 thousand ha), ripe and older plants take 35.4% (904.4 thousand hectares). This makes it possible to take regeneration measures.

Table 2. Forest distribution on slopes with different angles of inclination and elevation (m.a.s.l.).

N	Slope inclination (°)	Hectares (thousand)	Percentage (%)	Elevation (m)	Hectares (thousand)	Percentage (%)
1	0–10	165	5.5	0–500	673.2	22.4
2	11–20	496	16.5	501–1000	706.2	23.5
3	21–25	499	16.6	1001–1500	505	16.8
4	26–30	547	18.2	1501–2000	525.9	17.5
5	31–35	589	19.6	2001–2006	595	19.8
	36 >	709.3	23.6			
	Total	3005.3	100		3005.3	100

During the Soviet era—between 1930 and 1950—intensive industrial cutting activities were carried out throughout the country, which had grave consequences for the forests. More than half of the forested areas were degraded, some 0.5 million ha of forests were lost, and

high-productivity forests were destroyed. It resulted in acceleration of erosion processes.

Between 1950 and 1990, forests were managed principally with objectives for protection and recreation with timber and timber products being imported from Siberia, Russia. The annual timber production decreased about 10 times due to timber import from Russia, which was 2–2.5 million m^3—85% more than the country required.

Over the last few years, natural disasters became more frequent, especially in mountainous areas of the country, such as Adjara, Svaneti, and Racha. This also had an impact on the country's forests. Recent intensive deforestation activities are unprecedented in the history of the country. This is mainly due to the almost completely reduced imports of timber from Russia after Georgia's declaration of independence. Besides, uncontrolled illegal forest cuttings have been initiated. Especially vulnerable to cutting activities are former kolkhoz owned forests: their structure is destroyed, the modification of species is speeded up, erosion processes are accelerating, the forest forming plant species are substituted by satellite plant species and scrubs, or even worse, the slopes are simply washed away. Accordingly, in many places oak groves are replaced by oriental hornbeam, hornbeam, useless or evergreen scrubs and shibliak (**Fig. 4**).

Figure 4. Deforested area of oak-hornbeam forest around the calcareous quarry in Dedoplistskaro district. Photo by Maia Akhalkatsi.

Forests in Georgia are mostly heavily damaged by overcutting, forest fires, tree diseases, etc. The degradation of qualitative consistence and productivity of forests leads to the reduction—and sometimes, even causes a loss—of forest functions. As a result, avalanches and landslides occur quite often in the mountainous regions. Since the declaration of independence in 1990, Georgia's forests have been particularly hard-hit by poor management with widespread illegal timber harvesting and uncontrolled fuelwood exploitation. The latter one was driven by the acute energy crisis during the winter months. This situation was particularly serious in the disputed region located in the Western Georgia, where the unique Colchic relict forest containing old trees was being illegally destroyed (**Fig. 5**).

Figure 5. Cut down *Taxus baccata* trees in Colchic relict forest with diameter ca. 120 cm. Photo by Maia Akhalkatsi.

Another problem is related to overgrazing in the subalpine meadows of the East Caucasus. Domestic sheep moving from the lowland grasslands to winter pasturelands have a significant impact the endemic flora and fauna in steppes. Traditionally, sheep were grazed on alpine meadows, with subalpine meadows reserved for fodder production used solely during the winter months. Currently, the population of high mountain villages no longer has access to traditional grazing grounds in Georgia. This process started in the late 1980s and nowadays, livestock is kept near the villages all year round. As a result, the subalpine meadows suffer from overgrazing as well as degradation of fragile subalpine woodland ecosystems (**Fig. 6**).

Figure 6. Sheep grazing on a deforested subalpine secondary meadow of the subalpine birch forest. The Cross Pass, the Central Greater Caucasus (2340 m.a.s.l.). Photo by Maia Akhalkatsi.

Forest habitat types are determined by local distribution area and they are mostly deforested in different regions of Georgia. The results are not very accurate in regards to the current situation all over the country and they are mainly based on model data published by WWF (**Zazanashvili et al., 2011**). Tree types are distributed across different habitat types (**Table 3**).

The discussion on the forest resources in Georgia indicates that forestlands are potential to be protected as relic forests and endemic species, while people might require using forests as a source of wood biomass and non-timber resources. Policy changes are expected to have the greatest potential effect in this arena. Steps should be undertaken to ensure that unacceptable social impacts do not derive from the plantation expansion programs. The discussion on the reforestation success in Georgia made it clear that rapid poverty alleviation, spontaneous mass participation, and political commitment acted as a mainstream to reforest the degraded forestlands effectively. Nowadays, the total forest area of Georgia is distributed by governmental

Table 3. Forest habitat distribution areas as thousand hectares and percentage.

N	Forest habitat types	Hectares (thousand)	Percentage %
1.	Beech forests (*Fageta fruticosa*)	1060	46.6
2.	Dark-coniferous forests *(Piceeta orientale-Abieta nordmanniana)*	161.5	7.1
3.	Pine forests *(Pinus kochiana)*	91	4
4.	Oak or oak-hornbeam forests (*Quercitum -Carpinion caucasica*)	241	10.6
5.	Alluvial forests with alder trees – *Alnus glutinosa* and ash trees – *Fraxinus excelsior*	125.1	5.5
6.	Chestnut forests	72.8	3.2
7.	Hornbeam forests *(Carpinus caucasica)*	220.6	8.8
8.	Mixed forests	102	4.5
9.	Other types	220.6	9.7
		2294.6	100

laws across different protected areas (**Fig. 7**), which require further activities for conservation of relic and sensitive forest habitats.

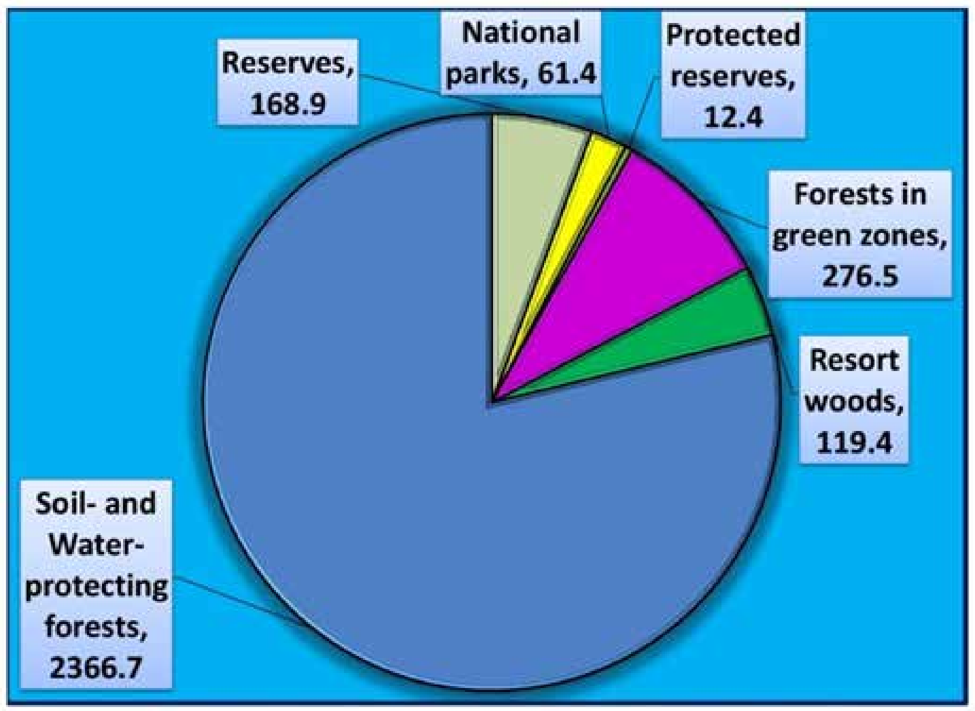


Figure 7. Classification of protected forest areas, soil- and water protecting forests and resort woods distributed across the territory of Georgia. The areas are shown as thousands of hectares, while the total area is 3005.3 thousand hectares. Photo by Maia Akhalkatsi.

Complete forest loss has the clearest impact on biodiversity, with most forest-dwelling species unable to live in habitats that replace forests. However, it is harder to measure the impacts of changes such as fragmentation and loss of microhabitats. Management often simplifies forests, reducing biodiversity and age range; as older and dead trees disappear, so do many associated species. Conversely, pioneer or weed species may increase. Biodiversity monitoring is costly, and our knowledge of many forest ecosystems is still incomplete. One concept that has gained increasing recognition in the last few years is that of critical thresholds for particular species, that is, the population level below which further decline and eventual extirpation or extinction is likely, and where these thresholds are known they can play a key role in monitoring impacts and planning restoration strategies.

Most people are aware of the global reduction in forest cover caused by ever-increasing human domination of the planet. A natural reaction to this forest loss is to engage in forest restoration activities. Across the planet, conservationists are working to increase overall forest coverage using a variety of strategies. In some cases, this includes attempting to intensify agriculture so that it requires less land, focusing on value over volume in wood products, and concentrating production in (native) plantation forests. Another strategy is to de-intensify agricultural uses and promote a mosaic of natural and anthropogenic elements, allowing native species and communities to fill in around our use of the landscape, and provide necessary ecosystem services to operate more freely.

Large areas of the world's forests have been lost or degraded and landscapes everywhere are being simplified by current land-use practices. In many tropical countries, increasing areas of forest or woodland are cleared for agricultural use. The same is true in some temperate countries although—for the most part—land-use patterns there have stabilized over the last century. Agricultural expansion and intensification have decreased the overall area of forest and woodland, simplified the structure of the remaining forests, and broken up forest areas into smaller and more isolated fragments.

2.4. Social and Political Relevance for Forest Restoration

Degradation is taken to mean a loss of forest structure, productivity, and diversity of native species. A degraded site may still contain trees or forest but it will have lost its former ecological integrity **(Lamb, Gilmour, 2003).** Degradation is a process of loss of forest quality that is in practice often part of the chain of events that eventually leads to deforestation.

Restoration ecology and forest habitat restoration present more integrated approaches to restoration. A series of tools and questions exist that can help identify potential benefits from restoration, although these need to be used with care to avoid overlooking some of the poorest members of society. Poor people rely on forests as a safety net to avoid or mitigate poverty and sometimes as a way to lift themselves out of poverty. It is important to recognise different levels of poverty and different types of dependence on forests when trying to understand the likely social implications of forest restoration.

The drivers of forest loss and degradation are complex and variable, moving from the extreme of deforestation for other land uses to more subtle forms of degradation through multiple overuse; either happening slowly or more rapidly depending on the pressures driving change. Who drives the changes in the forests and who benefits from them also helps determine the impacts. These are not simple events and do not have simple causal consequences. For local people, deforestation can be catastrophic, as in the case of large-scale clear felling by an outside agency that destroys resources without offering any alternatives, or in other cases it can be the planned precursor to an alternative land use system such as farming, which in terms of livelihood outcomes may provide more secure alternatives than that offered by the forest.

For the sake of understanding the likely impacts of forest loss or restoration, it is useful to define people in terms of their vulnerability and their relationships with forests and forest products.

Poverty is not a uniform experience for these four types of forest-related people and neither is it possible to say, for example, that all shifting cultivators are extremely poor or that all farming communities are "improving poor." This makes it even more difficult to generalize about the impacts that forest change will have on individual livelihoods. Within the same community, dependence on forests and wild lands will vary, although generally, the extremely poor will be the most dependent on the resources from natural habitats and the improving poor will be less dependent. However, those whose livelihoods are most interlinked with the forest resource, such as hunter-gatherer groups and shifting cultivators, are those who are the most vulnerable to any changes in that resource and are also the least able to move into other livelihood options.

It should be noted that these are by no means static categories; they change as the local and national environment changes. For example, increasing market penetration has profound effects on the choices or enforced changes that people have to make in their livelihood base. The key point to recognize here is the diversity of the types of relationships that people have with forests and therefore the diversity of impacts that changes in forests and associated landscapes might have on the livelihoods of those living in and around them.

This typology helps underline the importance of understanding the social situation of households and individuals. Attempts to address restoration in a social context, without recognizing the differences that degrees of poverty have on people's relative vulnerability and opportunities, most often at best ignore those in extreme poverty and at worst exacerbate their condition **(Fig. 8)**.

It is also important to move away from a broad-brush consideration of communities to recognition of differences between individual households and categories of well-being **(Hobley, 2005).** Many people assume that communities have common interests or, where they are conflicting, that disagreements could be resolved by working with the different interest groups, but this is not always the case. This becomes particularly important when considering the impacts of changes in forest cover and quality and how this is experienced by different households. For some of the most dependent people, forest change can be devastating, whereas for others with a broader livelihood portfolio that includes only limited dependence on the forests, changes in forest quality and extent may only have relatively minor effects. In such cases, responses to forest restoration will also be different between individual households in a community. The importance of a broad-based and carefully structured participatory process, linked to social mobilization and including attempts to build the capacity of different social groups to have a voice, cannot be underestimated

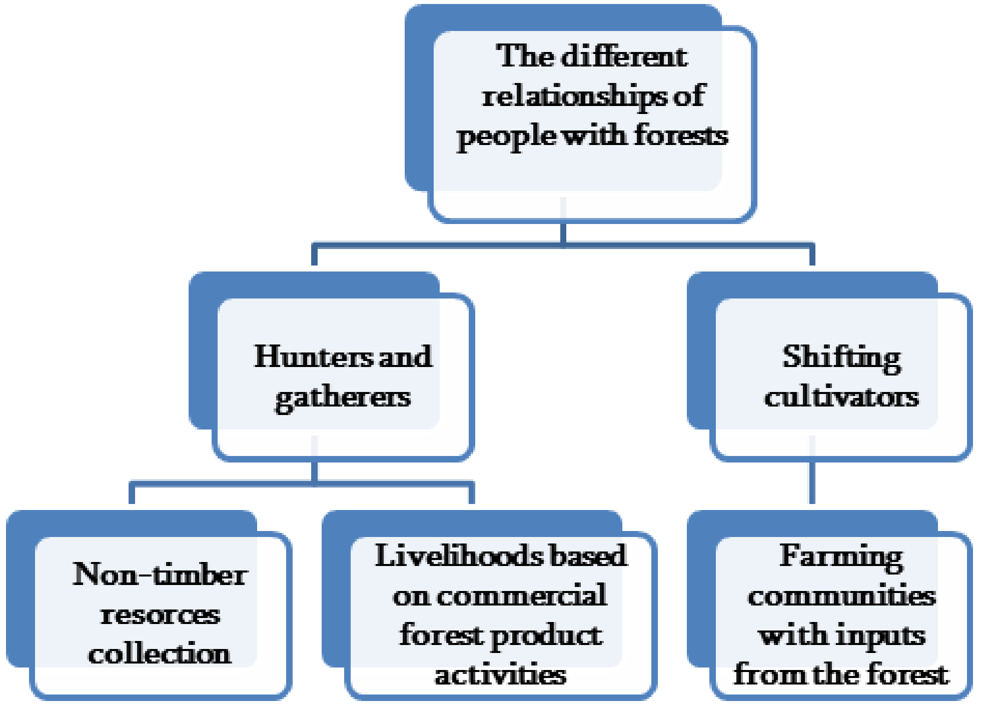


Figure 8. People relationship to forest resources. (Byron, Arnold, 1997).

Risk and uncertainty are universal characteristics of life in rural areas. Sources of risk include natural hazards like drought and flood, commodity price fluctuations, illness and death, changing social relationships, unstable governments, and armed conflicts. Some risky events like drought or flood simultaneously affect many households in a community or region. Other risky events, like illnesses, are household specific and again have differential effects depending on the overall robustness of a particular household and its livelihood strategies. Catastrophic forest loss, for example through fire or clear-felling, thus affects whole communities, but the intensity of the effects are not necessarily uniform.

In any process of restoration, and perhaps particularly restoration projects driven by conservation concerns, some key messages need to be incorporated into the planning and implementation of any programme:

1. Recognition of the differential importance of forests, products, and services on different people and therefore the differential impacts of changes in forest quality and extent;
2. Recognition of the role of forests in poverty prevention as well as poverty reduction;
3. The need to involve people in the decision making process to build voice and capacity to articulate voice in an institutional and political environment that is able to respond to these voices;

4. Recognition of the need to support the building of livelihoods that reduce people's exposure to risk and remove vulnerabilities;
5. Recognition that forests alone do not necessarily move people out of poverty but actually can secure them in poverty;
6. Support to decentralized service provision that can be socially responsive and tailored to particular ecological and economic conditions; and
7. Impacts of restoration also need to be carefully considered. Just as the impacts of degradation are not equally felt across livelihood groups, it is the case with restoration.

Restoration of forest cover for some may have negative livelihood implications. Often the beneficiaries of restoration are not those living locally to the forest but are downstream users of services, therefore, the distribution of costs and benefits of restoration need to be carefully considered.

Activities related to environmental protection have been carried out in Georgia since the late 20th century and several projects were funded by international foundations **(Table 4).**

Table 4. Environmental protection projects in Georgia.

N	Project Name	Supporter	Date	Funding
1	Borjomi-Kharagauli NP	The German Development Bank, KFW	1996–2007	6.7 million DM
2	The Georgia Integrated Coastal Zone Management	World Bank/GEF/ Government of Netherlands	1999–2004	$7.6 million
3	The Georgia Protected Areas Development	World Bank/GEF	2000–2005	$9 million
4	The Arid and Semiarid Ecosystem Conservation in the Caucasus	UNDP/GEF	2000–2002	$878,000
5	The Georgia Forestry Development Program	World Bank	2000–2007	$20 million

These projects are related to forest conservation—mainly within protected areas—and their medium-term objectives are: a) establishing three ecologically effective protected areas in the Eastern Georgia; b) facilitating the creation of a national network of protected areas; c) integrating biodiversity conservation into forestry, range management, and agriculture; d) strengthening institutions responsible for biodiversity conservation programs; e) improving public awareness of the values and importance of Georgian biodiversity; and f) promoting regional/international cooperation for conservation of biodiversity in the Caucasus region. The components of forest supporting projects are: a) policy planning and analysis, b) institutional assessment and restructuring, c) land use and forest management plans, d) human resources development and training, and e) public awareness. The Black Sea Environmental Programme has implemented priority actions outlined in the Georgia Biodiversity Strategy and Action Plan. Priorities include conservation of biodiversity at sites of international significance on Georgia's Black Sea coast, such as Kolkheti and Kobuleti wetland Ramsar sites; restoration of degraded habitats and resources within the Black Sea Large Marine Ecosystem; and participation in regional efforts to manage and sustain public goods of a transnational character.

The sad fact is that all too many restoration projects do not bother to find out what local people really want at all; if they do, then a collection of different and often opposing or mutually exclusive wants and desires emerge. There is still a lot to be learned and disseminated about reconciling nature and human needs, and about planning restoration areas within larger scales in order to return as wide a range of forest functions as possible. This requires the ability to work across disciplines, including agriculture, forest-compatible income-generation activities, forestry, and addressing water issues as well as specific social issues. It also—perhaps even more importantly—requires finding out how to bring the people most affected into the debate, not as a matter of duty or because funding agencies expect it but because this is vital and necessary for both nature and human well-being. This approach is also a challenge for restoration.

Globally, degraded land due to agricultural activities has been abandoned in Georgia during the Soviet period for different ecological and socioeconomic reasons. These and other deforested areas can be: (1) left to undergo secondary succession or passive restoration or (2) subjected to active restoration processes, mostly consisting of planting and managing native shrubs and trees. In the world, land abandonment and passive restoration have restored much more, and at a lower cost, than active restoration.

2.5. Forest Restoration Strategy

When forests are lost or degraded, there are numerous terms promoting different strategies when dealing with forest restoration. WWF is implementing forest restoration as an integral component of the conservation of large, biologically important areas such as the Caucasus ecoregion, along with protection and good management **(Zazanashvili et al., 2011).** Forest restoration seeks to balance human needs with those of biodiversity, thus aiming to restore a range of forest functions and accepting and negotiating the trade-offs.

Forests provide a large number of goods and services, including habitat for species, homeland for indigenous peoples, recreational areas, food, medicines, and environmental services such as soil stabilization. Moreover, as forest areas are reduced, pressure on remaining forests increases.

Ecological forest restoration attempts to recreate a native wild wood to restore its original forest. Thousands of native tree seeds from surviving woodland remnants in the vicinity have to be collected and use for seedling establishment to be planted of the site is being allowed to regenerate naturally. Rehabilitation emphasises the reparation of ecosystem processes, productivity, and services, whereas the goals of restoration also include the reestablishment of the pre-existing biotic integrity in terms of species' composition and community structure. It has as its main objectives the stabilisation of the terrain, assurance of public safety, aesthetic improvement, and usually a return of the land to what, within the regional context, is considered to be a useful purpose. Afforestation and reforestation refer to the artificial establishment of trees, in the former case where no trees existed before.

In the context of terminology related to restoration, given the flurry of interest, concepts, and definitions being touted, there is a need for: (1) a set of widely accepted definitions to be used more systematically and rigorously; (2) efforts and resources to be more focused on the "doing" than on the "defining"; (3) greater exchanges, debates, and sharing of experiences in order to disseminate the accepted concepts and the positive experiences; and (4) the accepted definitions in the restoration field to be shared with other relevant expert groups, such as development workers, foresters, extension officers, etc.

3. Restoring Ecological Functions

3.1. Restoring Forest Habitats in the Face of Climate Change

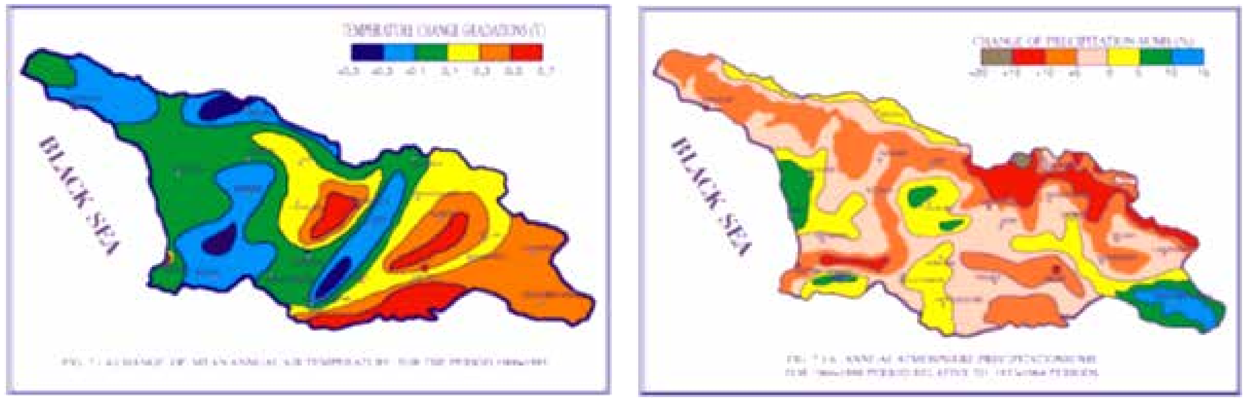
Climate changes have already started in the South Caucasus region with increasing temperatures, shrinking glaciers, rising sea level rise, reduction, and redistribution of river flows, decreasing snowfall and an upward shift of the snowline. Global warming to cause changes in the climate will come even if emissions of greenhouse gases were cut immediately to pre-industrial levels. The world is becoming warmer as a result of anthropogenic emissions of carbon dioxide and other greenhouse gases-emissions from power stations, vehicles, domestic wood stoves, and clearance of forests, which alone contributes 30% of total emissions **(Rosenbaum et al., 2004)**.

Climate in Georgia is temperate but fluctuates by elevation, that varies from 0 to 5184 m (air temperature is changed on the average of 0.65 °C per 100 m altitude); and by regions from the humid Western Georgia to arid zones in the Eastern Iori Plateau (annual precipitation varies from 1500–2000 and up to 4500 millimetres in the Western, Colchic part to 600–1000 mm in drier parts of eastern and southern regions **(Neidze, 2003)**.

The Caucasus Mountains are known for a high amount of snowfall. The Greater Caucasus Mountains (especially south-western slopes) are marked by heavy snowfall and avalanches are common from November to April. Snow cover may reach 5–7 meters in several regions of the western part of the Greater Caucasus, such as northern Abkhazia region in Georgia. The Lesser Caucasus Mountains are somewhat isolated from the moist influences coming from the Black Sea and therefore receive considerably less snow precipitation than the Greater Caucasus Mountains. The average winter snow cover in the Lesser Caucasus Mountains ranges from 10–30 cm.

Between 1906 and 1995, the mean annual air temperature in Georgia has increased in the eastern part of the country, whilst it has actually decreased in the west, including in the Greater Caucasus Mountain areas **(Map 4A).** The same change is determined for annual atmosphere precipitation sums **(Map 4B)** for 1964–1990 periods relative to 1937–1964 periods **(Taghieyeva, 2006).**

The biological components of forest formations will respond to changes in the climate as they have always done: some components of some formations may do better; others do worse; generally, the range of suitability for the present day forest formations will change. The models which were run in the study predict that conditions in the South Caucasus will become less suitable for most forest classes that occur in the region; overall there could be a reduction of 8% in the area of the South Caucasus suited to the forest classes that occur in the region today compared with actual forest cover in 2011 under the ecologically more favourable climate scenario and a reduction of 33% under the ecologically less favourable climate scenario.



A B

Map 4. A – Climate change of mean annual air temperature for the period 1906–1995 in Georgia;
B – Annual atmosphere precipitation sums for 1964–1990 period relative to 1937–1964 period (Taghieyeva, 2006).

Impacts will vary between bioclimatic zones and countries, with Georgia being affected less overall than Armenia and Azerbaijan. The impacts on forests will take many years to show and while some forest formations may benefit overall from climate change, most formations will become stressed and lose vigour. Unless species or genotypes that are better adapted to the changing conditions are able to colonize the site, the forest will gradually disappear **(Zazanashvili et al., 2011)**.

All ecosystems will experience climate change, but ecosystems of the alpine life zone (i.e. the high mountain environments above the treeline) are very sensitive to climate changes. The treeline on moist slopes of the northern exposition of the Greater and Lesser Caucasus is formed by the sub-alpine forest of birch elfin trees at the altitude above 1800 meters up to 2400–2500 meters **(Fig. 9)**. However, separate trees are common at the altitude of up to 2550 meters **(Akhalkatsi et al., 2006a)**. Inclination of slopes does not exceed 10–25° that determines stable cover of snow during winter. The mountain brown soil is characteristic, mainly on volcanic rock layers with the humus layer of 10–20 cm thick. The forest of this type is found in the Central Greater Caucasus. Namely, Kazbegi region as well as in the Lesser Caucasus. For example, around Tskhratskaro Pass, above Bakuriani. It is also common on the northern slopes of Shavsheti and Erusheti ranges **(Akhalkatsi, Kimeridze, 2012)**. In this type of habitat, the border of the forest is lowered by 200–400 meters as a result of anthropogenic impact, which is caused by excessive grazing and cutting of trees. However, as a result of recent global warming and decrease of grazing, the slopes where the birch grove had to be present earlier were repeatedly reforested **(Togonidze, Akhalkatsi, 2015)**. Those forests on the Greater Caucasus that are considered to be the so-called "forests of the church", where grazing and cutting has not taken place for ages and thus, are well preserved.

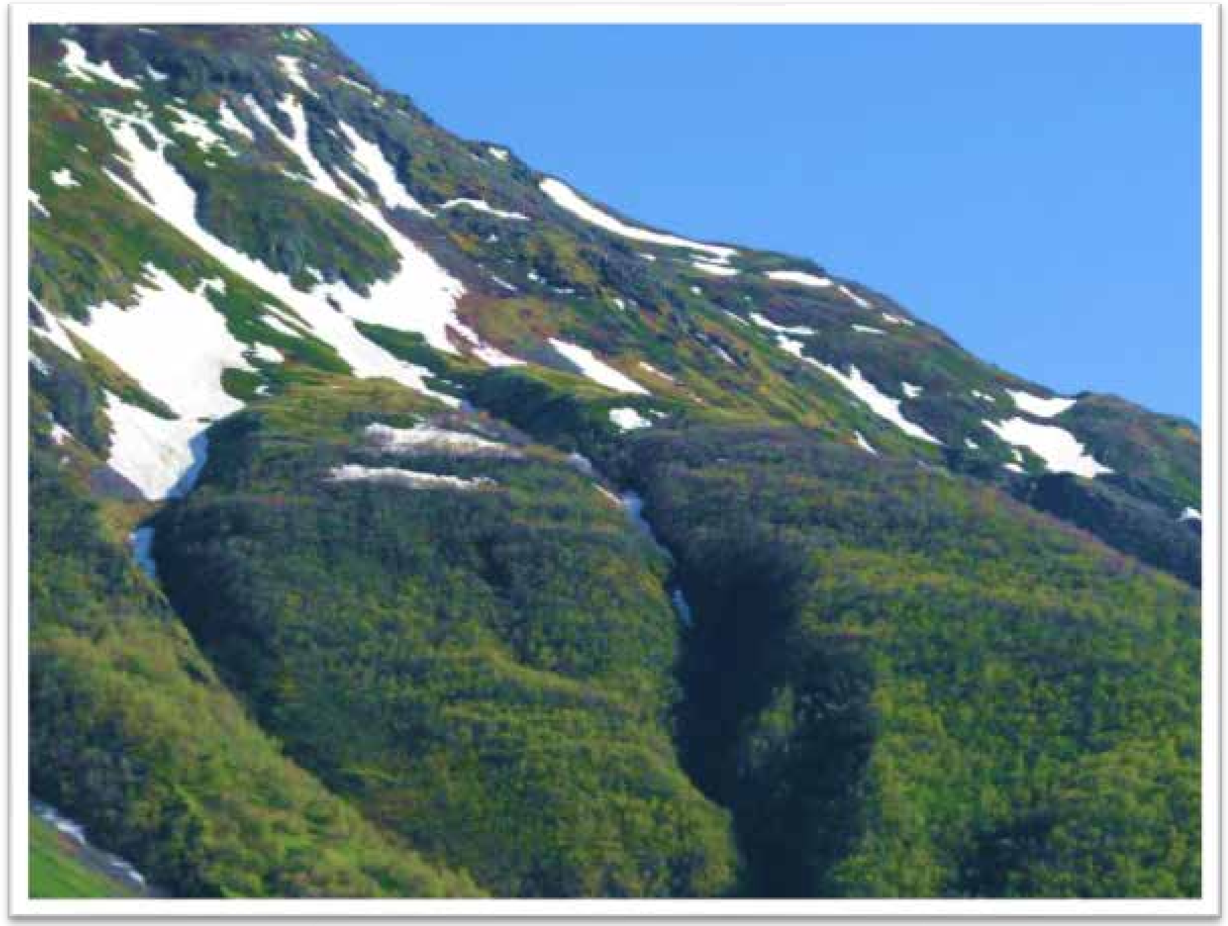


Figure 9. Subalpine birch forest with treeline ecotone in the Central Greater Caucasus region. Photo by Maia Akhalkatsi.

The timberline is situated at the altitude of 2400–2500 meters where 2–3 meter tall elfin birch and mountain ashes (*Sorbus caucasigena*) are found and Caucasian evergreen Rhododendron (*Rhododendron caucasicum*) and other evergreen shrubs are introduced as understory. The treeline reaches 2550 meters, where only dwarf trees of the birch grow among Caucasian evergreen Rhododendron shrubs. Characteristic species are: *Betula litwinowii, B. raddeana, B. pendula, Sorbus caucasigena, Salix caprea, S. kazbegensis, Rhododendron caucasicum, Vaccinium myrtillus, V. uliginosum, V. vitis-idaea, Daphne glomerata, D. mezereum, Anemone fasciculata, Polygonatum verticillatum, Swertia iberica, Festuca drymeja, Calamagrostis arundinacea, Dolichorrhiza renifolia, D. caucasica, Cicerbita racemosa* **(Nakhutsrishvili et al., 2006)**.

The other sensitive ecosystems to climate change are arid and semi-arid habitats, which are considered particularly sensitive to warming because they are determined by extremely low and high temperature conditions, respectively. The ecological effects of anthropogenic global climate change are of increasing concern for understanding and predicting climate driven vegetation change. Global circulation models exist that predict future climates and changes in coarse scale vegetation patterns. However, the efficacy of these models is limited by temporal and spatial scale problems and a poor understanding of how climate variation and human land use changes influence disturbance regimes and subsequent vegetation patterns.

Figure 10. Dry open woodland in the Eastern Georgia. Photo by Maia Akhalkatsi.

As well as gradual change in the climate brought about by global warming, forests face other impacts. There will be more frequent and more intense storms, bringing strong winds that will uproot and break the stems of trees, and heavy rain that will cause soil erosion and landslides. Parts of the region are likely to experience increased drought, leading to reduced plant growth, primary productivity and altered plant recruitment. Prolonged dry and hot weather will increase the risk of forest fires. All of these impacts increase the risk of outbreaks of pests and diseases. The general trend in environmental conditions will create attractive conditions for invasive species.

Arid open woodlands consist of xerophyte arboreal plants that do not create a closed canopy in upper layer but have xerophytic herbal cover (**Fig. 10**). It is distributed in fragmented forms, between the steppe and semi-desert vegetation in the arid zone of the Eastern Georgia.

Annual precipitation is 550 mm. It is preserved in its original form in Vashlovani State Reserve. Dominant species are: mastic (*Pistacia mutica*), species of juniper (*Juniperus polycarpos, J. foetidisima, J. rufescens*), hackberry (*Celtis caucasica, C. glabrata*), species of willow-leaved pear (*Pyrus salicifolia*), smoke tree (*Cotinus coggygria*), cattle-herder's cherry (*Prunus incana*), jasmine (*Jasminum fruticans*), black buckthorn (*Rhamnus pallasii*), and spiraea (*Spiraea crenata*). Thuja (*Biota orientalis)* has been planted on the territory of a summerhouse in Alani village by a Shiraki forester and became naturalized.

According to the Natura 2000 classification of habitat types, 4 sub-types of open woodland are identified **(Akhalkatsi, Kimeridze, 2012)**:

1) Dry open woodland with mastic (*Pistacia mutica*). The open woodland formed by the mastic is worth noting. It is associated with the habitat of the Iori River flood plain forest. Mastic trees are often at a long distance from one another and sometimes grow big in size (10.5 meters high with 0.5-meter diameter). Associated species of the mastic tree are: elm (*Ulmus carpinifolia*), black buckthorn (*Rhamnus pallasii*) and Georgian oak (*Quercus iberica*). In the second type of the forest, there are mastic, hackberry (*Celtis australis*), barberry (*Berberis vulgaris*), black buckthorn (*Rhamnus pallasii*), oleaster (*Elaeagnus angustifolia*), willow-leaved pear (*Pyrus salicifolia*), Jerusalem thorn (*Paliurus spina-christi*) and smoke tree (*Cotinus coggygria*). From shrubs, there are *Atraphaxis spinosa, Reaumuria alternifolia.* The mastic open woodland is also found in Kvemo Kartli, the gorge of the river Khrami, on slopes between vv. Asureti and Sadakhlo. Here, the following species dominate *Pistacia mutica, Acer ibericum, Celtis caucasica.*

2) Dry open woodland with juniper species (*Juniperus* spp.). The juniper is distributed in Southern Kiziki in the form of small stands, on slopes of northern exposition of Vashlovani Reserve, on Zilchi Mountain, southern slopes of Falanthuki Range. It can also be found in Mtskheta surroundings, near Shio-Mgvime, Karsani, etc. Species that form Juniper communities are – *Juniperus foetidissima, J. oblonga, J. polycarpos, J. rufescens, Ephedra procera, Rhamnus pallasii, Colutea orientalis, Jasminum fruticans, Prunus microcarpa, Atraphaxis spinosa, Cynosurus cristatus, Silene cyri, Teucrium polium, Campanula hohenackeri, Centaurea ovina, Stachys fruticulosa.*

3) Dry open woodland with willow-leaved pear species (*Pyrus* spp.). Dominant species are: *Pyrus salicifolia* and *P. georgica.* Endemic species are: *P. ketzkhovelii* and *P. demetrii. P. takhtadziani* and *P. georgica* grow in Sagarejo region, near village Khashmi. From other species *Paliurus spina-christi, Berberis vulgaris, Rosa canina,* etc. are worth noting. Endemic *P. eldarica* is found by A. Grossheim only in Azerbaijan, Samukhi region (Eliar-ougli). *P. fedorovii* is an endemic found in the surroundings of village Gldani and village Mukhrani. *P. oxyprion* can be found in Dedoplistskaro region in the Lekistskali ravine. *Celtis caucasica, Punica granatum, Rosa* spp., *Tamarix ramosissima* also grow in this place. Rare endemic species *P. sakhokiana* is found only in Dedoplistskaro region, on the Black Mountain. The stands are more dense than *P.* that of *P. salicifolia*, on the northern slope, in the depression. The understory made of Jerusalem-thorn and oriental hornbeam is developed here. On the Unagira Mountain, in the surroundings of Ateni village, grows *P. salicifolia* var*. angustifolia.*

4) Dry open woodland with hackberry species (*Celtis* spp.) is developed on the Black Mountain, big and small Zilchi, their slopes, and canyons. Dominant species are: hackberry (*Celtis australis, C. caucasica*) and mastic. The species that add to them are: saltcedar (*Tamarix ramosissima)*, oleaster, willow-leaved pear, Georgian maple (*Acer ibericum*), juniper (*Juniperus rufescens*).

In arid ecosystems, global climate change is projected to yield increases in frequency and intensity of drought occurring under warming temperatures **(Breshears et al., 2005)**, referred to here as global-change-type drought. Quantitative assessments of the triggers and potential extent of drought-induced vegetation die-off remain pivotal uncertainties in assessing climate-change impacts. Of particular concern is regional-scale mortality of overstory trees, which rapidly alters ecosystem type, associated ecosystem properties, and land surface conditions for decades. This emphatically underlines the urgent need for a well-coordinated implementation of comparative observation studies to detect climate-induced ecological impacts on arid ecosystems and especially important is to undertake fundamental research and conservation efforts on rare economic tree species threatening by extinction.

Species survival in arid and semi-arid ecosystems is highly dependent on annual climatic fluctuations and especially on precipitation that determine the temporal and spatial availability of soil water. In semi-arid and arid ecosystems, rain is the most important environmental parameter governing crucial life history processes in woody plants **(U.S. Forest Service, 2003)**. Hence, climate change related shifts in precipitation pattern will potentially have severe consequences for woody plant population dynamics. In arid areas, recent climatologic studies proposed either a decrease in mean precipitation of 5–15% by the year 2050, or an increase by up to 30–40% **(IPCC: Climate change, 2001)**. Further studies suggest an increase in the frequency and variability of extreme rainfall events **(e.g. Katz, Brown, 1992)**, as well as alternating phases with low and high rainfall. The large divergence between the various precipitation scenarios raises the question how woody plants would react along this spectrum.

The changes in forest health, vitality, and productivity caused by long-term changes in environmental parameters and increased risks of damaging events will have significant consequences for people living in the region. The region's forests will produce less timber and non-wood forest products such as mushrooms, berries, and nuts. The risk of flash floods, soil erosion, landslides, and avalanches will increase. The region's protected areas will lose some of the values for which they were designated. There will be changes in the landscapes, which have been familiar to generations.

The impacts of climate change on forests are likely to be substantial, and the negative impacts many times greater than any positive impacts. Forestry agencies and forest managers in some countries have already started to take practical steps to mitigate the impacts of climate change on forests. At a political level, at the 2011 meeting of European forestry ministers in Oslo, Armenia, Azerbaijan, Georgia and other European countries committed themselves to developing strategies for forests and climate change adaptation and mitigation. Although our knowledge about the vulnerability of forests to climate change is poor, and the exact nature and scale of the impacts impossible to predict; it is possible to develop adaptation strategies now.

Adapting the management of existing forests increasing the natural adaptive capacity and resilience of forests by increasing the diversity of species and provenances in forest stands; planting species and provenances that are more resilient or promoting them in naturally regenerated stands by selective tending and thinning; increasing the resilience and natural adaptive capacity of forests at a landscape level by reducing fragmentation and creating ecological corridors; adaptation of fire and pest and disease prevention and control practices; adaptation of silvicultural practices to manage declining and disturbed stands; implementing adaptive management and preparing forest management plans that take into account the increasing uncertainty about climate and the response of trees and forest formations to climate change.

Restoring degraded forest stands and reforesting former forested land means that the mitigation the impacts of further losses and the risk of further losses, restoring forest cover using native species and provenances that are adapted to future climatic conditions, will provide alternative supplies of forest products and services which are lost as a result of reduced productivity or complete loss of existing forests. At the landscape scale, forest restoration can reduce fragmentation of forest massifs, increase connectivity between forest stands, and increase the resilience and adaptive capacity of the forest fund.

Adaptation of protected forest areas and networks: protected areas networks need to be planned to enable species to adapt to climate-related changes. Optimally designed protected area networks should reduce barriers and obstacles between protected areas; they should create corridors and other elements so that in times of stress species can move to more favourable environments within the relative safety of a protected area. Protected area networks may need to be expanded to secure long-term representativeness of ecosystems and help species adapt to climate change. Protected area management can help ensure adaptation to climate change by managing specifically for anticipated threats.

Policy responses of the governments can change forest law and strengthen forest law enforcement mechanisms to mitigate anthropogenic pressures on forests; they can require forest managers to include mitigation and adaptation measures in forest management plans and they can change regulations on the choice of species and provenances to allow forest managers to select species and provenances within the natural species composition, that are better adapted to future climatic conditions. Governments can promote and fund research into the impacts of climate change on forests and mitigation and adaptation measures; they can implement the nationwide monitoring systems that are needed to keep track of climate change impacts and the success or failure of different response measures. Environment and forestry ministries and their agencies can make people aware of the impacts that climate change will have on forests and how those impacts will affect their lives. Forests and climate change can be incorporated into university and school curricula. Perhaps most important of all, a owners and managers of large areas of forest, the governments of the South Caucasus countries can become leaders in forest adaption, using state forests as field laboratories for testing different response strategies.

Climate change is arguably the greatest contemporary threat to biodiversity. It is already affecting ecosystems of all kinds and these impacts are expected to become more dramatic as the climate continues to change due to anthropogenic greenhouse gas emissions into the atmosphere, mostly from fossil fuel combustion. Climate change will result in added physical and biological stresses to forest ecosystems, including drought, heat, increased evapotranspiration, altered seasonality of hydrology, pests, disease, and competition; the strength and type of effect will depend on the location. Such stresses will compound existing non-climatic threats to forest biodiversity, including overharvesting, invasive species, pollution, and land conversion.

This will result in forest ecosystems changing in composition and location. Therefore, in order to increase the potential for success, it will be necessary to consider these changes when designing restoration projects. On the other hand, restoration projects can also be viewed as a key aspect of enhancing ecosystem resilience to climate change. Human development has resulted in habitat loss, fragmentation, and degradation. A first step in increasing resilience to the effects of climate change is enhancing or protecting the ecosystem's natural ability to respond to stress and change. Research suggests that this is best achieved with "healthy" and intact systems as a starting point, which can draw on their own internal diversity to have natural adaptation or acclimation potential, and therefore greater resilience. Any restoration activities that enhance the ecological health of a system can thus be seen as creating or increasing the potential buffering capacity against negative impacts of climate change. It should be mentioned that there are obvious limits to the rate and extent of change that even a robust system can tolerate. As a result, it is only prudent to conduct restoration for enhancing resilience in tandem with efforts to reduce greenhouse gas emissions, the root cause of climate change. For many with a forestry background, carbon dioxide sequestration might seem a concomitant advantage to restoration projects, which can aid in reduction of atmospheric concentrations of greenhouse gases.

Adaptation Strategy after completing a vulnerability analysis to determine how a forest system may be impacted by changing climatic conditions, the next step is to look at the range of adaptation options available in order to promote resilience. An effective vulnerability analysis will determine which components of the system—species or functions, for example—will be most vulnerable to change, together with consideration of which parts of the system are crucial for ecosystem health. An array of options pertinent to adapting forests to climate change are available, both to apply to forest communities at high risk from climate change impacts as well as for those whose protection should be prioritized given existing resilience. Long-term resilience of species will be enabled where natural adaptation processes such as migration, selection, and change in structure are allowed to take place due to sufficient connectivity and habitat size within the landscape. Restoration can provide a series of critical interventions to reduce climate change impacts. Basic tenets of restoration for adaptation include working on a larger scale to increase the amount of available options for ecosystems, inclusion of corridors for connectivity between sites, inclusion of buffers, and provision of heterogeneity within the restoration approach.

3.2. Restoring Native Forest Habitats

In many countries, the most pressing restoration need from a conservation perspective is not for new forests but for higher quality in existing forests. Restoring ecological quality requires a proper understanding of the components of a natural forest: composition, pattern, functioning, and process of renewal, resilience, and continuity in time and space. Approaches to restoring quality include active management to restore missing microhabitats and steps to influence both process and the way in which the forest renews itself.

Forest management has changed the composition and ecology of the remaining forests in many parts of the world. Intensive management of native temperate forests in Europe, North America, and parts of Asia has resulted in forests that are species-poor, artificially young, lacking many of the expected microhabitats and with radical changes to ecology and disturbance patterns. Logging in many tropical forests has removed the largest trees, fragmented habitats through the construction of logging roads and skid trails, and often opened forests up to exploitation by settlers and poachers. Although these forests still exist, their ability to support biodiversity or to supply goods and services for local human communities may have been radically reduced. Or more precisely, their structure has been altered to supply one particular good—timber products—at the expense of other goods and services. Changing priorities mean that there is now increasing interest in managing forests for biodiversity, environmental services, recreation, and cultural and social benefits, as well as for timber production. In places where there are large areas of intensively managed or logged over forest, the primary focus of restoration activities may well be on restoring forest quality in existing stands of trees rather than extending the area under trees; in effect, this usually means returning the forest to a more natural composition and ecology. Six major components are important in defining the naturalness of a forest ecosystem:

1. The composition of tree species and other forest-living plant and animal species, where changes can include both loss of native species and problems from the occurrence of non-native invasive species;
2. The pattern of intraspecific variation, as shown in trees by canopy and stand structure, age-class, under-story, with changes in managed forests commonly being toward younger, more uniform forest stands;
3. The ecological functioning of plant and animal species in the forest as manifest in food the presence of important microhabitats such as dead wood and leaf litter;
4. The process by which the forest changes and regenerates itself over time, as demonstrated by disturbance patterns, forest succession, and the occurrence of periodic major disturbances from storms, fire, or heavy snowfall;
5. The resilience of the forest in terms of tree health, ecosystem health, and the ability to withstand environmental stress, which is of increasing importance during a period of rapid climate change; and

6. The continuity of the forest particularly with respect to total size, but also the existence of natural forest edges (often lost in managed habitats), connectivity of forest patches and the impact of fragmentation.

Restoration of quality can sometimes be achieved just by withdrawing management or other pressures, allowing natural ecological functioning to reassert itself gradually. However, in other cases, where, for instance, species have been lost from a locality, or where remaining pressures are undermining natural disturbance patterns, more active restoration efforts may be needed. Over the past two decades, limited experience has built up in restoration of forest quality, although there is still a great deal to be learned.

Most of the experience in restoration of forest quality in Georgia currently exists in relict and mountain forests, as shown by the examples below, although the importance of restoring forest quality is also increasingly being recognised in the Colchic refuge forest.

3.2.1. Beech Forests with Colchic Understory (Fageta Fruticosa Colchica)

The existence of the dense understory differentiates the beech forest of Georgia from the one in the rest of Europe. The beech forest with the Colchic understory **(Fig. 11)** is the composing part of the ecoregion of Colchic mixed broad-leaved forest.

It is widespread in the Western Georgia and is found on north-western slopes of the Greater Caucasus and the Adjara-Imereti Range. The climate is moist with about 2500 mm of annual precipitation. In the South Kolkheti, forests of this type start from the seacoast. In the northern part, it does so at the 200 m.a.s.l. and reaches about 2250 meters. As a result, the type of vegetation significantly differs. There are several sub-types. Sometimes sub-types are mixed with one another, which makes their classification difficult **(Dolukhanov, 2010)**.

Colchic forests are extremely rich in terms of flora **(Akhalkatsi, Kimeridze, 2012)**. They contain relict species of the tertiary period – fern, ***Hymenophyllum tunbrigense,*** as well as arboreal plants – ***Fagus orientalis, Castanea sativa, Zelkova carpinifolia, Pterocarya fraxinifolia, Diospyros lotus, Taxus baccata.*** Species mixed with beech trees are: ***Abies nordmanniana, Picea orientalis, Pinus kochiana, Quercus imeretina, Q. hartwissiana, Acer laetum, Carpinus caucasica, Tilia begoniifolia, Ficus carica, Pyrus caucasica, Malus orientalis, Staphylea colchica, S. pinnata,*** etc.

The following bushes create the understory in the beech forest: ***Laurocerasus officinalis, Rhododendron panticum, R. ungernii, Ruscus panticus, R. colchicus, Ilex colchica, Daphne pontica, Epigaea gaultherioides, Vaccinium arctostaphylos, Viburnum orientale,*** and ***Buxus colchica.*** The following lianas can be found: ***Hedera colchica, Dioscorea caucasica, Tamus communis, Periploca graeca***. Ferns – ***Matteuccia struthiopteris, Athyrium filix-femina, Polypodium vulgare, Phyllitis scolopendrium, Pteris cretica,*** etc. From the grass cover, the following are worth mentioning: ***Asperula odorata, Calamintha grandiflora, Festuca drymeja, Salvia***

Figure 11. Colchic beech forest with cut down trees in the Western Georgia. Photo by Maia Akhalkatsi.

glutinosa, Viola alba.

There are 6 sub-types and 14 plant communities:

1) Beech forest with the Pontic Rhododendron understory – ***Fageta rhododendrosa (Rhododendron ponticum, R. ungernii)*** is typical for the Colchic forest. The understory with ***Rhododendron ponticum*** can be found in almost all forest massifs in the Western Georgia. It is rare in the Eastern Georgia but can be found in Baniskhevi, Kvabliani and Nedzvistskali gorges. The average annual precipitation amount in its distribution area is 1400 mm. The area of its distribution starts from the seacoast and ends at 1950 m.a.s.l. In the mountains with high level of moisture in Guria and Adjara, it can reach altitudes of 2100–2200 meters. It grows both in flat open areas and heavily inclined slopes. It gives preference to slopes of northern exposition but in case of high levels of moisture, it grows on southern exposition. It does not like depressed areas with high levels of moisture and poorly drained soil.

Plant communities are sorted into two types:

1.1) Typical beech with Pontic Rhododendron understory (***Fageta rhododendrosa typical***), which is widespread at altitudes of 400–1700 m.a.s.l. The annual amount of precipitation is

1700–2500 mm. Pontic Rhododendron cover is extremely dense. Other common plants are *Trachystemon orientalis, Buxus colchica, Rubus* spp.

1.2) Beech forest with the understory (*Fageta rhododendrosa ungernii*) of Ungern Rhododendron (*Rhododendron ungernii*), which is a relict and local endemic. It can be found in the areas with high levels of moisture. Annual average precipitation in these places reaches 3000 mm. Small populations can be found in the seaside mountains of Adjara, in the upper parts of the Bartskhana, Chakvistskali, Koronistskali and Kintrishi Gorges. They are also common around upper streams of other rivers in the Kolkheti, namely the Bzhuzha, Natanebi, Bakhvistskali, and Supsa Rivers.

2) Beech forest with the laurel *(Laurocerasus officinalis)* understory (*Fageta laurocerasosa)* is similar to Pontic Rhododendron and is common in the areas with high levels of moisture, where the amount of average annual precipitation is 2000 mm. The amplitude of vertical spreading varies between 700 and 2000 meters. In contrast to Pontic Rhododendron, laurel grows well on limestone and well-illuminated slopes of the south. Besides Kolkheti, it is common in the form of small populations far from the areal. For example, in the Eastern Georgia it is widespread in the Alazani basin and the Ilto River gorge. Existence of such a widely disseminated areal of distribution is related to ornithochoria, since birds eat its fruit and disseminate seeds on large distances. Different from Pontic Rhododendron is the grassy cover of the laurel understory: *Sanicula europaea, Asperula odorata, Viola alba, V. reichenbachiana, Dentaria bulbifera, Calamintha grandiflora, Salvia glutinosa, Geranium gracile,* etc., as well as ferns: *Dryopteris filix-mas, D. carthusiana, D. assimilis, Polystichum braunii* are better developed.

Plant communities are sorted into three types:

2.1) Typical beech forest with laurel *(Laurocerasus officinalis)* understory (*Fageta laurocerasosa typica)* is widespread in the areas, where the annual amount of precipitation does not exceed 1700 mm.

2.2) Beech forest with the understory (*Fageta ilicitoso-laurocerasosa*) of holly (*Ilex colchica*) and laurel *(Laurocerasus officinalis)* can be found on limestone mountains in Abkhazia and Samegrelo – on mountain massifs of Kvira, Migaria, and Askhi.

2.3) Beech forest with the mountain fescue (*Festuca drymeja*) cover and laurel understory (*Fageta festucoso-laurocerasosa*) are found only in two places. The first is in the tract of Kvira Mountain, in the upper part of the karstic limestone macroslope with the inclination of 28º at the altitude of 1780 meters. The second one occurs on the same mountain, at the altitude of 1700 meters on the southern slope with 30º inclination. In the first area, the forest is represented only by the beech; whereas in the second one, it is mixed with *Acer trautveteri.*

3) Beech forest with the Colchic butcher's broom *(Ruscus colchicus)* understory (*Fageta ruscosa)* is quite rare. However, the butcher's broom itself is characteristic to quite many various communities. However, it is a small type of a plant and, therefore, is less visible. It is common in large quantities where other species of Colchic understory are excluded from communities due to certain circumstances. That is why the existence of the understory of only butcher's broom is the indicator of the reduction of the conditions that are essential for

the existence of the Colchic type understory.

4) Beech forest with the typical understory (*Fageta magnovacciniosa*) of Caucasian blueberry (*Vaccinium arcto-staphylos*). It is most widely distributed in Kolkheti. In the Eastern Georgia, it is common in the Lagodekhi region.

Plant communities are sorted into two types:

4.1) Beech forest with the typical understory of Caucasian blackberry (*Fageta magnovacciniosa typical*). It is common in the Western Georgia, distributed in the middle and upper zones of the forest at the altitudes of 900–2150 meters. In the Eastern Georgia, it is common in the Lagodekhi Reserve and extends to the Zakatala Reserve on the territory of Azerbaijan. Besides *Vaccinium arctostaphylos,* the understory is created by Colchic Ivy – *Hedera colchica* (Western Georgia), or *H. pastuchowii (*Eastern Georgia*),* Blackberry – *Rubus* spp., mountain blueberry – *Vaccinium myrtillus,* fern – *Gymnocarpium dryopteris,* grass cover – *Festuca drymeja, Paris incompleta, Oxalis acetosella,* rare species – *Trachystemon orientalis, Neottia nidus-avis, Monotropa uniflora.*

4.2) Beech forest with the cover of mountain fescue (*Festuca drymeja*) and Caucasian blueberry understory (*Fagetum festucoso-magnovacciniosa*) are common on the slopes of southern exposition, in the upper zone of the forest (900–1500 m). The understory is sparse. Besides Caucasian blueberry, azalea (*Rhododendron luteum*) is also represented. The following spieces dominate in the grass cover: *Solidago virgaurea, Gentiana schistocalyx, Calamintha grandiflora, Oxalis acetosella, alamagrostis arundinacea.*

5) Beech forest with azalea *(Rhododendron luteum)* understory (*Fageta azaleoza*) is less dependent on moisture conditions and it is often found on dry southern slopes as well. As usual, besides the beech forest it also grows in oak-hornbeam forests.

Plant communities are sorted into three types:

5.1) Beech forest with the azalea (*Fageta azaleosa media*) understory of the middle zone of the forest is common in mountain massifs of the Western Georgia with the average annual precipitation of 800–1500 mm. Characteristic landscape is the southern slope with the embossed relief of average inclination. Hornbeam, Georgian oak and Caucasian maple (*Acer velutinum*) are mixed with beech. Species of the understory are: *Festuca drymeja, Rubus* spp., *Vicia crocea, Trachystemon orientalis.*

5.2) Beech forest with azalea (*Fageta azaleosa superior*) is mainly common at the altitudes of 1700–1900 meters. The spruce (*Picea orientalis*) is also mixed with beech.

5.3) East Georgian beech forest with the azalea understory (*Fageta azaleosa iberica*) is widespread in the Aragvi gorge, in the upper streams of the Rivers Iori and Alazani, as well as in the mountains on the left side of the River Alazani valley. It grows at the altitude of 1000–1700 meters—or even higher in some places—on slopes of different expositions with embossed landscape.

6) Beech forest with Oriental Viburnum *(Viburnum orientale)* understory (*Fageta viburnosa)* is characterized by a small synecological areal of distribution. The Oriental Viburnum forms the understory mainly in the beech forest. It rarely occurs in the fir-forest or other

types of forests. From different forms of the Colchic type understory it holds the most moistened location. It can be common outside Kolkheti in the upper streams of the Rivers Aragvi and Alazani. The area of its distribution varies between 900 and 1900 meters. It mostly grows on the slopes of northern exposition, on little hillsides or flat open spaces. It cannot be found on the slopes with the inclination of more than 25º. Oriental Viburnum is the Colchic relict. Its close relative species *Viburnum acerifolium* grows in the eastern part of the USA.

Plant communities are sorted into three types:

6.1) Beech forest with the typical understory of Oriental Viburnum (*Fageta viburnosa typica*) grows in the middle zone of the forest of the Western Georgia, 1100–1600 m.a.s.l. It is more common on slopes of small and middle inclination of the Greater Caucasus. Besides it, Caucasian blueberry and laurel grow in the understory. From other plants, blackberry, box, *Trachystemon orientalis, Dentaria bulbifera, Paris incomplete,* etc. dominate.

6.2) Beech forest with blackberry-Viburnum understory (*Fageta ruboso-viburnosa*) is common in Kolkheti forests and the most eastern parts of their area of distribution – the Aragvi gorge. In addition to beech, maples (*Acer platanoides, A. pseudoplatanus, A. trautvetteri*) can also be found. Bushes – blackberry, Caucasian blueberry, holly, nut (*Corylus avellana*), elder (*Sambucus nigra*) and ferns – *Dryopteris filix-mas, Athirium filix-femina* are found here as well.

6.3) Beech forest of the upper forest zone with the Viburnum understory (*Fageta viburnosa superior*) can be found only in the Western Georgia at the elevation above 1700 meters and it is rare. There are the following species that are characteristic to the upper zone of the forest and drier biotopes: *Calamagrostis arundinacea, Gentiana schistocalyx, Oxalis acetosella, Gymnocarpium dryopteris, Festuca drymeja, Asperula odorata, Cardamine pectinata, Neottia nidus-avis, Epilobium montanum,* etc.

3.2.2. Colchic Broad-Leaved Mixed Forest

Colchic broad-leaved mixed forest is mainly distributed in the Western Georgia, in non-marshy lowlands and lower zones of the forest **(Dolukhanov, 2010).** It holds the eastern slopes of the Adjara-Imereti range and north-western part of the Greater Caucasus **(Fig. 12).** The boundary of vertical distribution is from 200 to 1000–2000 m.a.s.l. However, in the southern part of Kolkheti, it goes down to almost the sea level. Yellow, brown, and red soil of the forest can be found in the area of its distribution. Characteristic climatic feature is high humidity. Annual average precipitation in such types of a forest is 2500 mm. Such a high index of moisture is mainly characteristic to narrow gorges, where the annual precipitation is almost always equal and the temperature is moderate. Kolkheti forest differs from other broad-leaved forests by the evergreen understory with special composition of species **(Akhalkatsi, Kimeridze, 2012).** It contains many relict mesophytic species of the Caucasus. It is particularly represented by tertiary relicts. Among them, the poikilohydric living relict, fern – *Hymenophyllum*

Figure 12. Colchic broad-leaved mixed forest in the River Chorokhi gorge in Adjara, the Western Georgia. Photo by Maia Akhalkatsi.

tunbrigense is worth noting. It grows in Southern Kolkheti. Overall, in such a type of a forest 50 coniferous/evergreen and 80 herbaceous species are described. 6 dominant tree species are distinguished, that create syntaxons of various composition – chestnut (*Castanea sativa*), beech (*Fagus orientalis*), Imereti oak (*Quercus imeretina*), Colchic oak (*Q. hartwissiana*), Alder (*Alnus barbata*) and hornbeam (*Carpinus caucasica*).

From hard-wood plants, the following are common: Zelkova (*Zelkova carpintfolia*), Georgian oak (*Q. iberica*), elm (*Ulmus glabra, U. elliptica*), maple (*Acer laetum*), Norway maple (*Acer platanoides*), wire-but (*Pterocarya fraxinifolia*), lime (*Tilia begoniifolia*), maple (*Acer campestre*), willow (*Salix micans, S. pantosericea*), Caucasian wild pear (*Pyrus caucasica*), apple (*Malus orientalis*), *Diospyros lotus*, ash (*Fraxinus excelsior*), pine (*Pinus kochiana*), and Yew (*Taxus baccata*).

From evergreen bushes, the following are worth noting: *Rhododendron ponticum, Laurus nobilis, Ruscus colchicus, R. ponticus, Daphne pontica, Ilex colchica, Rhododendron ungernii, Epigaea gaultherioides,* and *Buxus colchica*. From deciduous bushes, the following can be encountered: relict *Vaccinium arctostaphylos, Staphylea colchica, Viburnum orientale, Philadelphus caucasicus, Euonymus leiophloea, Hypericum xylosteifolium, Swida australis, Corylus avellana, Frangula alnus, Mespilus germanica, Rubus caucasicus, Crataegus microphylla,* etc. Ferns are represented by *Matteuccia struthioptenis, Athyrium filix-femina, Blechnum spicant, Dryopteris affinis,* etc.

The epiphytic ferns are represented by *Polypodium serratum.* On the cliffs, there are: *Phyllitis scolopendrium, Pteris cretica,* etc. Lianas are widely represented and create an impenetrable plant cover, paricularly in forests. Widely distributed species are: Colchic ivy (*Hedera colchica*), Tamus (*Tamus communis*) and silk-vine (*Periploca graeca*), hops (*Humulus lupulus*), prickly ivy (*Smilax excelsa*), and clematis (*Clematis vitalba*, *C. viticella*). In Abkhazia, there are: Caucasian Dioscorea (*Dioscorea caucasica*), wild vine (*Vitis vinifera* ssp. *sylvestris*), and American *V. labrusca*; characteristic species also are epiphytic lichen old man's beard (*Usnea barbata*), and mosses (from Neckeraceae family).

The following representatives of herbaceous plants are common: *Brachypodium sylvaticum*, *Oplismenus undulatifolius*, *Cardamine impatiens, Oxalis corniculata, Fragaria vesca, Lapsana intermedia, Brunnera macrophylla, Clinopodium vulgare, Arthraxon langsdorffii, Salvia glutinosa, Veronica officinalis, Viola alba.* Invasive species are: Northern-American *Baccharis halimifolia,* Pan-tropical *Paspalum paspaloides, Andropogon virginicus,* etc.

8 sub-types are determined:

1) beech-chestnut forest (*Fagus orientalis – Castanea sativa;*) is a moist forest, widespread on slightly declined slopes, clay soil; 2) Hornbeam-chestnut forest (*Carpinus caucasica – Castanea sativa*); 3) beech-chestnut-hornbeam forest (*Carpinus caucasica – Fagus orientalis-Castanea sativa*); 4) Beech – alder -chestnut-hornbeam forest (*Alnus barbata – Carpinus caucasica – Fagus orientalis – Castanea sativa*) can be found in moist, slightly inclined locations of the northern slopes; 5) hornbeam forest with oak (*Carpinus caucasica -Quercus harwissiana*) is found in Abkhazia on the terrace up to 30 m.a.s.l.; 6) Imereti oak and hornbeam riparian forest (*Quercus imeretina-Carpinus caucasica)* grows along moist narrow gorges; 7) Colchic broad-leaved mixed forest with boxwood (*Buxus colchica*) understory is found in limestone places. 8) Colchic broad-leaved mixed forest with Pontic Rhododendron (*Rhododendron ponticum*) understory is found in Adjara at the altitudes of 960–1060 meters in the Koronistskali River gorge. Characteristic spieces are: *Epigaea gaulterioides, Ilex colchica, Betula medwedewii, Quercus pontica, Vaccinium arctostaphyllos, Viburnum orientale, Rhododendron luteum, R. ponticum, R. ungernii.*

3.2.3. Zelkova forest (Zelkova carpinifolia)

Zelkova (*Zelkova carpinifolia*) is the tertiary relict. Its area of general distribution is Kolkheti and Lenkoran in Azerbaijan **(Dolukhanov, 2010).** In the form of refuge on small territories, it is found in Kakheti and Karabakh. Monodominant forest of Zelkova is extremely rare. Such a forest is preserved in Akhmeta region, Babaneuli Reserve. Zelkova stand is found in several places in Akhmeta region – Pichkhovani, Laliskuri, and Argokhi. Forests occur on foothills of the mountains, slopes of various expositions at the altitudes of 430–500 meters. In the Western Georgia, Zelkova forest occupies lower places. The upper margin of its distribution is 750 meters. However, in Karabakh and Lenkoran, it can be found at the altitude of up to 1700 meters. In Kolkheti, Zelkova forest is mixed with other deciduous plants – *Q. imeretina, Q. iberica, Q. hartwissiana, Carpinus caucasica, C. orientalis.*

There are 2 sub-types and 11 plant communities **(Akhalkatsi, Kimeridze, 2012)**:

1) Zelkova – hornbeam and oak forests – *Zelkova-Carpineto-Quercetum*, are characteristic to the Western Georgia. The following communities are differentiated: 1.1) Zelkova forest with Imereti oak **(Fig. 13),** *Zelkoveto-Querceta (Quercus imeretina)*; 1.2) Zelkova forest with oak and Colchic butcher's broom, *Zelkoveto-Querceta ruscosa (Ruscus colchicus)*; 1.3) Zelk-

Figure 13. Zelkova (left) and *Quercus imeretina* (right). Photo by Maia Akhalkatsi.

ova forest with oak and false-brome cover, *Zelkoveto-Querceta brachypodiosa (Brachypodium sylvaticum)*; 1.4) Zelkova forest with oak and azalea, *Zelkoveto-Querceta rhododendrosa (Rhododendron luteum)*; 1.5) Zelkova forest with oak and sedge cover, *Zelkoveto-Querceta juncosa (Juncus effusus)*; 1.6) Zelkova forest with oak and hornbeam, *Zelkoveto-Querceto carpinosa (Carpinus caucasica).*

2) Zelkova and oriental hornbeam forest – Zelkova *carpinifolia – Carpinus orientalis*, is characteristic to the Eastern Georgia (**Fig. 13**). The following communities are observed: 2.1) Zelkova and Jerusalem thorn forest, *Zelkoveta Paliureto (Paliurus spina-christi)*; 2.2) Zelkova forest with astragal, *Zelkoveta astragalosa (Astragalus brachycarpus)*; 2.3) Zelkova forest with oriental hornbeam, *Zelkoveto-Carpineta (Carpinus orientalis)*; 2.4) Zelkova forest with hawthorn and bog cranesbill, *Zelkoveto-Crataegeta (Crataegus pentagyna) geraniosa (Geranium palustre)*; 2.5) Zelkova forest with nut and wild basil, *Juglandeto-Zelkoveta clinopodiosa (Clinopodium vulgare).*

3.2.4. Sensitive Forest Habitats in Georgia

Georgia is a country with very diverse habitat types. The habitat classification has been done recently **(Akhalkatsi, Tarkhnishvili, 2012).** Many forest habitat types are identical to the habitats of the Interpretation Manual v. EUR27. However, some habitat types are new habitat type candidates: 1) Beech forests with Colchic understory (*Fageta fruticosa colchica*); 2) Kolkheti broad-leaved mixed forest; 3) Zelkova forest (*Zelkova carpinifolia*); 4) Arid open woodlands; and 5) Sub-alpine birch krummholz.

There are some habitats, which are identical to the related European habitats by species composition at the generic level, but differ by species. The similarity between European and Caucasian plant species is mainly congeneric and not conspecific. Therefore, some habitats, which are similar to the European habitat types, should be considered as sub-types: 1) Beech forests without understory (*Fageta sine fruticosa*); 2) Dark-coniferous forest *(Piceeta orientale-Abieta nordmanniana)*; 3) Pine forest *(Pinus kochiana)*; 4) Yew forest *(Taxus baccata)*; 5) Hornbeam forest *(Carpinus caucasica)*; and 6) Boxwood forest (*Buxus colchica*).

The following might be considered as sensitive habitats: 1) Beech forests with Colchic understory (*Fageta fruticosa colchica*; **Fig. 3**); 2) Kolkheti broad-leaved mixed forest (**Fig. 12**); 3) Bog woodland *Tilio-Acerion* forests of slopes, screes and ravines; 4) Alluvial forests; 5) Alluvial forest with alder trees – *Alnus glutinosa* and ash trees – *Fraxinus excelsior* (*Alno-Pandion, Alnion incanae, Salicion albae*); 6) Riparian mixed forests; 7) Yew forest *(Taxus baccata*; **Fig. 14A**); 8) Zelkova forest (*Zelkova carpinifolia*); 9) Boxwood Forest (*Buxus colchica*; **Fig. 14B**); 10) Sub-alpine birch krummholz **(Akhalkatsi, Kimeridze, 2012)**.

A B

Figure 14. A – *Taxus baccata*; B – *Buxus colchica*. Photo by Maia Akhalkatsi.

The first step in restoring quality of forests is to determine what is missing. Many different definitions of naturalness exist at a site level, although most of these do not identify the different components involved. Most aspects of quality restoration can be achieved by removing the pressures that are currently reducing quality, such as overgrazing, changes in fire regime (either unnaturally high or low incidence of fire), poaching, and over collection. The simplest and cheapest tools available are agreements with stakeholders, for example, ensuring that shepherds keep sheep or goat flocks away from certain forests or reducing non-timber forest

product collection. Options that are more expensive include fencing against grazing animals, antipoaching patrols, and fire watching. Active management to restore natural dynamics are missing from the forest ecosystem, or unnatural elements (e.g., invasive species) are present, more active intervention may be required. Many invasive species only become established when there are gaps in the canopy so that removal for a period can lead to their virtual elimination, in other cases more long-term control strategies may be needed (particularly in the cases of invasive animals).

Much more information is needed about the ability of different forest ecosystems to recover quality over time and particularly about the likely speed of recovery; this information is important in making decisions about whether or not to undertake more active (and expensive) forms of restoration. Methods for control of invasive species are in some cases still also poorly developed, as is management of artificial disturbance. Codes of practice and perhaps principles for artificial disturbance remain to be developed.

3.3. Restoring Soil and Ecosystem Processes

Ecosystem processes, especially those directing successions, are the working parts of a successfully restored habitat. The ground processes are the first key to many harshly degraded situations restorationists have to face, and thus require specific attention. Reestablishment of biodiversity implies a fully functioning ecosystem. It is necessary to link human restoration efforts with the reestablishment of ecosystem processes in order to maximize biodiversity and ecosystem services (e.g., clean water, stable soils) while minimizing additional human inputs. Simply planting local vegetation and adding agricultural levels of fertilizer is not necessarily sufficient. Restoration activities focused solely on maximizing substrate stability or primary productivity frequently result in arrested succession and require further effort to encourage successional change **(Walker, 2005).**

An ecosystem is defined as a series of interactions among a particular set of organisms and between those organisms and their physical environment. Restoration addresses inputs, outputs, and internal dynamics of the flow of energy and matter. Typical measures of inputs include sunlight, water, nutrients, and organisms. Typical outputs include water, eroded soil, and organisms. Internal fluxes include nutrient cycling, primary productivity, and decomposition.

Additional ecosystem processes concern the interaction of the biota to disturbance (resistance, resilience, succession, invasion) and the development of structure and biodiversity. Successful restoration complements the natural recovery process of succession, following removal of constraints such as unstable, toxic, or infertile substrates or the lack of adequate soils. Successful restoration also allows succession to proceed and leaves an ecosystem both resistant and resilient to disturbance. Because we are able to predict successional trajectories only in the broadest sense (of functional groups, biomass, and nutrient accumulation), restoration that incorporates successional dynamics is often experimental.

Soil substrate stability is essential before restoration can proceed. For example, the following actions treat successively more serious erosion conditions: mulch, fertilizer, transplants, silt fences, contouring, jute cloth covers, rock-filled gabions, redirecting water flow, and lining alternative drainage channels.

The Caucasian mountain region is made up of three separate mountain systems (the Greater and Lesser Caucasus and Talysh mountains) and the lowlands of the Transcaucasian depression located between the Black and Caspian Seas **(Neidze, 2003)**. The core of the Greater Caucasus mountain range is composed of Precambrian and Paleozoic crystalline rocks, mostly granites and gneiss. The mountains of the southern macroslope are made of Jurassic and Triassic slates, sandstones, allevrolites, argillites, massive limestone, and tuffs **(Romanika, 1977).** The Lesser Caucasus at Javakheti Plateau is composed of Upper Cretaceous and Tertiary igneous rocks including lavas and shallow intrusive rocks such as andesite, basalt and dolerite **(Klopotovski, 1950)**.

The soils of the southern macroslope of the Greater Caucasus mountain range belong to the Western Transcaucasian Mountain Province **(Ivanova et al., 1963).** Within the lower vertical zone (up to 300–500 m.a.s.l.), either mountain zheltozems or gray forest soils predominate. Higher, up to 1800–2000 m, the soils belong to the brown mountain-forests acid non-podzolized type. Most soils within the forest belt correspond to either Inceptisols or Ultisols. The Lesser Caucasus including Javakheti, Tsalka-Dmanisi and Erusheti uplands is covered with the mountain chernozems (which are formed at altitudes from 1200–2200 m) and meadow chernozem-like soils. In highlands, they are replaced by mountain-meadow soils. Besides, the alluvial soils, redzinas, brown, as well as the meadow-brown soils occur here, with the predominance of brown forest type of soil in the mountain forest belt **(Neidze, 2003).**

Soil processes are key to successful restoration. Beginning with severely disturbed substrates, organic matter additions are the fastest way to incorporate critical soil microbes. Earthworm additions, inoculations of mycorrhizae, and additions of limiting nutrients all potentially accelerate soil development and facilitate woody plant invasions or plantings, especially in severely disturbed habitats. However, mycorrhizae can act as parasites when nutrient limitations are severe. Minimal additions of topsoil or other sources of nutrients and soil biota can reduce the risk of over-fertilisation and dominance by early successional species that preclude tree establishment.

Restoration can also involve reducing soil nutrients (via carbonrich straw, sawdust, or sugar, or additions of lignin-rich plant litter that immobilise nutrients) if the goal is a naturally infertile site. In fact, the whole successional pathway on volcanic surfaces is altered to favour plants adapted to higher nutrients, particularly nitrogen **(Vitousek, Walker, 1989).**

Toxic conditions can be ameliorated by bioremediation, or the use of plants, mycorrhizae, and microbes. Once toxins are reduced, restoration of native communities can begin. Additions of topsoil from late successional communities, sometimes combined with sludge, composted yard wastes, or other concentrated organic matter source, often accelerate succession. Arrested succession can be avoided by dense plantings of native species, particularly ones that attract vertebrate dispersers.

Biodiversity is a key goal to restoration, and its reestablishment implies a fully functioning ecosystem. If a diverse biological community resembling the reference ecosystem is self-sustaining, then landscape and successional dynamics have likely been incorporated. In addition, adequate substrate stability, drainage, depth, and fertility have been achieved. However, restoration generally requires ongoing monitoring and strategic alterations.

We need to better understand the role that individual species have in the restoration of ecosystem processes. We have tended to focus on nitrogen fixers used in agricultural settings and neglected vascular species that concentrate nitrogen and phosphorus from infertile soils. We have also neglected the nature and specificity of plant mycorrhizal associations and their role in restoration. Species that have similar functional attributes (fix nitrogen, grow early and fast in succession, host key pollinators or dispersers, have deep roots that break through compacted soils, etc.) may offer insights into better approaches to restoration. Similarly, keystone species (ones with ecosystem and community impacts disproportional to their biomass) could be important to restoration efforts **(Walker, 2005).**

Invasive species are becoming ubiquitous and restorationists need to address the impact of such species on ecosystem processes. Do they alter nutrient dynamics, soil stability, soil salinity, fire frequency, or primary productivity? If so, restoration efforts must not ignore these new influences.

Restoration is essentially the manipulation of succession, yet we understand little about how ecosystem processes vary through succession. Temporal replacement of vascular plant species reflects and influences a complex of ecosystem processes, including, generally, a reduction in light availability and an increase in nutrient availability **(Vitousek, Walker, 1989)**.

When belowground processes are ignored or only treated in a crude way (through fertilisation or stabilisation, for example), restoration suffers. The interplay of soil organisms with soil stability, fertility, and/or toxicity and with animals and vascular plants is perhaps the ultimate key to successful restoration.

Orchids are considered as indicator species of habitat disturbances **(Rose, 1999; Akhalkatsi et al., 2014).** The sensitivity to the habitat conditions of orchid species is determining to both abiotic environmental variables, such as climate, weather, topography, and soils **(Landsberg, Crowley, 2004)** and by their symbiotic relation with soil mycorrhizal fungi and specific pollination mechanisms by insects **(Hutchings, 2010).** Orchid seeds cannot germinate and develop in the wild without the appropriate mycorrhizal fungi, which involves the reciprocal transfer of carbon, nitrogen, and other nutrients between a seedling and its fungal partners **(Rasmussen, 1995; Smith, Read, 2008).** Mature orchids remain depending on their mycorrhizal fungi during the periods of growth and reproduction **(Bunch et al., 2013).** Therefore, orchids are associated to the fungi in nature and they are depending on habitat conditions supporting micorrhizal fungi conservation in soil composition **(Weston et al., 2005).** The distribution of soil fungi in concrete habitat is related to spatial variation in pH and the availability of carbohydrates, nitrogen, and phosphorus **(Kiers et al., 2011).** The disturbances of habitat conditions affect soil composition and forest degradation might be the factor of changes of soil chemistry selecting a suite of fungi that drives the distribution of orchid fungal associations across landscapes **(Wolfe, Klironomos, 2005).** Thus, forest degradation changing vertical structure of habitat may be correlated in the soil environment changes and orchids will represent as indicators of changes with fungal association.

Terrestrial orchid species of Georgia are adapted to a great variety of habitats such as shrubbery or wetlands, alpine meadows or open woodlands and even forests **(Akhalkatsi et al., 2006b).** They preferably occur on calcareous soils even in forests covering limestone sediment areas in the Western and Eastern Georgia. Vegetation of limestone rock is found mainly in the West Caucasus from Abkhazia including Racha **(Nakhutsrishvili, 2013).** A very interesting community of limestone rock massif is in Javakheti, on the Chobareti mountain range, plateau of Tetrobi, which is recognized as a protected territory **(Akhalkatsi et al., 2009).** In the Eastern Georgia, there are just small locations of limestone rocks in Kartli and Kakheti. In Kiziki, it is located in the surrounding of Dedoplistskaro and in Kakheti, in Kvareli district near Shilda village **(Akhalkatsi et al., 2014).**

Therefore, the investigation of forest habitat disturbances on calcareous habitats rich in orchids and other geophytes is of high importance **(Piqueray et al., 2007).** Almost all native orchid species distributed in Georgia are threatened due to extreme anthropogenic impacts. The major negative factors leading to the habitat destruction and by that, endangering orchid species by the extreme reduction of the number of individuals within the populations and causing their extinction are overgrazing, plant collection in undisturbed habitats, pollution, road and pipeline constructions, deforestation, land degradation, urbanization, climate change, etc. **(Akhalkatsi et al., 2003).**

Destruction of calcareous habitats is strongly connected to limestone quarry mining and extraction of calcareous sediments causing cleaning of vegetation cover and soil. Surrounding area of quarry is under human impacts during quarry handling and changes of habitat structure affect species density and fertility. Main idea was to conduct inventory of plant species and habitat structure to develop recommendations and management principles on conservation of orchids dominated in calcareous plant communities. Habitat with many orchids and other geophytes species was found at the adjacent to Dedoplistskaro limestone quarry region. The operation of this quarry started in 1954 and it is still active and managed by HeidelbergCement AG since May 2006, which is interested in restoration of habitats after implementation of quarry extraction. Population ecology methodology and sky exposition effect on species density and fertility of orchids in disturbance and natural forest habitats have been used to determine species status and develop recommendations on their conservation **(Akhalkatsi et al., 2014).**

Degraded forest habitat conditions are supporting micorrhizal fungi conservation in soil conditions and orchid existence is available **(Weston et al., 2005).** Intensive cut down forest changed to scrub habitat shibliak containing some short trees and shrubs and having higher sky exposition shows strong negative impact on the populations of orchids remaining only 6 species - *Anacamptis pyramidalis, Ophrys oestrifera* subsp. *oestrifera*, *O. spegodes* subsp. *caucasica, Orchis morio* subsp. *caucasica, O. purpurea* subsp. *caucasica, O. simia*. The completely open dry meadow secondary steppe illuminated more intensively lost all orchid species (Akhalkatsi et al., 2014). These results confirm the data that habitat conditions supporting micorrhizal fungi conservation in soil conditions and sky exposition depending on forest vertical structure change is affecting soil composition and changes of soil chemistry selecting a suite of fungi that drives the distribution of orchid fungal associations across landscapes **(Weston et al., 2005; Wolfe, Klironomos, 2005).**

Thus, forest degradation changing vertical structure of habitat may be correlated in the soil environment changes and orchids will represent as indicators of changes with fungal association. In addition, besides the illumination in habitats, grazing should have very intensive effect on soil composition change leading to decrease of humidity and minerals **(Kiers et al., 2011).** Such degradation of forest has strong influence on soil composition and it is necessary to apply forest restoration to conserve the native species of the habitats.

3.4. Restoring Water Quality and Quantity

Forests certainly play a critical role in regulating hydrology. Loss of forests has been blamed for everything from flooding to aridity. There appears to be a clear link between forests and the quality of water from a catchment, a more sporadic link between forests and the quantity of water, and a variable link between forests and the constancy of flow. What forests provide depends on individual conditions, species, age, soil types, climate, management regimes, and needs from the catchment. Forests in watersheds generally result in higher quality water than alternative land uses, because other uses—agriculture, industry, and settlement—are likely to increase pollutants entering headwaters, and forests also help to regulate soil erosion and sediment load. The precise interactions between different tree species and ages, and different soil types and management regimes, are still often poorly understood, making predictions difficult. Opinion also remains divided about the role of forests in maintaining regular water flow.

Water is, in theory, a renewable resource. The potential role of restoration with respect to water supply needs to be considered on a case-by-case basis and on a long time-scale. Far better tools and methodologies are needed for calculating net gains of different restoration and management actions from the perspective of water supply. There is also a need to better understand the linkages between water supplies and forest cover to help use these links as arguments for restoration. For several countries, reliance on non-renewable (or only slowly renewable) groundwater sources masks a problem that will become more acute as these are exhausted. In 1998, twenty-eight countries experienced water stress or scarcity (defined as being when available water is lower than 1000 cubic metres per person per year); by 2025, this is predicted to rise to 56 countries. Overall, our main water requirements are for crop irrigation, but the need for clean drinking water is also critically important. These problems will increase in the future as the rapid processes of population growth and urbanisation continue and as climate change makes rainfall more erratic and increases the regularity and severity of droughts **(Dudley, Stolton, 2005)**.

Forested catchments have important local impacts in regulating water flow. Undisturbed forest is also the best watershed land cover for minimizing erosion by water and hence also sedimentation. Any activity that removes this protection, such as litter collection, fire, grazing, or construction of logging roads, increases erosion. Suspended soil in water supplies can render irrigation water unfit for use, or greatly increase the costs to make it useful.

Species survival is almost completely depended on species propagation by seeds. In arid and semiarid ecosystems, there is a strong dependence of the rates of seed production and seedling establishment on the soil water content. Conditions of limited soil water availability in drought years lead plant into a state of water stress, which, causes limitation in seed productivity and quality and, if prolonged, is responsible for loss of turgidity, wilting and death of plants. While adult plant is better adapted to water limitation due to the deep root system able to uptake ground water, soil water content more sever affect has on germinating seeds, due to the direct or indirect dependence of the processes on the soil moisture conditions. Seedlings of many species of arid habitats have difficulty becoming established due to the aridity of the environment, which leads to high levels of competition among the existing vegetation and emerging seedlings for the limited water resources. On the other hand, anomalously high precipitation, occurred in some years, may allow rapid tree growth and increased stand densities, resulting in potentially greater intraspecific competition for drought-limited water and greater susceptibility to drought, beetle infestation, and associated pathogens **(Katz, Brown, 1992).**

The reproductive phenology is the most sensitive phenomenon to the climate change. Investigation of drought effect on the duration of phenological stages in garden legume ***Trigonella coerulea*** **(Akhalkatsi, Lösch, 2005)** have shown that the total duration of the reproductive period (i.e. time from appearance of the first flower until maturation of the last fruit) was approximately similar for all treatments. However, the duration of separate phenological phases varied among treatments. Drought-exposed plants had the longest period of seed formation and shorter periods of seed filling and maturation. The shortening of the seed filling period leads to the reduction of the final seed dry mass. Limitation in water availability at the terminal stage of seed development, during maturation drying, may affect loss of moisture from the seeds and reduce their quality, which in consequence will be expressed in lower germination ability. This difference had effect on germination percentage of seeds of drought-exposed plants, which was low. It is expected in experiment that the differences in separate phenological stages will influence seed quality and their germination ability.

Water, among other physical environmental factors, plays an important role in the initiation of seed germination and seedling development. The uptake of water by seeds is the initial step to germination and is conditioned by the difference in water potentials between seed and soil. The establishment of a seedling to the definite site can be restricted by substrate water potential to which germination is sensitive to water availability. The time for germination of ***T. coerulea*** seeds has been considerably prolonged already at substrate water potential –0.5 MPa, when compared to control seeds germinated in water **(Akhalkatsi, Lösch, 2001).** The slowing affects not only radicle emergence, but as well the seedling growth. For seedling establishment in the field these changes might be dramatically enough, as a short radicle will be affected by water stress during rapid drying of the soil surface. It will be test in the laboratory conditions requirement of studied species on substrate water potential and determine threshold values necessary for germination success. This will allow predicting species survival chances under changing soil moisture.

Most arid regions in Georgia – Iori Plateau, semi desert biomes of Shida and Lower Kartli, xerophytic habitats in Meskheti etc., are water-limited ecosystems **(Nakhutsrishvili, 2013).** Therefore, small changes in precipitation amount or season may affect biological components that maintain nutrient and water cycles and energy flow through these ecosystems. In order to model the influence of climatic change on the plant reproduction and water supply in these ecosystems, it is important to simulate the natural balance that exists between water limitations and species propagation. Furthermore, although arid and semi-arid lands cover approximately one third of the earth's surface, few experimental warming studies have been conducted in these systems. This study might be considered as significant contribution in solving of such an important problem.

The potential role of restoration needs to be considered on a case-by-case basis and probably also on a long time-scale. Establishing fast-growing plantations is unlikely to do much to help either the quantity or the quality of water, while carefully located and managed secondary forests can do much to regulate sediment load, other pollution, and erosion, and may in some situations also eventually affect flow. Restoration for water supplies should also look at options for reducing impacts from managed forests through, for instance, removing unnecessary roads or changing their location, camber, and drainage facilities.

In April/May 2005, heavy rainfall, warm temperatures, and a sudden onset of the seasonal snowmelt resulted in extensive flooding across large parts of Georgia, including landslides and mudflows in many mountain areas. The First National Communication Reports also provide some interesting forecasts for each of the three countries of the Caucasian ecoregion on the potential impact of climate change on ecosystems, natural resource production, and economy. The forests and alpine ecosystems will show a significant altitudinal shift upwards, semi-desert and desert areas will expand, river flows decline, and agriculture production and livestock breeding will suffer significantly.

The rapid melting of the Caucasus glaciers will continue, possibly to an extent where hardly any glaciers will be left at the end of the 21st century. This will have severe impacts on river flows, as glaciers store water and ensure a steady supply of water to the river systems during the warmer and drier parts of the year. At first, there will be increasing water flows due to the melting of the water stored in the glaciers over hundreds of years causing floods and increased erosion. When less and less glaciers are left, the water flow of the rivers of Caucasus will gradually become more shifting with strong flows following rainy seasons and lower than current average flows during the warm and dry periods. This will have a significant negative impact on agriculture and water availability. In Georgia, a general decline of the economically valuable Sweet chestnut tree (***Castanea sativa***) is expected, and many high-altitude plant species associated with ice and snow cover are estimated to go extinct in the lower mountains of southern Georgia. Arid areas in eastern Georgia, which already are intensively grazed by livestock, are also seen as particularly vulnerable.

In general, watershed values are an additional argument for restoration rather than being associated with specific restoration techniques. Information for policy makers about the value of different forested watersheds remains scarce, and models for predicting responses in individual catchments are at best approximate. Restoration for water purposes within individual catchments will vary according to circumstances and will be able to draw on many of the tools outlined elsewhere. Two approaches may be particularly useful here: 1)Protect, manage, restore: Using forest cover to maintain water supplies at a watershed scale often requires a mosaic approach, where protected areas, other protective forests, and various forms of management are combined depending on existing needs and land ownership patterns. Restoration then becomes a management option that can be used in any of the above. Agreeing on the mosaic and balancing different social, economic, and environmental needs on a landscape scale requires careful planning and negotiation. 2) Payment for environmental services (PES): The central principles of the PES approach are that those who provide environmental services should be compensated for doing so, and that those who receive the services should pay for their provision.

The glaciers of the Caucasus are melting rapidly, in accordance with the global trend. During the last century, the glacial volume in the Caucasus declined by 50%. In a recent study, it was shown that 94% of the glaciers had retreated up to 38 m/year. In the Georgian part of the Greater Caucasus **(Fig. 15)**, the glaciers currently retreat by 5 to 10 metres per year, with a maximum value of 25 m/year.

Many governments are making decisions about forests and water based on flimsy data and poor methodologies. Far better tools and methodologies are needed for calculating net gains of different restoration and management actions from the perspective of water supply, and WWF is currently planning to collaborate with the World Bank to help develop them. More basically, there is need for greater understanding of the links between forests and water, perhaps initially through better diffusion of existing research and case studies.

Georgia is rich in hydropower resources but hydroelectric plants produce only about 60% of their potential capacity due to a low level of maintenance. Georgia's energy sector lags well behind that of its neighbours and other countries in Central and Eastern Europe and still remains incapable of reliably meeting its current and future energy demands. One obstacle has been the non-payment of the energy consumed, but through management improvements in the largest electricity distribution company (United Energy Distribution Company), this figure dropped from 80% in 2004 to 20% in mid-2006. The Ministry of Energy is currently implementing a four-year Georgia Energy Security Initiative financed by USAID, the German KfW and other donors. Amongst the activities is the rehabilitation of existing rural small-scale hydropower plants. Other promising renewable energy sources are wind and geothermal. The Kyoto Protocol was subsequently ratified by Georgia in June 1999.

Figure 15. Mount Kazbek with several melting glaciers causing climatic catastrophes in the Tergi gorge by water. Photo by Maia Akhalkatsi.

In conclusion, many species in the South Caucasus with specialized habitat requirements will likely decline due to climate change. Particularly vulnerable are species dependent on alpine habitats in the Lesser Caucasus where the amount of living space will dramatically shrink and species confined to already fragmented habitats like wetlands will suffer. Species already facing threats from other human activities like livestock grazing in arid lowland areas will also experience problems to cope.

3.5. Restoring Non-Timber Forest Products

Non-timber forest products (NTFPs) are defined as biological resources of plant and animal origin, derived from natural forests, managed forests, plantations, wooded land, and trees outside forests. The economic and social significance of NTFPs to sustain people's livelihoods and local, national, and international markets justify the need to invest resources in harvesting, growing, and planting a wide range of native plant species. Applying and adapting the existing ecological restoration techniques to NTFPs can help secure focal species' habitat requirements and diversify natural resource production on which sustainable forest management is based.

Historically, in many forest areas, rural communities have developed forest management systems that meet multiple functions or purposes, in which their economies are based on the harvesting and production of a wide range of NTFPs channelled through local, national, or international markets. Under these circumstances, forest landscapes have been to a certain extent human-shaped, characterized by a rich mosaic-like structure integrating natural forests, several wooded, shrub and grassland formations, and semi-natural agroforestry land areas, including extensive agricultural land. Many traditional multipurpose forestry systems have been lost or collapsed in numerous forest areas due to socio-political instability or macroeconomic drivers. The result has been the intensification of one single forest use—the conversion of forest land into agriculture or non-native tree plantations—and significant biodiversity loss and land degradation.

The production of NTFPs can be expected to produce less severe environmental impacts to forest ecosystems than timber extraction. Valuing and supporting new economic opportunities based on NTFPs as part of multipurpose forest systems can contribute to both improving the environmental benefits of forest landscapes and to sustaining and improving livelihoods, especially in less favoured rural areas.

Considering people's high dependence on NTFPs for their livelihoods, there is a significant economic incentive for many countries to develop the NTFP production potential of their forests and to generate positive socioeconomic benefits for rural populations while ensuring that these are compatible with conservation values. However, to deliver this potential there is a need to modify current economic notions that govern forest management, notably by enlarging and improving market opportunities, and securing payment mechanisms and incentives for land owners/users to restore forest resources and the goods and services that they provide.

The NTFP markets are also important at the regional and international levels as they provide revenues for the actors directly involved and for the government. At the international level, it is estimated that the trade in NTFPs amounts to $11 billion. The European Community, the United States, and Japan account for 60 percent of world imports of NTFPs, and the general direction of trade is from developing to developed countries.

Forest biodiversity, via NTFPs (harvested or hunted biological products from wild or cultivated sources), plays an important role in addressing poverty for marginalized, forest dependent communities. The NTFPs contribute to livelihood needs, including food security, health and well-being, and income. In many parts of the world, these resources are critical for the poorest members of society who are often the main actors in NTFP extraction and may provide them with their only source of income. Ninety percent of people who earn less than one dollar a day depend on forests for their livelihoods, according to the World Bank.

Quantifying in economic terms the value of NTFPs and the income they can provide rural families is an important step forward for understanding the prevalent role of forest resources in rural subsistence. If NTFPs were appropriately valued, this could provide a powerful argument to governments and the private sector to alter or reverse wrong spatial planning decisions in forest landscapes of outstanding biodiversity. When planning the conversion of forests into agricultural land for subsistence reasons, it is necessary to estimate the real economic value of these forest resources in order to make an informed decision. Economically oriented projects involving the use of native plant species should be subjected to a thorough cost-benefit analysis before being implemented. Generally speaking, there is a growing need to argue and reaffirm the fact that NTFPs significantly contribute to many local and national economies, and have an unknown potential that needs to be further researched.

In all cases, specific research and field-testing is needed to get the necessary know-how on harvesting, growing, and planting the wide range of trees, shrubs, and herbs native to each forest ecosystem, as well as to facilitate natural regeneration and habitat improvement techniques. Standardized protocols for seed collection, mycorrhization of nursery plants, nursery and field techniques for reduction of transplant shock, need to be developed through pilot experiences.

Certification is a policy tool that attempts to foster responsible resource stewardship through the labelling of consumer products. Even if forest certification has tended to focus on timber products, opportunities exist to promote sound ecological and social practices in NTFPs' management to support restoration in degraded forest landscapes of outstanding biodiversity and increase local communities' revenues and trade opportunities through this market tool.

The use of NTFPs in forest landscape restoration programmes poses new challenges to the forestry sector traditionally orientated toward afforestation with a few fast-growing timber tree species in degraded areas. New expertise and know-how on managing, harvesting, growing, and planting a wide range of trees, shrubs, and herbal NTFP species is required to undertake a thorough assessment of the potential and opportunities for candidate NTFP restoration operations.

During the last two decades NGOs, private cooperatives, and research institutions have played an important role in raising awareness, developing NTFP production cooperatives, and assisting local communities and governments in developing pilot field experiences and restoration protocols for growth in tree nurseries and planting of a wide range of NTFPs. Currently, the forestry sector curricula and university study programmes are under revision for integrating ecological restoration and NTFPs' conservation and management.

Government regulations about NTFPs' conservation, access rights, management, and commercialization are not always well defined. Moreover, existing laws are occasionally contradictory and require resolution. NTFP management falls under different ministries and legislations, making it a difficult issue to deal with for managers and certifiers. In the Mediterranean region, there is a cork oak forest conservation law in Portugal, while in North African countries, local communities' rights of access for NTFPs in cork oak forestland are not always defined and the governments have the control of cork as a product.

International organizations and NGOs may play a greater role in advocating and assisting forest managers and governments to improve NTFP legislation and guidance, given that insufficient resources or incentives have been allocated to products that traditionally have generated small amounts of taxable income for states. Certification may serve to catalyse governments and multilateral organisations' nascent efforts to reinforce markets and legislation related to NTFPs.

4. Forest Restoration after Disturbances

4.1. Plantation of Tree Species

Plantations are a useful tool for restoration especially in areas where degradation is advanced, for instance in conditions of severe soil compaction, invasion by grasses, and advanced fragmentation. In many cases, information is lacking on local tree species that can be used for plantations: site adaptability, seed sources, germination and nursery requirements, and need for fertilization. Techniques for planting and tending of species are important to consider: need for fertilizers, mycorrhizae, irrigation, etc. It is always preferable to use native species instead of exotic species, if a native species is available and grows well in the region.

Figure 16. Pine forest planted in the surroundings of Tbilisi in 1968. Photo by Maia Akhalkatsi.

The forest restoration was actively used in Georgia since the 1960s and many areas were reforested mainly by pine forests (**Fig. 16**). The research will contribute to conservation of biodiversity and enrichment of knowledge on resources and current state of the populations of economic trees in Georgia. New knowledge on current status of populations and impacts

threatening edible plants will be gained and recommendations on sustainable utilization of resources from the wild will be developed. This will ensure conservation of biodiversity in Georgia.

The idea that properly conserved and wisely used biodiversity guarantees the effective functioning of ecosystems will be disseminated. Local population has to realize that overuse of biodiversity will cause severe impact on their livelihoods and they will be the first to suffer when these resources are degraded or lost. On the other hand, they have to understand that the biodiversity will offer great potential for marketing unique products, such as edible or ornamental plants, many of which are extremely valuable. Effective solution of the problem of biodiversity loss might be encouragement of smallholder farmers to cultivate economically valuable plants on their ground and supply the market. This will reduce uncontrolled utilization of this extremely vulnerable species in the wild and contribute to the conservation of biodiversity.

Tree plantations are sometimes the only alternative in restoring forest landscapes, at least in the short term, especially on very badly degraded soils. Low soil fertility, soil compaction after abandonment from cattle grazing, and invasion by grasses and other aggressive vegetation can be serious obstacles to natural forest regeneration. As the area of degraded lands expands, there is a greater need for tree species that can grow in such conditions and yield useful products (timber, fuelwood, and others) as well as environmental benefits (recovery of ecosystem biodiversity, soil conservation, watershed protection, carbon sequestration).

Tree species chosen for a plantation in the context of forest restoration can provide benefits from the tree products (timber, fuelwood, leaf mulches, etc.), and from their ecological effects, for example, nutrient recycling, or attracting birds and other wildlife to the landscape.

Tree diversity is controlled largely by drought stress in the seedling and small sapling stages. In drier sites, a smaller fraction of tree species may have sufficiently deep root systems as seedlings to survive prolonged periods of drought than is the case in wetter sites. The hypothesis will be tested by a watering experiment on seedlings transplanted to sites with greater or lesser dry season soil moisture and drought stress within an experimental plot. The experiment will demonstrate whether dry season watering increases seedling survival and growth compared with seedlings in non-watered control plots.

Effect of water availability will be determined on the variations in reproductive phenology, seed development, and seedling establishment in rare tree species both, in their natural habitats, and under controlled laboratory conditions. During this study, it will be monitored by tree seedling establishment of forest species in experimental plots, as well as in natural forest plots. Additionally, seed rain, microclimatic conditions, soil water potential, and seed/seedling herbivorous will be measured in selected plots to evaluate alternative mechanisms underlying patterns of seedling establishment.

Description of populations of target species in natural area of distribution will provide information on current status of the rare species, their abundance, vitality and fertility. We will determine the sensitivity and responses of physical, chemical, and biological components within the habitat representing a variety of soil types, precipitation timing, and air and soil temperature gradients, which will be monitored by data loggers.

The technology of seed propagation of rare plants and set up of plantings will be developed. This technology will benefit local farmers and foresters who can propagate these species on grounds and sell them both in Georgia and abroad. Wild pear might be used for grafting increasing drought resistance property of pear varieties. The Georgian Almond might be used for the same purpose. Special interest represents wild grape to be used in grape breeding worldwide. The collection of germplasm has a big importance for world breeding centres that will have interest to use this material in breeding and gene engineering. Germplasm collection and propagation technology might be used by local farmers for setting up plantings of economically valuable tree species. Foresters and greening organization may use these data to set up forest-parks and greening zones by these valuable plant species. Foreign breeding centres will have definite interest to purchase the germplasm of these rare plant species for the purpose of genetic engineering to increase in cultivated varieties the resistance to disease and drought, which is characteristic for studied species.

Currently, leading breeding centres of the world, such as at USDA and FAO, have a big interest to collect germplasm and use it for breeding purposes. The materials, which will be studied in this project, have both high conservation value, and at the same time, are characterized by diseases drought resistance. This determines high value of these plants to use them in plant breeding. Special emphases should be made that we will provide as well complete information and technology on seed propagation peculiarities of studied plants.

Effective solution of the problem of biodiversity loss might be gain of new knowledge on economically valuable plants and development of recommendations on sustainable utilization of resources from the wild. The idea that properly conserved and wisely used biodiversity guarantees the effective functioning of ecosystems will be disseminated. This will reduce uncontrolled utilization of this extremely vulnerable species in the wild and contribute to the conservation of biodiversity.

The choice of a tree species depends on whether both productive and ecological advantages can be achieved in the same system, and in some cases, one function, either productive or environmental, may be desired. Within a forest landscape, the preferred choice for restoration would be natural regeneration. Planting would only be a secondary option, to be used in cases where natural regeneration cannot proceed due to the obstacles mentioned above (poor soil conditions, long distances to seed sources, isolation, invasion by aggressive grasses).Within a landscape context, there should be a balance of socioeconomic goals (e.g., productivity) and biodiversity objectives for restoration.

The following factors influence species' choice for plantations:

1. Fast-growing, native pioneer species with high productivity are recommended for the initial stages of restoration of degraded lands. These species can help in facilitating the environment for later successional, longer-lived species whose end products are more valuable (better timber quality);

2. Preference should always be given to local species, especially those that are endangered. Fast-growing exotic species such as eucalypts, acacias, or pines should be used only when there are no available seeds of native species, or when environmental conditions are too harsh for any native species to survive. Exotic tree species predominate both in industrial and rural development plantations worldwide; however, native trees are more appropriate than exotics, because (1) they are often better adapted to local environmental conditions, (2) seeds may be more generally available, and (3) farmers are usually familiar with them and their uses. Besides, the use of indigenous trees helps preserve genetic diversity and serves as habitat for the local fauna;
3. Disadvantages of the use of native species are (1) uncertainty regarding growth rates and adaptability to soil conditions; (2) general lack of guidelines for management; (3) large variability in performance and lack of genetic improvement; (4) seeds of native tree species are often not commercially available and have to be collected; (5) high incidence of pests and diseases ; and
4. One of the strongest arguments for the use of native tree species in plantations is the high value of the wood and its increasing scarcity in commercial forests. Many native tree species of valuable timber grow well in open plantations, with rates of growth comparable or superior to those of exotic species in the same sites.

Most plantations whose purpose is to restore forest landscapes also have a productive purpose. Globally, half of forest plantations are for industrial use (timber and fibre), one quarter are for nonindustrial use (home or farm construction, local consumption of fuel wood and charcoal, poles), and one quarter are for unspecified uses. Among the unspecified uses, there are small-scale fuelwood plantations, plantations for wood to dry tobacco, etc. Therefore, species' choices reflect the end use of each plantation, while considering the purpose of forest restoration.

For several native species in developing countries, there may not be enough genetic selection for the desired traits (fast growth, soil recovery, or other). For many native species, studies on the phenology of trees may be needed (i.e., timing of flowering, fruiting, seed production, and seed collection). In addition, there must be enough seed storage capacity, which in some cases may require refrigeration, desiccation, and other procedures to accommodate seeds of tree species from mature forest. In the case of seeds from pioneer species, these are generally smaller, drier, and easier to store. When the information is not known, specific tests have to be developed to understand the germination requirements and characteristics of each seed. Finally, growing requirements in the nursery must also be known, including need for fertiliser, inoculation with mycorrhizae, and time when they can be transplanted to the field conditions.

Farmers most often prefer species whose silvicultural characteristics are well known, and species that have well-defined end uses and good markets. In many cases, they also prefer native to exotic species. Seed or seedling availability in local nurseries is also an important factor defining farmers' preferences. Research on other species, including indigenous trees, is underway at universities and other research institutions. For some native species, genetic improvement has advanced with trials of seed origin and progenies, the first step in the domestication of a species.

Information on the following ecological characteristics of tree species will be useful in helping to select them for plantation purposes: light requirements, growth under different soil fertility conditions, resistance to drought, tolerance to low or high pH, tolerance to high concentrations of toxic metals, resistance against pest and disease, ability to sprout and to respond to pruning and coppicing, seed production, germination characteristics, need for inoculation with mycorrhizae, need for fertilizers, wood characteristics, and uses. In most cases, basic ecological information on tree species can be found at universities, ministries of agriculture, or departments of forestry. Local information can also be obtained from nurseries, agricultural or forestry cooperatives, and from conversations with local producers. However, sometimes, native species are poorly known, yet another reason for people's tendency to use exotics, which have been better studied.

Mixed species' plantations have been established at several locations with varying results. However, results from a number of field experiments suggest that mixed designs can be more productive than monospecific systems. In addition, mixed plantations yield more diverse forest products than pure stands, thereby helping to diminish farmers' risks in unstable markets. Farmers may prefer mixed plantations to diversify their investment and as a potential protection against pest and diseases, in spite of the technical difficulties of establishing and managing mixed plantations. Mixed stands may also favour wildlife and contribute to higher landscape diversity. As seen from the example presented above, mixed plantations can have many productive and environmental advantages over conventional monocultures. However, their main disadvantage lies in their more complicated design and management. Mixed plantations thus are often restricted to relatively small areas or to situations when diversifying production is a great advantage, such as for small farmers of limited resources.

For forest habitat restoration, only native species should be used in plantations, except if, as in some of the cases mentioned earlier, there are good specific arguments for the use of exotics. Therefore, increased knowledge of characteristics and silviculture of native tree species is needed to assist in this objective. In particular, more information is needed on the performance of indigenous species in plantation conditions. In addition, silvicultural guidelines for plantations with indigenous species are needed to increase their adoption by local farmers. Market values are also an important factor influencing the adoption of native species by local farmers. A key question in species' choices with the dual purpose of restoration and production is how to balance economic objectives with biodiversity ones.

Finally, there are some trade-off issues: is it best to have smaller areas of exotic plantations or larger areas of native plantations?

4.2. Erosion Control in Restoring Forests

Forest landscape restoration requires the stabilisation of soil resources. The loss of soil to erosion leads to irreversible changes and degrades physical, chemical, and biological properties. Although natural erosion occurs on many landforms, accelerated erosion (caused by human activity) is the appropriate focus of most restoration efforts. Wind erosion is a serious problem that may occasionally be reduced by planting trees. Hill slope erosion, wind erosion, and mass movement (slump erosion) are common problems. Increasing the cover of vegetation or litter, preferably both, is the most effective strategy for reducing erosion.

Hill slope erosion is caused by the direct impact of raindrops on the soil surface, overland flows, and small channel flows (**Fig. 17**). Overland flow begins as surface depressions are filled and when rain falls faster than water infiltrates into the soil. Although overland flow is often viewed as a sheet of water flowing over the surface, it typically includes numerous shallow, but easily definable channels, called rills. The relative amount of sediment detached and transported by inter-rill flow is small compared to splash and rill erosion. Rills are small enough to be removed by normal tillage operations, but may become too large to remove with tillage.

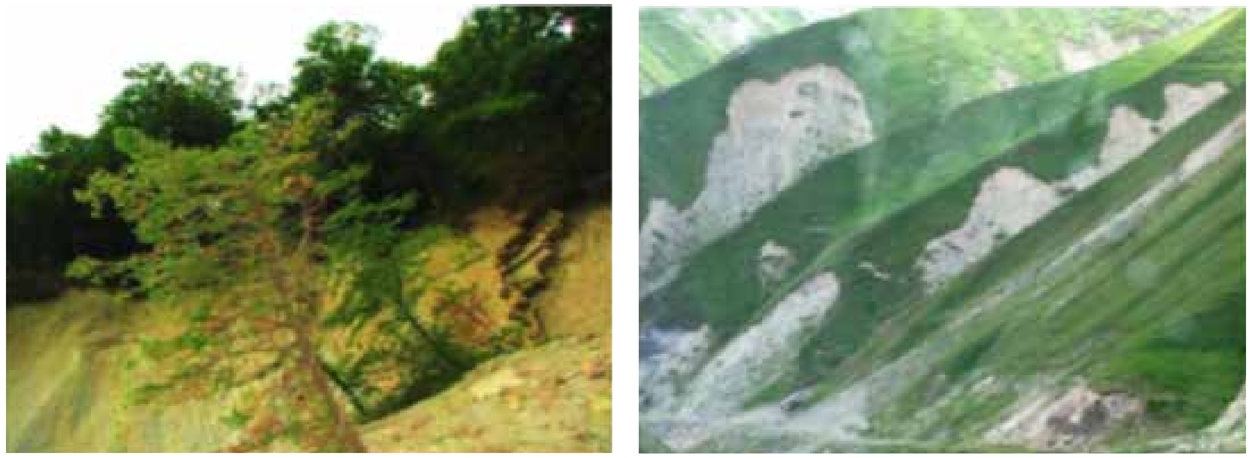


Figure 17. A – Soil erosion in forest area with relict species *Taxus baccata*; B – Soil erosion in degraded forest area in subalpine zone. Photo by Maia Akhalkatsi.

Rill erosion is substantially more erosive than overland flow and is a function of hill slope length, depth of flow, shear stress, and critical discharge. Rill erosion starts when the eroding force of the flow exceeds the ability of the soil particles to resist detachment. Flow depth and velocity increase substantially where surface irregularities concentrate overland flows into rills. Once rills are established, the concentrated flow develops more detachment force, and the rill formation process is enhanced. Rill development moves upslope as head cuts. Some rills develop rapidly and become more deeply incised. These master rills become longer and deeper than their neighbours. Occasionally flows from adjacent rills break into master rills by eroding the boundary between them. As the rill flow becomes concentrated toward master rills, previously parallel rills develop a recognisable dendritic drainage pattern. Flow concentrations and velocity increase until the more deeply incised rills become gullies.

Wind erosion is greatest on fine soil particles such as silt, clay, and organic materials. This wind-driven sorting increases the proportion of coarse materials in wind-eroded sites. Wind-blown particles are moved in three ways: (1) saltation, the bouncing of particles across the surface; (2) suspension in wind; and (3) surface creep, the movement of larger particles caused by the pushing action of saltating particles striking larger particles **(Toy et al., 2002).** The amount of wind erosion is affected by soil erodibility, surface roughness, climate, unsheltered distance of soil exposed to wind, and vegetation cover. Thus, wind erosion is reduced by rougher soil surfaces, lower wind speed at the soil surface, and more plant or litter coverage of the soil surface.

Mass movement is the downward movement of slope-forming materials without the primary assistance of a fluid. It occurs on steep slopes under the influence of gravity, often exacerbated by the weight of water in the soils. Mass movement occurs on steep slopes when deforestation, mining, fire, overgrazing, construction, or cultivation disrupts the landform-climate-vegetation equilibrium by removing the vegetation.

Well-vegetated slopes generally move downward much slower than less vegetated slopes **(Morgan, Rickson, 1995).** Plants, especially woody plants with strong, deep roots, greatly increase soil strength, providing a stabilising effect on the slope. In some cases, the plants also transpire significant quantities of water from the slope, thus reducing the weight that contributes to mass movements.

Increasing the cover of vegetation or litter, preferably both, is the most effective strategy for reducing erosion. Plants protect the soil with their canopy, add litter to the soil surface, and stabilise the soil with their roots. Litter on the soil surface reduces erosion. Soil erosion from water or wind, is reduced with strategies that accomplish the following:

1. Maintain or establish a cover of vegetation, especially when erosion is most probable. Although perennial plants are most desirable, annual plants may provide critical, short-term seasonal protection;

2. Create a ground cover of litter, rocks, woody debris, erosion matting, or other materials until vegetation becomes established;

3. Increase soil surface roughness with aboveground structures or soil surface manipulations (such as pits or furrows) that are perpendicular to water or wind flows. This increases infiltration, reduces water velocity, and increases the wind speed necessary to initiate saltation;

4. Reduce fetch length of unobstructed slope surfaces. This reduces the ability of water or wind to detach and transport soil particles and minimises opportunities for overland flows to coalesce and form larger rills and gullies; and

5. Incorporate biomass into the soil where possible. Like the previous strategies, it increases the rate and capacity of infiltration, thus reducing the amount of water available for erosion. Biomass incorporation also stimulates plant growth and soil biotic development that improve soil structure and nutrient cycling.

Each of the previous strategies provides some protection against mass movement. Two additional strategies provide specific protection for slopes susceptible to mass movement:

1. Steep slopes susceptible to mass movement are most effectively stabilised with trees and shrubs that have strong woody root systems. Significant taproot development below the slip surface greatly increases slope shear strength, which has a strong slope-stabilising influence.

2. High transpiration rates reduce susceptibility to mass failure by reducing the amount of water in the soil. Water increases the slope shear stress that causes mass movement of a slope. Transpiration increases as the leaf area of a particular species becomes higher.

Thus, transpiration losses of new plantings are often increased with higher planting densities or larger trees. It is also important to select species that transpire during the highest water season when mass movement is most probable.

The most effective tools for reducing erosion are governmental policies and land management practices that maintain healthy vegetation and a cover of duff, litter, or woody debris.

Though conceptually simple, this protects the soil from raindrop impact, increases infiltration, reduces runoff, reduces saltation, and significantly reduces soil erosion. Once the area has been cleared, re-establishing a ground cover prior to the next erosion season is essential.

Poor grazing management probably contributes to more land degradation than any other practice, even in forested environments. Grazing practices that allow plants to periodically grow and reproduce will stabilise soil resources more effectively. Recently planted may require protection from grazing animals for several years.

Fuel wood, timber, or any other type of wood harvesting must be scheduled and spatially arranged to maintain good soil coverage of plants and litter. Uneven aged and mixed species' forests are more easily harvested in small areas, which reduce the size of disturbed areas that can contribute to soil loss.

Harvesting methods that reduce the presence of skid trails will reduce the concentration of water flows that increase erosion problems. Practices that leave more leaves, duff, and woody debris on the surface will reduce erosion hazards

Ultimately, perennial plants are the most effective and practical means of protecting the soil. However, it is often necessary to provide a "window of opportunity" during which plants can be established. Soil protection is essential and may be obtained with the use of locally available organic materials. Organic materials can be incorporated into the soil or placed on the surface to reduce erosion, increase infiltration, and moderate temperature extremes.

Examples of organic materials include woody debris following wildfire, animal waste, fibre and other readily available materials that can be used to protect the soil surface. Gravel or rocks may also be used as aboveground obstructions or to protect the soil surface.

Features that roughen the soil surface have the potential to reduce wind and water erosion while increasing soil water available for plant growth. Pits, microcatchments, furrows, or cultivation may be used in appropriate circumstances to roughen the soil surface. Rocks, gravel, terraces, soil bunds, or plant materials are potential aboveground obstructions where available. These surface changes contribute to additional plant growth that establish positive feedback improvement systems that continue to increase infiltration, water storage, and nutrient cycling.

Government policies may increase soil erosion from forests or they can be crafted to encourage the restoration and management of forest landscapes that provide important goods and ecological services without accelerating soil loss. Policies that prevent the complete removal of trees on the steepest slopes have the greatest impact on soil loss.

Forest restoration programmes are usually planned based on the attributes and objectives of specific fields, ownership units, or forest openings. This approach effectively assumes that the sites are functionally isolated from other parts of the landscape or watershed.

This can lead to problems since each part of a landscape is continuously gaining and losing water, nutrients, soil, organic materials, and seed. Organic materials, landform, or microtopographic features control these movements of water, nutrients, and organic materials. A greater recognition and understanding of these resource fluxes can be used to great advantage in forest landscape restoration.

4.3. Forest Restoration after Fires

The fire situation needs to be analysed as well as possible with available data to support decisions about restoration. Identifying and engaging with those who light fires, have fire responsibilities, or are impacted by fires is critical. Protecting the restoration site from fire until species being used can withstand fire, if it is a natural disturbance, is essential. The need to restore a landscape for its conservation objectives after fire has impacted may appear to be clear and is often obvious. While it is difficult to compile precise figures, during the Russo-Georgian War in 2008, for example, the forest in the protected area of the Lesser Caucasus Trialeti range was set on fire. In fire-sensitive ecosystems, fire causes severe damage (**Fig. 18**). Throughout history, there have been large fires that have damaged human assets and impinged on human perceptions. Some of these events have framed human response to fire. Fire is a prominent disturbance factor in most vegetation zones throughout the world, the most ubiquitous after human urban and agricultural activities **(Bond, van Wilgen, 1996).**

Figure 18. Forest in the protected area of the Lesser Caucasus Trialeti range set on fire during the war with Russia in 2008. Photo by Maia Akhalkatsi.

In many ecosystems, fire is a natural, essential, and ecologically significant force, organising physical and biological attributes, shaping landscape diversity, and influencing the global carbon cycle. Fire has been part of the landscape since Mesozoic times. Forest fires occur because of either anthropological or natural causes. Lightning is the most common natural cause of fire. The majority of fires around the globe are caused by human activity. The extent and timing of fires differs between natural ignitions and fires by people, those by people generally being smaller.

One widely known example, tropical rainforest ecosystems, are characterised by high levels of humidity and moisture, they do not normally burn and are extremely prone to severe fire damage when they do. Damage from fire can be long lasting on a tropical forest ecosystem.

Just as too much fire can cause problems, so can too little. Many fires in boreal forests are caused naturally by lightning. However, some countries, such as the United States, have had a policy of suppressing most fires that threaten to grow out of control. Under these circumstances, fire suppression can lead to unnatural conditions in which forests, which have historically experienced small intermittent fires, no longer burn. Fire suppression can lead to a build-up of dead biomass, and altered tree species' composition.

Fire has played, and will continue to play, a major role in shaping ecosystems throughout the world. Fires can produce local extinctions of species, alter species' composition and successional stages, and bring about substantial changes in ecosystem functioning (including soils and hydrology). In almost all forest ecosystems throughout the world, humans have altered the natural fire regimes by changing the frequency and intensity of fires. People have excluded or suppressed fires and changed the nature of the landscape so that a naturally occurring fire will not behave in the same way it would have done in the absence of human impact. The interrelationship between humans, fire, and forests is a complex one and has been the subject of many studies and reports. In some ecosystems, however, fire is an uncommon or even unnatural process that severely damages vegetation and can lead to long-term degradation. Such fire-sensitive ecosystems, particularly in the tropics, are becoming increasingly vulnerable to fire due to growing population, economic, and land-use pressures.

The cycle of fire impact hinges around these regime characteristics. The impact of a fire will be positive or negative depending on the degree to which the fire conforms to a regime that the landscape can accommodate. Wrong season, too small or too large, too high or too low an intensity, and too often or not often enough and the cycle may become out of balance leading to negative impacts. If the cycle remains too far out of balance with the landscape, then fire may lead to a long-term alteration to the ecosystem.

These characteristics of fire can create significant impacts if they hinder the ecosystem's capacity to absorb and harness their influence. So fire may not be intrinsically positive or negative but always has the potential to have a profound impact with potentially long-term effects. Fire is of specific concern where a particular landscape represents a significant or unique ecosystem of global importance. Under such circumstances, it becomes even more important to evaluate and manage the role of fire to sustain those values. Changes in the fire regime that fall outside the capacity of the landscape to contain them will possibly influence a cycle of impact that, depending on perspective, will be considered either negative or positive.

Fires are part of the natural disturbances to which forests are adapted. To restore forests that were devastated by fires there are large-scale, very intense, and frequent human-induced fires:

1. Geographical information system (GIS) assessment of soil degradation and hydrologic erosion risk of the different landscape components;
2. The GIS assessment of the fire incidence in the forest cover and mycorrhizal soil component in the mosaic of habitat types within the forest landscape;
3. Analysis of the socioeconomic impact, including forecasts in productivity loss and risk of abandonment of forest uses and rural exodus;
4. Planning the different technical options to be adopted within the landscape for preventing degradation and activating the natural recovery of burned areas, including burned vegetation management techniques; it is preferable not to remove burned vegetation from the forest area, as it provides protection to soil and to the natural regeneration;
5. Active restoration in landscape areas with risk of soil erosion and little or no natural regeneration in the first years. As much as possible, it would be preferable to promote planting by combining root-sprouting species;

6. Management of sprouting trees, mainly oak species, through cutting operations to accelerate the establishment of healthy coppice woodlands;
7. Clearance of fire-prone monospecific shrublands, for example, rocky rose shrubs and plantation of scattered trees and shrubs, as well as pasture patches to increase plant diversity, accelerate succession, and reduce the risk of fires;
8. Non-intervention in areas with low fire impact where the natural regeneration has a good after-fire response;
9. Reducing the risk of fires recurring in the forest landscape;
10. Creation of natural firebreaks within the forest landscape, especially in areas where forest management options have simplified the landscape structure;
11. Restoring riparian forest vegetation in ravines and river networks;
12. Redesigning tree plantations where timber/pulp commercial tree stands should be alternated with silvipastoral woodland stands—dominated by oak, ash, chestnuts, juniper, stone pine, etc.;
13. Restoring the economic and social potential of the burned forest landscape;
14. Activities should be participatory in order to understand and restore the economic and social values of burned forest landscapes; and
15. Restoration should be designed and planned to reduce large-scale fire risk and may imply the need for funding schemes, such as governmental subsidies or environmental services payments, to support the establishment of natural and economically beneficial firebreaks, and to diversify the existing land-use options in private and public land.

Adverse impacts of restoration after fires are most likely to result from the use of inappropriate (exotic) species, physical restoration efforts that change or impact soils or drainage features, or replanting that alters the preferred mix of local species.

The major input required for framing restoration after fires is strong insight into the fires themselves. Collectively, fire-related data, identification of the fire regime, and clarity about cause (ignition, source of fire, motivation for fire) provide a solid foundation for dealing with the fires and then restoring the landscape if it proves possible and desirable. For developing nations, fire is often perceived as part of that development. Consequently, analysis of livelihood requirements and sectoral use of fire in economic development is needed.

There is increasing recognition of the often-strong capacity communities have in fire management. Their reasons, skills, and understanding can be highly developed and should be harnessed. The community/local understanding of fire and its role as well as techniques for using fire should be the basis for improving fire management.

4.4. Invasive Alien Species Risk in Forests Restoration

Introduced species that become invasive can become a major concern as they can cause significant ecological and economical damage. Restoration may often equate to the removal of these species. On the other hand, in some cases, attempts to restore using inappropriate species has itself led to the problem of invasive alien species (IAS). Restoration may often equate to the removal of these species. Prevention and best practices for alien species are amongst the most important tools to contain the problem. Because the problem is transboundary, it is necessary to create common protocols and to enhance the capacity to deal with invasive alien species.

Globalisation has encouraged the free movement of goods but also of plants. On the one hand, plants are available from virtually anywhere in the world for various uses, but on the other hand, species that are moved by people from one part of the world to another can expand beyond the area where they were planted, and end up causing substantial damage to natural ecosystems. Further, global trade, transport and tourism also provides new opportunities for unintentional introduction of species, for example by introducing a non-native species of beetle that can devastate plants being used to restore a forest.

Perhaps as many as 10 present of the world's 400,000 vascular plants, have the potential to invade other ecosystems and harm native biota in a direct or indirect way. Invasive species can transform the structure and species' composition of ecosystems by repressing or excluding native species, either directly by outcompeting them for resources or indirectly by changing the way nutrients are cycled through the system.

Invasive alien species have many negative impacts on human economic interests. Weeds reduce crop yields, increase control costs, and decrease water supply by degrading water catchment areas and freshwater ecosystems. Pests and pathogens of crops, livestock, and trees destroy plants outright, or reduce yields and increase pest control costs. Removal of IAS often forms an important component of efforts to restore forest quality to existing forests. The degraded oak-hornbeam forest near calcareous quarry in Dedoplistskaro district was restored by invasive tree species ***Ailanthus altissima*** (**Fig. 19**), which is distributed in many degraded areas. However, these may in turn cause serious damage to the natural landscape unless properly supervised and managed.

In addition, some stakeholders may not wish for an invasive species to be removed, for example, if the species in question provides economic benefits. In such cases, it will be necessary to negotiate trade-offs and see how best to contain the species and ensure that its proliferation can be controlled. Preventing damage requires predicting which species can cause harm and preventing their introduction, and dealing effectively with the cases in which a species is already causing problems. It is not always simple to distinguish an alien species from an invasive one; taxa that are useful in one part of a landscape may invade other parts of the landscape where their presence is undesirable. The first line of defence is to avoid introducing non-native species in the first place, so forest restoration should use native species to the

Figure 19. Invasive tree – *Ailanthus altissima*, distributed in degraded oak-hornbeam forest area. Photo by Maia Akhalkatsi.

maximum extent possible.

That said, it may well happen that a non-native species has characteristics that are especially valued by the local people, for example producing valuable fruit, nuts, or gums. In such a case, special efforts are required to ensure that the species does not become invasive. Great care is required to ensure that such species serve the economic purposes for which they were introduced, and do not escapes to cause unanticipated negative impacts on native ecosystems and their biodiversity. One management option would be to plant only sterile forms, so reproduction and spread would be impossible. An even better option, especially when seeking to restore habitats, is to use only native species.

4.5. Restoration as a Strategy to Ecoregion Visions

More extreme weather events have characterized the weather in the South Caucasus in the last ten years, which have led to flooding, landslides, forest fires and coastal erosion with significant economic losses and human casualties as a result. An increasing number of governmental and nongovernmental conservation institutions have recognised that in order to achieve lasting conservation impacts it is necessary to work on a larger scale than has been the case in the past. Although there are a number of ways of defining useful ecological units for planning conservation, the concept of the ***ecoregion*** is increasingly being adopted, including by WWF, the global conservation organisation.

In any case, the competition for land among a range of interests and stakeholders necessitates that all forest conservation activities, including forest restoration, be strategic and for a specific purpose(s), be it conservation or otherwise. This strategic focus should ideally be identified through a participatory process that leads to a long-term "vision" for the desired future state of the area. Increasing the quality and quantity of forest cover is an important general goal for conservation, both for ecosystem services (watershed protection, climate regulation, etc.) and for the needs of those species that depend on forests. However, due to the intense competition for land between the forces of development and conservation, efficiency in how and where forest restoration occurs is critical. In other words, while increased tree cover will nearly always be beneficial from a conservation perspective, if possible, restoration efforts should be focused in such a way that multiple conservation and social goals are reached

Figure 20. Relict tree species – *Pterocarya fraxinifolia* of the Caucasus ecoregion refuge forests. Photo by Maia Akhalkatsi.

Conservation of forests in mainly associated with relict species, which are remnants of old periods without glaciation and occur in the West Caucasus region, while Colchic forest is a real refuge of the Caucasus ecoregion. Many relict species remain in this forest nowadays. One interesting relict species *Pterocarya fraxinifolia* is distributed in riparian forests both in the Western and Eastern Georgia (**Fig. 20**).

The goals of biodiversity conservation and ecoregion conservation are as follows:

1. Representation of all distinct natural communities within conservation landscapes and protected areas' networks;

2. Maintenance of ecological and evolutionary processes that create and sustain biodiversity;

3. Maintenance of viable populations of species;

4. Conservation of blocks of natural habitat large enough to be resilient to large-scale disturbances and long-term changes.

More than likely, any comprehensive conservation strategy in an ecoregion will involve a combination of protection, management, and restoration, plus the abatement/amelioration of threats. The relative proportion of each strategy that is appropriate is a function of both the overall conservation status of the ecoregion, and the location in the ecoregion—and this will change over time. For example, restoration is not necessarily an appropriate strategy in all ecoregions or landscapes. One can imagine that restoration may not currently be the highest priority in those ecoregions that are composed mostly of wilderness or large forest blocks, such as in the Amazon. A primary output of many ecoregional visions is a map of priority areas, where conservation activities are more focussed than in the surrounding matrix of the ecoregion. Yet even in the matrix, some proportion of protection, management, and restoration activities will be appropriate, and in the case of the wilderness ecoregions mentioned above, over the long-term, restoration may rise in priority in those ecoregions as more comprehensive protection and better management are instituted.

From a conservation standpoint, the decisions about how much protection, management, and restoration will be a natural consequence of attempting to achieve the above four conservation goals in a strategic fashion in an ecoregion or a landscape within that ecoregion. Is there enough of a given target habitat present in the ecoregion or landscape to meet representation objectives that we can simply protect a (greater) proportion of it? Or will some areas containing that habitat need active or passive restoration in order to meet the prescribed target for that habitat? Can existing multiuse buffer zones of forest simply be managed in their current state to provide landscape connectivity, or will some areas need to be rehabilitated to restore connectivity?

Forest "restoration" activities range from active planting, to management (e.g., invasive species' removal), to more passive restoration (creating the conditions that will allow natural processes to regenerate high-quality forest). Because active restoration is so resource intensive, it should generally be the last option selected to meet a conservation objective. The key point is that from a conservation perspective restoration activities should not be undertaken for the sake of restoration; rather, the activity should be a strategic response to a specific need identified during the formation of conservation goals. The Forests of the Lower Mekong ecoregion has endeavoured to find the right balance of protection, management, and restoration—all stemming from the conservation goals highlighted during the ecoregional vision process.

Conceptually, it is a relatively simple matter to decide whether restoration is necessary or not. By selecting conservation targets that are applicable to the aforementioned four goals of conservation, it should quickly become clear whether or not the relevant ecoregion or priority landscape still contains the necessary components to satisfy all four goals. If there are elements missing or the ecoregion/landscape is too fragmented, some restoration is probably necessary. At the basic level of the four conservation goals, the following discussion illustrates how the need for restoration can be identified.

Conservationists need to represent all natural communities in some sort of a conservation network, which is generally a mix of different levels of protection. It is important that the mix of natural communities is one that has existed before a major disturbance rather than the existing mix. However, all of these original communities may no longer be present in the quantity and quality necessary, and that is where the potential application of restoration comes in. This is especially true during periods of climate change when species will need to move in response to changing conditions.

One of the first steps in any conservation planning initiative is to obtain or develop a map of historic (sometimes called "potential") natural community types across the entire ecoregion priority landscape. A number of coverage's may suffice for this purpose, including historic vegetation maps, potential vegetation maps, or maps of plant communities or ecosystems. In the case where land conversion has made this task impossible, maps of environmental domains, which are unique combinations of substrate (soils or geology), elevation, and climate classifications, may be developed. If these environmental domains are carefully developed, they should represent unique environmental classes that correlate with the species living in them.

It should also be noted that each natural community is itself made up of seral stages, and the appropriate mix of seral stages, or more likely the allowable ranges of seral stages, corresponding to a natural range of variation, must be specified. The ability of a natural community type to support a natural range of seral stages must be protected, or if necessary enhanced, and this may also require some forest restoration activities. An example is the relative lack of primary, or old-growth forest, in many temperate forest ecoregions compared to historic levels. Efforts to increase the proportion of late seral stages are an appropriate application of forest restoration in this case. Many ecoregional programmes, especially those in developed or densely populated countries, have found that the amount of lowland and riparian communities are in short supply— they have already been converted for human uses. Clearly, in such situations, restoration will necessarily be an important component of the overall conservation strategy if representation targets are to be met.

The idea behind this goal is that all species should have conserved viable populations, but in practice, it is never possible to plan for all species (if for no other reason than that all species are never really identified). During any large-scale conservation initiative, therefore, focal species are selected for special attention. Focal species are chosen because they are "keystone," highly threatened endemics, habitat specialists, or because they are very "area sensitive" and

act as umbrellas for a number of species with smaller area requirements. The number of focal species chosen will vary from ecoregion to ecoregion, and certainly from priority landscape to priority landscape, but is generally a manageable number of five to 20 species from the above categories.

After determining what the list of focal species is, the next step is to determine the number of breeding individuals that represent a viable population, or potentially a viable subpopulation in the case of a priority landscape. This is not a trivial determination, and there is an extensive literature discussing rules of thumb for the number of breeding individuals that constitutes a viable population—with little consensus. In some cases, a species-specific and resource-intensive population viability analysis will be necessary. If a viable population estimate is difficult to come by or there are severe limits to the number of individuals that are possible, the bottom line is that a target level should be chosen that represents the largest conceivable achievable population level. For restoration purposes, the specific needs of each focal species must be analysed individually.

The many evolutionary and ecological processes that create and sustain biodiversity are complex, and often poorly understood. Gene flow, migration, pollination, seed dispersal, predator-prey dynamics, and nutrient cycling are some of the many that should be considered when a conservation plan is developed. All of these processes can potentially benefit from restoration activities, because many species (and the processes that they are involved in) will respond positively to restored forest quality, but some of them will benefit more obviously than others. Gene flow and migration can directly benefit from restored forest corridors, as in the above examples. Likewise, if key processes such as pollination or seed dispersal are threatened by insufficient forest area to support the species that are performing these functions, restoration activities would be appropriate.

Ecological systems are by their very nature dynamic, and it is important to incorporate large habitat areas and sufficient connectivity between habitat areas in order to build resiliency into the protected area network. Increased connectivity is the main option available to conservation planners trying to anticipate the effects of anthropogenic climate change. Species' ranges are already beginning to shift in latitude and altitude; this is true not only for animals but for plant species as well. Again, reconnecting now disjunct habitat patches through restored forest corridors is an appropriate application for forest restoration activities to help migration to keep pace with changing conditions. In addition, managing the landscape in such a way that it provides more flexibility for species and gene flow in times of stress is an important element of restoration.

This connectivity strategy will be important for every ecoregion across the planet to consider. Ecoregions likely to be faced with this threat in the near term are tropical montane ecoregions that contain significant topographic relief. Climatological changes are concentrated in narrow bands, and maintaining altitudinal connectivity will be critical for allowing habitats to shift in response to changing temperature and moisture regimes.

Restoration activities are important for all ecoregions where human activities have fragmented the ecoregion, and this includes most ecoregions. Rising temperatures and changing precipitation patterns will cause natural communities to shift latitudinally and altitudinally. Without restoration to reconnect fragmented habitat patches with corridors, natural communities will have great difficulty shifting across human-dominated landscapes.

In the preceding discussion, the need for restoration fell into two broad categories: increasing the area of a particular forest type for representation or for particular species/ processes, and restoring particular landscape features, especially corridors, which allow specific ecological processes to operate. Sometimes there are choices of where restoration is most appropriate. All other things being equal, it is generally easier to restore the less degraded example of a forest type, since less effort or time will be required. All other things are rarely equal, however. How does one decide which semi-irreplaceable example of a forest type to restore if there are several choices?

The use of a geographic information system (GIS) is practically mandatory when considering spatial planning for conservation. The GIS allows spatial maps to display conservation options, and more powerfully, allows the user to combine biological and socioeconomic information to analyse ways of meeting conservation goals at the least socioeconomic "cost". Additional tools that work alongside and with a GIS are decision support software tools, which allow numerous competing variables to be combined. Depending on the particular tool used, a single best conservation configuration may be generated or a range of choices can be portrayed. In some of these tools, once a decision is made regarding a particular portion of the landscape, the entire study area can be recalculated to portray the next best options.

Further development is needed for tools to prioritise restoration needs. Current decision support tools are able to identify remaining habitat for inclusion in protected area networks, and these tools can be used to work with maps of previously existing potential vegetation. However, further refinement of these tools and associated techniques to identify areas that could be restored to meet representation goals is needed.

5. Forest Restoration Programs

5.1. Framework for Forest Restoration Planning

While no two restoration experiences will follow the same pattern, indicative steps to planning a restoration initiative are important, particularly when dealing with large scales or landscapes. Success depends on wise planning, balancing short-term with long-term goals, and allocating the funding available for the restoration programme as efficiently as possible. Learning from past restoration programmes and their successes and failures is an important starting point to help plan better restoration actions in the future. There are few tools dealing with planning restoration in large scales. A five-step logical planning process is being proposed.

Restoration of natural systems is a difficult, energy-consuming, and expensive undertaking. It is almost always a long-term, complex, and trans disciplinary process. This is particularly true when dealing with highly degraded ecosystems and landscapes. Inevitably, conflicts of interest and other problems arise.

Ecologically speaking, the restoration of highly degraded forest usually requires initiating an embryonic ecosystem within a few years (usually less than 10 to 15 years after degradation), which will be only fully restored—very often after additional corrective or fine-tuning interventions—after a period of at least 50 years in the tropics, and of 100 years or more in the extratropical zones. However, forest policies and restoration programmes are generally financed only on a short- to medium-term basis. A 10- to 15-year project span, in most cases, is the longest possible perspective, both for political and financial reasons. Bearing this in mind, restorationists should (1) adapt short-term restoration goals and techniques to minimise the number of costly corrective actions; and (2) plan ahead to secure funds for carrying out monitoring and evaluation, corrective actions, or "aftercare" in the long term.

Also, forest restoration requires inputs and expertise from various academic and practitioner fields like ecology, silviculture, economics, public policy, and the social sciences, which need to be combined in an efficient way. Meanwhile, the relative lack of experience with broad-scale conservation means that filling the knowledge gaps through research programmes also takes time. 5 to 10 years is the minimum period needed to investigate critical plantation techniques for native species, etc. However, very little money is available to finance pure research programmes unless they can be linked to real implementation and visible successes in the field. Bearing this in mind, restorationists should define short-term goals and activities that get restoration underway, along with long-term goals for how it can be sustained over the time period required. A critical, pragmatic aim is to achieve at least some rapid field results, for example on carefully selected pilot sites, to build support for longer-term efforts.

Where restoration is to be carried out as part of a wider conservation effort, at the landscape or ecoregional levels, we would propose that it be planned as an embedded element within an integrated programme that also involves protection of whatever is left of untouched nature, and the promotion of good ecosystem management, as guided by the principles of stewardship sustainability, and sustained use. This approach includes identifying a series of conservation targets—in this context, what forest functions we wish to restore—and "reconciling" these with the needs, tastes, and expectations of other stakeholders, especially the indigenous populations.

An essential first step of any forest restoration programme is the identification of the problem being addressed and agreement on the solutions and the targets for restoration. Such targets should ideally contribute to wider ecological and socio-economic objectives at a landscape scale. Very often, restorationists must start from zero to raise awareness on the state of degradation in the landscape, analyse the root causes, and then convince other stakeholders of both the need for and the feasibility of forest restoration. Depending on the context (the existing level of awareness, politics, funds available, etc.), this step could last for several years and require extensive effort.

Experience suggests that restoration usually only works in the long term if it has support from a significant proportion of local stakeholders. Finding out the needs and opinions of stakeholders is therefore important: What forest functions do they want to restore and are there potential clashes of interest? It should be recognised that the restorationists (conservation NGO or other) are themselves stakeholders with a particular interest (i.e., restoring biodiversity), which may need to be reconciled with other stakeholders' priorities.

Outputs of this step are:

1. Recognition and common understanding of the degradation, root causes, and solutions;
2. Stakeholders' involvement and participation;
3. Partnership development for an efficient restoration programme (written key ideas of the programme and memorandum of understanding); and
4. Secured budget for the restoration programme for at least a first pluri-annual period (e.g., five years).

Here is a step that is not necessarily easy to "sell" to local stakeholders. The geographical scope can be much wider than many people are used to working with or even conceptualising (or want to work with, as it has some implications for development, too). Ideally, as mentioned above, a vision and strategy for restoration should be developed within an integrated "protect–manage–restore" approach, especially because the investment needed to restore has to be reinforced through synergy with management and protection activities.

Assessment is needed to determine how restoration targets might be achieved, including determining current or potential benefits from forests in the landscape (biodiversity, environmental services, and resources for subsistence or sale) and the potential for restoration through use of reference forests and other techniques. An important part of the process is deciding the realistic boundary of the area or areas that we wish to restore. Definition of key areas for protection, analysis of degradation, and the predictive anticipation of threats can all help to define priority landscapes where investment in restoration is most justified.

Outputs of this step are:

1. Definition of conservation targets at various pertinent scales (ecoregion, landscape);
2. Analysis of the broad consequences on the habitats of past degradation, active pressure, and potential threats;
3. Definition of the role of restoration along with identification of protection and management needs; and
4. Identification of the priority areas that require restoration and explanation of the reasons why: Which habitats, landscape units, or community functions do we need to restore? Which species do we need to eradicate, control, or reintroduce?

Considering ecological characteristics, but also socio-economical context or goals assigned to the restoration project, several trajectories, and restoration options could be developed for the same project. Choosing among these options requires careful study and data gathering. This will necessarily mean reconciling different points of view and opinions. Agreement can be a phased and continuing process; that is, it may be possible to agree to some specific and useful restoration interventions without reaching agreement about the whole future of the habitat. The way in which such agreements are reached will naturally depend on the political and social realities of particular countries or regions; the general principle that decisions should be as participatory as possible applies throughout.

Outputs of this step are:

1. Assessment of current/potential benefits from the landscape for people, and for biodiversity;
2. Assessment of the current, past, and reference habitats states;
3. Definition of what we can expect to restore;
4. Development of possible land-use scenarios in space (including maps);
5. Development of possible restoration trajectories to achieve short-term and long-term goals (including models, time frames, and maps);
6. Reconciliation of land-use options: how can we achieve specific goals while meeting or reconciling conflicting demands, tastes, and needs?;
7. Set of goals, strategies, and tactics for each zone and problem in the landscape;
8. Set of priorities in space and time;
9. Identification of restoration trajectories, technical options, steps, and phases, (especially remembering the monitoring and "finetuning" phases necessary to fully achieve long term restoration goals); and
10. A written restoration plan, strategy, and set of tactics, with identified time frames, maps, allocated funds, and quantified targets.

This step is the most visible part and usually the most costly. Some projects start for example, by directly investing all the available funds to plant trees on an emblematic or strategic site. However, this ignores the previous planning steps recommended above and can easily end up wasting time and resources in restoration activities that either do not work or are in suboptimal locations. It is of course judicious to start small-scale actions, such as one or more pilot sites, for the sake of "learning by doing," to demonstrate the feasibility of key restoration goals and to test silvicultural techniques (for example planting, but also natural regeneration). However, we would strongly recommend that larger scale activities also be undertaken in the context of careful planning and assessment.

Outputs of this step are:

1. Development of pilot sites;
2. Implementation of large-scale actions;
3. Lessons learned from first results, both successes and failures; and
4. Design and implementation of changes/ adaptation in the restoration programme.

In practice, a few years or decades after starting implementation, even if restoration has hitherto been successful, unexpected results of previous work or changing circumstances (evolution of the socioeconomic context, for example) could alter the most preferable restoration trajectory. This could even lead in some cases to redefining overall project goals. Such modifications should not be considered as a failure of the overall programme, but rather as a normal step in the restoration of a complex set of ecosystems within a larger landscape matrix. Thus, the restoration work is not "finished after planting." To sustain restoration success in the long run, and to anticipate potential problems, a simple monitoring and evaluation framework needs to be set up from the outset of the programme in order to facilitate adaptive management and corrective actions. Outputs of this step are:

1. Regular evaluation (social, economical, ecological);
2. Restoration trajectory reappraisal; and
3. Design and implementation of corrective actions.

Restoration planning in habitats or large scales is still in its infancy. Much further work is needed to refine and improve the planning process and define appropriate tools.

5.2. Monitoring and Forest Restoration Success

An effective monitoring and evaluation system is recognised as an essential part of a successful restoration project, allowing measurement of progress and more importantly helping to identify corrective actions and modifications that will inevitably be needed in such a long-term process. We propose that in addition to measuring obvious indicators such as area of forest, such monitoring and evaluation systems will usually need to cover issues relating to naturalness of the forest being created at a landscape scale (not necessarily at an individual site), environmental benefits, and livelihood issues.

Worldwide, monitoring and evaluation have become in the past decade a major issue with strong repercussions in national forest policies both for conservation (e.g., efficiency of protected areas, status of endangered species) and management (e.g., sustainability standards, impact assessment, ecocertification, and market driven demand). At various scales (from local to international), issues like the design of the best framework for evaluation and monitoring, the choice of an efficient—but not too expensive—set of criteria and indicators, has led to intense debates between major stakeholders in forest management, including nongovernmental organisations (NGOs).

A Forest restoration is almost always a long-term, complex, and multidisciplinary process. On the one hand, forest restoration requires recreating within a few years (usually less than 10 to 15 years) an embryo ecosystem that will only be fully developed after several decades. On the other hand, forest restoration requires inputs and expertise from fields like ecology, economics, public policy, and social sciences, further complicating monitoring and assessment. For a long time, some forest restoration issues have been the subject of considerable raised tensions and interest, especially, for instance, when comparing the economic benefits of some large afforestation programmes, with their ecological and social disadvantages. How can we be sure that the choices made when starting restoration projects will succeed in reaching the defined goals in the long run? Forest restoration successes are seldom complete or easy to evaluate, and the type of global indicators used by foresters (such as planted trees' height or diameter growth, or plantation cover) give very little information to help assessment in the modern sense of restoration in large-scale conservation.

Thus, monitoring and periodic evaluation of advances in the restoration process is not an optional extra, but a critical and essential part of restoration, that restorationists need to consider mainly in order to do the following:

1. Confirm the hypotheses used to develop the restoration programme and ensure that defined goals are reached and the time frame respected. For example, from an ecological perspective, it is important to restore damaged components of forest ecosystems and reintegrate them within the landscape;
2. Proceed to fine-tuning management actions that correct problems encountered during restoration (e.g., lower or higher survival of seedlings than expected) or incorrect choices;

3. Adapt restoration actions to changes along a restoration trajectory, which will inevitably last several decades, especially with respect to aspects that go far beyond what those initiating the project could forecast (e.g., social issues such as demand for land, awareness of environmental issues; economic issues such as wood prices or demand for nontimber forest products (NTFPs); and ecological issues such as climate change);
4. Prove to stakeholders that the investments (not only financial) in the restoration programme are worthwhile;
5. The needs for further development are important here. They include the following:
6. Improvement in methodologies for monitoring and evaluating human well-being in the context of restoration: Although lists of attributes, indicators, and methodologies exist in the literature, very few have been adapted to forest restoration. Adapting and field testing them will be necessary in the coming years;
7. A unified procedure for monitoring restoration programmes: Attempts to develop a common form and approach to monitoring and evaluating large-scale restoration efforts, such as the REACTION programme described above, are essential, although they pose considerable challenges. Development of these programmes are needed in other geographical regions, coupled with field tests and modifications; and
8. Economic tools to secure funds for assistance in long-term monitoring and fine-tuning: Sustainable financing remains a key problem to restore forest ecosystems in the longer term.

Designating a specific part of a state's forest service to be responsible for forest restoration, and subsequently integrating restoration into normal management procedures (through the management plan) could be part of the solution.

Finally, field testing and learning from years of experience are still essential to build up a database of knowledge.

5.3. Commercial Plantations in Forest Restoration

Plantations can represent an opportunity for the restoration of landscape functions, but they can also represent a threat to natural systems. A basic principle to be agreed to is that plantation forestry should provide multiple production and environmental functions. Considerable work has been done on more environmentally friendly approaches to tree establishment.

A rapidly increasing proportion of the world's wood is coming from plantations. Many of these are large-scale industrial plantations and they are often established on degraded lands.

Such plantations can represent an opportunity for the restoration of landscape functions but they can also represent a threat to natural systems. Tree planting has been seen as the solution to many environmental problems as witnessed by national tree planting campaigns, programmes to re-green deserts, etc. Elsewhere environmental groups campaign against all plantation forestry on the grounds that it replaces native vegetation and often intrudes on land used by local people. Plantations are often viewed as sterile monocultures with little biodiversity or other environmental value yet many studies have shown that even intensively managed industrial plantations often support surprisingly high biodiversity values. In addition, industrial plantations can form parts of landscape mosaics in ways that help to provide a mix of production and environmental functions.

There is now more interest in the landscape ecology of plantation forestry. Significant recent experience comes from Western Europe and the Mediterranean, and the books on landscape ecology listed in the references begin to describe these experiences.

Much still has to be learned about how emerging understanding of landscape ecology can be used as a tool for forest landscape restoration. This is one of the challenges of conservation for the coming decades.

A new challenge is emerging that will play a major role in the future of plantations and landscapes. This is the prospect of significant funding for afforestation in attempts to sequester carbon. These forest plantations will be acceptable to the conservation community only if they provide multiple environmental benefits. This means that forests established to sequester carbon will have to provide landscape and biodiversity benefits as well. They will have to contribute to forest landscape restoration.

5.4. Best Practices for Industrial Plantations

Forest plantations have been a major threat to forests and forest biodiversity because of poor management practices and little or no planning for their location within landscapes.

Well-managed and appropriately located plantations, however, can sometimes play an important role in healthy, diverse, and multifunctional forest landscapes. There is an urgent need for capacity building with respect to good social and environmental management for plantations.

The area of forest plantation in the world has increased by 17 percent in the last decade, half from the conversion of natural forests to plantations, and half from afforestation or reforestation on previously non-forested or deforested lands. Timber plantations often impose significant environmental and social costs, particularly when they are established through the conversion of natural forests, as has often been the case, for example, in Indonesia and Chile. Indiscriminate forest clearing, uncontrolled burning, and disregard for the rights and interests of local communities have often been associated with plantation establishment

Unless there are significant changes in policies and practices, in many regions the expansion of plantations will continue to threaten forests of high conservation value, freshwater ecosystems, forest-dependent peoples, and habitats of endangered species.

However, well-managed and appropriately located plantations can play an important role in healthy, diverse and multifunctional forest habitats, for instance, by providing a sustainable source of timber and freeing up other areas to be set aside as reserves. The plantation industry can also, if properly managed, generate valuable foreign exchange earnings and employment opportunities for producer countries.

The principles of forest landscape restoration recognise that plantations can play a role in a sustainable forest landscape, if they are well managed and have the support of local communities and are well-sited within the landscape (e.g., not in areas of high or potentially high biodiversity). Key elements of sustainability within the plantation forest industry are the following:

1. Maintenance of high conservation value forests: plantations should not replace high conservation value forests. This will normally require well-informed negotiations among a wide range of stakeholders to integrate plantations with the mosaic of other land uses;
2. Multifunctional forest landscapes: plantations should enhance environmental values by providing corridors between, and buffer zones around, natural forest areas and should enhance social values by providing benefits to local communities;
3. Sound environmental management practices: the industry should adopt management practices that minimise environmental impacts such as air and water pollution, forest fires, soil erosion, pest invasion, and biodiversity loss;
4. Respect for rights of local communities and indigenous peoples: the industry should recognise legal and customary rights of local and indigenous communities to own, use, and manage their lands, territories, and resources. • Positive social impacts: the industry should maintain or enhance the social and economic well-being of plantation workers and communities; and
5. Proficient regulatory frameworks: regulatory frameworks should encourage best practices.

At a minimum, the industry should respect all national laws. Responsible behaviour will often require performance standards exceeding local and national laws, especially where regulatory frameworks are underdeveloped or governance is weak.

Transparency: the industry should adopt and make public, policies, practices, and implementation plans pertaining to their social and environmental performance. They should encourage independent, publicly available performance monitoring, involving local stakeholders in both development of standards and performance monitoring.

Assuring that plantations play a positive rather than a negative role depends on two factors:

locating plantations in places where they do not destroy valuable natural habitat or undermine people's livelihood options, and managing them in ways that minimise detrimental impacts.

Many plantations are badly planned. Baseline surveys and consultation with local communities can help to reduce problems. A number of tools exist:

1. Initial cost-benefit analysis: draws on desk studies, remote sensing, and initial site surveys to determine whether further investment is justifiable, and covers government policies and regulations; tenure; social issues relating to local communities; geography (soil, climate, topography); existing land use; nearby protected areas; existing and planned infrastructure (roads, rivers, etc.); options for plantation species; and economics;
2. Feasibility study: provides the information needed to make the decision about whether or not to go ahead with the project, covering topography; vegetation/land cover; ecology and biodiversity; soils; hydrology of major watercourses and ground water sources; land use and land rights; socioeconomics; interest in investment projects; field trials of possible plantation species if necessary; and economics; and
3. Principles for plantation establishment: several existing principles provide the basis for site location and should include minimising impact on important natural habitats and minimising detrimental impacts on local human communities.

Once a suitable site has been identified, care needs to be taken to minimise the environmental and social costs of the plantation, with particular emphasis on groundwater contamination, soil erosion, and fire disturbance.

Several codes of practice and detailed guidelines exist and it is possible to apply for a credible third-party certification scheme.

There is an urgent need for capacity building with respect to good social and environmental management for plantations, which needs to go beyond the minority of companies that embrace best practice through certification and include pressure on all companies, including through the marketplace, to meet minimum best practice standards. From a technical perspective, better guidelines for site selection are required, as are tools to help plan the retention of natural vegetation within plantations.

Such national strategies and plans can also encourage collaboration between different scientific disciplines and approaches that can seek new options to deal with invasive alien species (IAS) problems.

5.5. Maintenance of Forest Restoration

Global interest in forest restoration was partly triggered by environmental concerns about plantation forestry. Rural people complained that the exotic species planted did not provide fodder for their animals or supplies of the non-timber products that they needed for their daily subsistence. Tree-hugging campaigns were launched to prevent the clearing of natural forests by the plantation agencies.

In many forest commercial plantations will have a potential role in restoration. Much will depend on where in the forest they are located and how they are managed. Plantations do not always have to be of a single species. It is not always necessary to keep the land under the trees bare; weeds and spontaneously colonizing local trees can be encouraged.

Mixed local species can be planted along watercourses or around the periphery of the plantation to soften the visual impact of the plantation and provide habitat for wildlife. Plantations can be used to provide corridors between patches of natural woodlands. Plantations can provide many products and thereby reduce the pressure on natural forests. Plantations can sometimes be used as nurse crops to help improve the soil and create conditions so that native species can become established.

Plantations are often established using industrial techniques that tend to result in uniform stands that are relatively low in biodiversity and other environmental and social values. Nevertheless, considerable work has been done on more environmentally friendly approaches to tree establishment. In any use of commercial plantations to contribute to landscape restoration objectives, it is essential to ensure that the plantations are managed to the highest possible standards. The key to harnessing the potential beneficial roles of plantations will be to develop a vision of what the ideal configuration of the landscape would look like. This vision needs to be based on an understanding of the uses that all stakeholders will make of the landscape. Public participation in the process of developing this vision is important. Commercial plantation companies must be brought into this process as early as possible and be convinced that the commercial viability of their enterprises will be enhanced through developing their plantations in an environmentally sustainable way. Arguments for this might include the avoidance of local opposition or even sabotage of the plantations, the possibility of achieving green certification and thus better market access, and the general advantages that come with being seen as good corporate citizens. The basic principle needs to be agreed on— that plantation forestry can and should provide multiple production and environmental functions. This multifunctionality can be achieved through diversification within the plantation or by the development of landscape mosaics that are designed in such a way that production and environmental functions are spatially distributed so that the "whole is greater than the sum of the parts." Achieving optimal landscape mosaics is often difficult because it requires coordinated land allocation by different land managers and owners. Formal spatial planning can often achieve this, but informal negotiations amongst local landowners can also be effective. Some large plantation operators control enough land to establish mosaics within a single landholding.

A number of science deals with the issue of how plantation management can support biodiversity conservation objectives. Many of them focus on the biodiversity that can be encouraged within the plantations themselves.

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