The European Union's Thematic Programme on Environment and Sustainable Management of Natural Resources including Energy (ENRTP)

Adaptation of Forests to Climate Change

Report of Desk-Based Research on Resilience of Forests to Climate Change and Transformation Measures

INCREASING THE RESILIENCE OF FOREST ECOSYSTEMS AGAINST CLIMATE CHANGE IN THE SOUTH CAUCASUS COUNTRIES THROUGH FOREST TRANSFORMATION

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Merab Aleksidze Str.11, 0193 Tbilisi, Georgia
Tel.: + (995 32) 237 500 Fax: + (995 32) 237 501
www.panda.org/caucasus *office@wwfcaucasus.ge*

Author : Mike Garforth, Consultant

Editor : Malkhaz Dzneladze, WWF-Caucasus

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Report of Desk-Based Research on Resilience of Forests to Climate Change and Transformation Measures

WWF Caucasus Programme Office
Tbilisi

Table of Contents

Acronyms and Abbreviations

CCF	Continuous Cover Forestry / Continuous Cover Forest Management
CNF	Close to Nature Forestry
CO2	Carbon dioxide
ENRTP	Thematic Programme of the European Union on Environment and Sustainable Management of Natural Resources including Energy
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FSC	Forest Stewardship Council
GCM	General Circulation Model
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
MENR-AZ	Ministry of Ecology and Natural Resources of Azerbaijan
MEPNR-GE	Ministry of Environment Protection and Natural Resources of Georgia (*since Feb-2011 the Ministry of Environment Protection of Georgia*)
MNP-AM	Ministry of Nature Protection of Armenia
PEFC	Programme for the Endorsement of Forest Certification
UK	United Kingdom
UKWAS	UK Woodland Assurance Scheme
UN	United Nations
UNDP	United Nations Development Programme
UNFCC	United Nations Framework Convention on Climate Change
WWF	Worldwide Fund for Nature

Units of Measurement

ha	hectare
m	metres
masl	metres above sea level
^oC	degrees centigrade
Gg	Gigagramme (10^9 grammes)
tonne	metric tonne (10^3 kilogrammes)

1. Introduction

This report was prepared in the framework of the project *Increasing the resilience of forest ecosystems against climate change in the South Caucasus Countries (Armenia, Azerbaijan, Georgia) through forest transformation* (the Project). The Project is financed by the European Union (EU) in the framework of the EU's Thematic Programme on Environment and Sustainable Management of Natural Resources including Energy (ENRTP).

The purpose of the Project is to establish the necessary conditions for the national forest administrations of the south Caucasus countries to develop and implement strategies for transforming monoculture forest stands into highly resilient, "close to nature" forest stands. The project purpose is to be achieved through raising awareness about climate change impacts on forests, demonstrating practical measures to make forests more resilient, and providing staff of forest administrations and local community members who use forests with the necessary knowledge and skills to transfer the development and implementation of transformation measures to other forest stands.

Structure of the report

Chapter 2 of this report presents a short overview of the forests of Armenia, Azerbaijan and Georgia, their importance, and the pressures and threats that they face.

Chapter 3 presents information about changes in the climate in the region up to the present day and predicted future changes from modelling studies.

Chapter 4 describes the impacts of changes in the climate on forests generally and the impacts that we should expect on forests in the South Caucasus.

Chapter 5 describes strategies for mitigating the impacts of climate change on forests including adaptation of forests to climate change.

Chapter 6 discusses resilience and close to nature forest management and recommends a process for elaborating transform plans for the pilot sites.

Chapter 7 provides a brief outlook for the pilot sites in the face of the uncertainty surrounding the predictions about the future climate.

2. Forests of the South Caucasus Countries

2.1. Extent and types

Forests[1] cover 4 million hectares of the South Caucasus countries, which makes up 22% of the countries' combined land and inland water surfaces: Armenia 307 thousand hectares (10.3%), Azerbaijan 990 thousand hectares (11.4%), Georgia 2,793 thousand[2] hectares (40.7%) (FAO, 2010a).

The region's present day forest cover is much less than when human beings first started to clear forests on a substantial scale for agriculture and settlements.

It has been estimated[3] that the former area of forests may have been as much as 9 million hectares, from which we could deduce that 55% (5 million ha) of former forest cover has been cleared.

The region's wide variety of climatic zones in combination with variation in soils and relief has provided conditions for the

[1] In this context "forest cover" means the area under "forest" and "other wooded land" as defined by the Food and Agriculture Organisation (FAO, 2010). FAO defines "forest" as "*Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.*" FAO defines "other wooded land" as "*Land not classified as "Forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5–10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use.*"

[2] In this report commas are used to denote thousands, full stops (periods) are used to denote decimal points.

[3] Zazanashvili et al (2011).

development of a wide variety of vegetation formations[4]. All of the six forest formations identified in the Caucasus Ecoregion (Bohn et al, 2007) are found in the South Caucasus. The following description is adapted from Zazanashvili et al, 2011.

Forests dominated by beech (*Fagus orientalis*) are the largest in area. In the Colchic region of western Georgia beech forests occur almost from sea level to the upper forest boundary. At 1,000-1,400 masl, beech is partially substituted with spruce and fir. In less humid areas of the South Caucasus the lower boundary of the beech forests moves higher in mountains; here beech mainly grows on northern slopes, leaving more lighted slopes to oak, oak-hornbeam, and hornbeam forests.

Oak forests used to be widespread but clearance for agriculture, viticulture and fruit growing and pressure of grazing have substantially reduced their range.

They have survived mainly in hard-to-access ravines, on comparatively poor soils and on steep rocky slopes. In the lower and middle parts of the forest zone the main species is *Quercus iberica*. Lowland/riverside and flood plain forests in the eastern part of the region are formed mainly from *Q. pedunculiflora*. The prevailing species in the Talysh forests is *Q. castaneifolia* prevails, in the foothills of Colchic region *Q. hartwissiana*, and *Q. imtretina*, and *Q. dschorochensis* prevail in Adjara on drier valley slopes. The relict and Colchic endemic *Q. pontica* is common in the lower subalpine belt in the western part of Colchic region. Usually oak is mixed with hornbeam forming oak-hornbeam forests (with *Carpinus orientalis, C. caucasica*).

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[4] The region's climate zones range from north subtropical humid in the west of Georgia (average annual temperature 12 - 16°C, annual precipitation 1,600 - 2,000 mm) to subtropical arid extending from south-east Georgia towards the Caspian Sea coast of Azerbaijan (average annual temperature 12 - 16°C, annual precipitation less than 200 mm), and from cold moderate mountain in parts of the Greater Caucasus and West Lesser Caucasus mountain ranges (average annual temperature 7-10°C, annual precipitation 800-1,600 mm) to temperate arid mountain extending from central Armenia through Nakhchivan (Azerbaijan) (average annual temperature 7-10°C, annual precipitation <200-400 mm) (Zoi Network, 2011).

Chestnut, frequently together with hornbeam and beech, forms forests on mountain yellow soils and acidic brown soils in the mountains and foothills of Colchis and in some places in the Eastern Greater Caucasus (e.g. on the slopes of the watershed ridge towards the Alazani-Agrichay depression). In Colchis, chestnut is found from the sea level to 1,200-1,300 masl, and in the eastern South Caucasus between 500 and 1,100 masl. As one of the most precious species of the Caucasus, chestnut historically has been felled intensively, which has resulted in the chestnut area shrinkage and significantly deteriorated health of the trees.

Dark coniferous forests composed of fir (*Abies nordma*nniana), spruce (*Picea orientalis*) and spruce with beech occur in the mountains of Colchis and in western areas of Eastern Georgia, where they are found in the middle and upper parts of the forest zone (from 900-1,100 to 2,000-2,150 masl), though optimally in the altitudinal range 1,400 to 1,750 masl. Light coniferous forest formed from pine (*Pinus kochiana*) occurs mainly in the upper reaches of the Kura river catchment.

A number of other distinct forest types occur in the region but form only a small part of the total area of forest. They include forests formed from maple (*Acer campestre*), maple and elm (*Ulmus minor*), lime (*Tilia cordata*) and alder (*Alnus* spp.). "Crooked forests" growing at the upper forest boundaries include birch (*Betula* spp.), mountain ash (*Sorbus caucasigena*), beech (*Fagus orientalis* in the western Caucasus), oriental oak (*Quercus macranthera* in the east and South Caucasus), high-mountain maple (*Acer trautvetteri*), and occasionally pine (*Pinus kochiana*). Forests formed from species adapted to low soil moisture levels are found in the drier eastern and south-eastern parts of the region; these forests typically have a much more open canopy. Species which form these so-called arid, sparse forests include juniper (*Juniperus spp.)* and pistachio (*Pistacia mutica),* willow-leaf pear (*Pyrus salicifolia*), Georgian maple (*Acer ibericum*) and pomegramate (*Punica granatum*).

In the past, arid sparse forests occupied a much larger area but gradual conversion to grassland as a result of cattle and sheep grazing has substantially reduced its extent.

Floodplain forests are found in the lowlands on low river terraces, generally growing on alluvial, swampy or moist soils. Many types formed from a variety of species, including black poplar (*Populus nigra*) and white (or silver) poplar (*Populus alba*), alder (*Alnus barbata*), ash (*Fraxinus excelsior*), pedunculate oak (*Quercus pedunculiflora*) and field elm (*Ulmus minor*).

In addition to natural forest types described above, in the beginning of 1990s there were 198 thousand hectares (4.8% of the total forest area) of artificially propagated plantations. The area of plantation in each of the three countries and the percentage of the country's total forest cover were: Armenia 55 thousand hectares (18%); Azerbaijan 59 thousand hectares (6%); Georgia 84 thousand hectares (3%).

2.2. Importance of the region's forests

Forests in the region fulfil a variety of functions and provide a number of products and services.

Biodiversity

Armenia, Azerbaijan and Georgia lie in the Caucasus ecoregion - one of WWF's 35 "priority places" and one of 34 "biodiversity hotspots" identified by Conservation International as being the richest and at the same time most threatened reservoirs of plant and animal life on Earth. Forests are the most important biome for biodiversity in the region, harbouring many endemic and relic species of plants and providing habitats for globally rare and endangered animals (Williams et al 2006).

Carbon sequestration

Forests contribute significantly to climate change mitigation through their carbon sink and carbon storage functions. Conversely, forest degradation and deforestation result in increased net emissions of carbon dioxide. In the South Caucasus countries the picture is a mixed one. In 2010 forests (excluding other wooded land) in Armenia, Azerbaijan and Georgia respectively held 10.2, 46.3 and 168.4 million tones of carbon in above ground biomass (FAO 2010c).

Based on the data reported in the Second National Communications to the UNFCC (MNP-AM 2010; MENR-AZ 2010; MEPNR-GE 2009), in the year 2000 Georgia's forests absorbed a volume of CO2 equal to 25% of the country's gross CO2 equivalent GHG emissions; for Azerbaijan the percentage was between 7% and 8%. In contrast, there were net emissions of CO2 of 1,563.6 Gg from Armenia's forest, largely as a result of high levels of logging. Although the data is 12 years out of date, it illustrates the importance of forests, and the importance of responsible stewardship of forests, in the regional carbon balance. The picture in 2012 will be different because the GHG emissions of all three countries have increased on year 2000 levels and carbon sequestration by the countries' forests will have changed, though it is highly unlikely that carbon sequestration will have increased in the same proportion as the increase in GHG emissions.

Soil and water protection

Forests play an essential role in the protection of soils and water resources. Loss of forest often leads to erosion, increased risk of flooding and water shortage. The services provided by forests become even more important with climate change, which is likely to result in more irregular rainfall patterns and extended drought periods.

Forest products

Many households in the region use wood from the region's forests as fuel; for example one study reported that in Armenia 61% of all households still used wood as fuel in 2010 in spite of a substantial increase in the number of households being connected to the gas distribution network (Junger and Fripp 2011). Rural households harvest nuts, berries and mushrooms from forests for domestic consumption and for sale. Georgia's forests support a relatively small (in comparison with most other European countries) but locally important wood processing industry; according to FAO

2011a about 100,000 cum of industrial roundwood were harvested in 2009[5].

Culture and health

The region's forests provide opportunities for recreation, education and other social activities.

2.3. Pressures on forests in the region

Apart from the negative impacts of climate change, which are discussed in Chapter 3, the region's forests are under pressure from unsustainable logging for industrial wood and fuel wood and grazing by domestic livestock (which prevents regeneration). Official data on the amount of unsustainable and illegal logging is not reliable because it is based on reported cases, which in many cases are not complete and/or recorded in accurate manner. A recent survey in Armenia indicated that illegal logging for fuel wood could be several times more than the annual allowable cut set by the state forest agency (ICare 2011).

3. Climate change in the region

3.1. Observed changes in the region's climate

Climate change is already occurring in the South Caucasus. According to a recent study on climate trends in the region led by UNDP (UNDP 2011), Armenia, Azerbaijan and Georgia all show statistically increasing trends in mean annual temperature, mean daily minimum temperature and mean daily maximum temperature over the last century. About half of the meteorological stations in Armenia and Azerbaijan and about one quarter in Georgia show statistically significant trends in annual temperature. Almost all the meteorological stations have recorded increases in the duration of warm spells – either consecutive days above 25 ºC or consecutive nights higher than 20 ºC.

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[5] In Azerbaijan logging of industrial roundwood is not sanctioned officially. In Armenia officially sanctioned logging of industrial roundwood amounts to only 10,000 - 15,000 cum a year (Junger and Fripp 2011).

According to the same report the evidence for trends in annual precipitation is less convincing, although there are stations in Armenia and Azerbaijan that have experienced precipitation declines. Armenia's 2nd national communication to the UNFCC reported that annual precipitation decreased by 6% during the previous 80 years (MNP-AM 2010). Azerbaijan reported that average annual precipitation was below the long term norm in almost all regions and on average had fallen by 9.9%; differences seemed more significant in the Kura-Aras Lowland (a decrease of 14.3%), in Ganja-Gazakh (a decrease of 17.7%) and in Nakhchivan (a decrease of 17.1%) (MENR-AZ 2010).

Armenia has reported an increase in the intensity and frequency of hazardous hydro-meteorological phenomena. In the period 1975-2005 the total number of hazardous hydro-meteorological phenomena increased by 1.2 cases per year, and in the last 20 years of the same period (i.e 1985-2005) the increase was 1.8 cases per year (MNP-AM 2010).

3.2. Scenarios for the future climate of the region

In their 2nd national communications to the UNFCC, all three countries presented projections for changes in precipitation and temperature based on the results of modelling. All the projections indicated that the mean annual temperature will increase significantly by the end of the present century. Projections based on the A2 emission scenario[6] were: 1.8 ºC-5.2 ºC and 3.5 ºC-4.9 ºC, in western and eastern Georgia, respectively; 4 ºC - 5.1 ºC in Armenia; and 3 ºC-6 ºC in Azerbaijan. While the projections for temperature appear clear cut, there were discrepancies in the projections for precipitation.

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[6] GHG emissions scenarios are alternative images or "storylines" of how the future might unfold and are used to analyse how driving forces may influence future emission outcomes and to assess the associated uncertainties. The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in a continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines. (IPCC 2000)

One model projected increases in mean annual precipitation in western Georgia and Azerbaijan, while other model for Georgia projected declines.

A subsequent study (UNDP 2011) using projections from four General Circulation Models[7] (GCM) which simulate historical climate reasonably well projected declines in precipitation for all three countries: 20-31% in Armenia, 5-23% in Azerbaijan, and 0-24% in Georgia by the end of the century under the A2 emissions scenario. Across the four selected GCMs and using the A2 emissions scenario the projected changes in mean annual temperature by 2050 are: Armenia 1.1 ºC – 1.9 ºC, Azerbaijan 1.0 ºC – 1.6 ºC, Georgia 0.9 ºC – 1.9 ºC. By 2100, the projected increase is more dramatic: Armenia 4.4 ºC - 5.5 ºC, Azerbaijan 3.6 ºC - 4.1 ºC, and Georgia 4.1 ºC - 5.5 ºC.

4. IMPACTS OF CLIMATE CHANGE ON FORESTS

4.1. How climate change affects forests

Before discussing the impacts of climate change on forests it is important to consider that the main driver of human-induced climate change – the concentration of CO2 in the atmosphere - affects the growth of trees directly. Current concentrations of CO2 are not optimum for photosynthesis and CO2 emissions would therefore be expected to enhance growth rates assuming all other environmental conditions remained constant. Controlled environment experiments on young trees typically show that biomass production increases by 30–50% when the CO2 concentration is doubled (Broadmeadow and Ray 2005). Although mature trees are unlikely to respond as much in a forest environment (Oren *et al.*, 2001), some increase in productivity is likely and will be accompanied by a range of other effects including lower stomatal conductance leading to reduced water use on a leaf area basis (Medlyn *et al.*, 2001), an increase in leaf area (Broadmeadow and Randle, 2002), possible changes in

[7] General Circulation Models (GCMs) are spatially-explicit, dynamic models that simulate the three-dimensional climate system using as first principles the laws of thermodynamics, momentum, conservation of energy and the ideal gas law. (UNDP 2011)

timber quality (Savill and Mather, 1990) and in the nutritional quality of foliage to insect herbivores (Watt *et al.*, 1996). However, since all other environment conditions will not remain constant we can expect any increases in productivity resulting from higher levels of CO2 in the atmosphere to be offset, and in many situations completely cancelled, by changes in the climate resulting from higher levels of CO2 and other GHGs.

Changes in temperature, rainfall, wind and humidity

Changes in temperature, rainfall, wind and humidity affect forest trees in many ways, including photosynthesis and respiration (and therefore growth), reproduction, pollination, seed dispersal, phenology, pest and disease resistance and competitive ability (Broadhead, Durst and Brown 2009; Maroschek et al. 2009). The response of individual trees determines the way in which the forest responds. If changes in the climate exceed a species' physiological tolerances the rates of biophysical forest processes will be altered (Olesen et al. 2007, Kellomaki et al. 2008, Malhi et al. 2008). After a certain point the vegetation will reach a threshold beyond which it no longer comprises a forest; it will have changed its state. Under severe drying conditions, forests may be replaced by savannahs or grasslands (or even desert).

More frequent extreme weather events

Strong winds can cause severe damage to forests by uprooting and breaking the stems of trees. Heavy rain can cause soil erosion and landslides. The disturbances caused by such events reduce productivity in the short term and can make forests more vulnerable to pests and diseases.

More frequent and more devastating fires

Prolonged dry and hot weather will increase the risk of forest fires. Severe fires destroy organic matter and nutrients are lost by volatilization. Frequent fires can also increase soil erosion, reduce regeneration and in dry areas may accelerate desertification (Kolström, Vilén and Lindner 2011).

More frequent and more severe outbreaks of pests and diseases

Increases in precipitation favour many forest pathogens by enhancing sporulation, dispersal and host infection (Lucier et al 2009 citing Garrett et al. 2006). Warm climate conditions have clearly contributed to some recent insect epidemics: e.g. bark beetles in North America (Lucier et al 2009 citing Berg et al. 2006, Tran et al. 2007, Raffa et al. 2008), defoliators in Scandinavia (Lucier et al 2009 citing Jepsen et al. 2008), aphids in the United Kingdom (Lucier et al 2009 citing Lima et al. 2008) and the processionary moth in continental Europe (Lucier et al 2009 citing Battisti et al. 2005, 2006). The drought stress of trees will make forests more vulnerable to infestation by insect herbivores and fungal diseases (Kolström, Vilén and Lindner 2011).

More favourable conditions for invasive species

Climate change can affect forests by altering environmental conditions and increasing niche availability for invaders (Lucier et al 2009 citing McNeely 1999, McNeely et al. 2001, Hunt et al. 2006, Ward and Masters 2007, Dukes et al. 2009, Logan and Powell 2009). As a result of climate change, dominant endemic species may no longer be adapted to the changed environmental conditions of their habitat, affording the opportunity for introduced species to invade, and to alter successional patterns, ecosystem function and resource distribution (Lucier et al 2009 citing McNeely 1999, Tilman and Lehman 2001).

4.2. Impacts of climate change on forests in the South Caucasus

A recent study of the impacts of climate change on forests in the South Caucasus predicts that conditions will become less suitable for most of the forest types that occur in the region at present (Zazanashvili et al 2011). Under an ecologically less unfavourable GHG emissions scenario there could be a reduction of 8% in the area suited to the forest types that occur in the region today compared with actual forest cover in 2011. Under an ecologically more unfavourable emissions scenario there could be a reduction of 33%. The models run in the study predict that impacts will vary between bioclimatic zones and countries with Georgia being affected less overall than Armenia and Azerbaijan.

The impacts of climate change on forests in the region 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. Modelling based on an ecologically more favourable GHG emissions scenario predicts that conditions will become more suitable over a larger part of the region for dry woodlands, *Buxus*, *Castanea*, *Parrotia* and *Zelkova*. Under the ecologically less favourable scenario conditions will become more suitable over a larger part of the region only for dry woodlands and *Zelkova*.

The study predicts different impacts in the three countries. Under the ecological more favourable GHG scenario, in Georgia conditions become more favourable overall for the forest types that occur in the country today, while in Armenia conditions become slightly less favourable and in Azerbaijan conditions become a lot less favourable. Under the ecologically less favourable climate scenario, the area suitable for existing forest formations in Armenia and Azerbaijan will fall substantially (by 52% and 62% respectively) and several forest types will disappear. In Georgia the predicted impact is less than in Armenia and Azerbaijan - a reduction of 11% in the area suitable for existing forest types.

The impact of long term climate change on forests predicted by the study will take many years to show. Forest formations occupying sites which will become less suitable for them will gradually become more and more stressed; the most vulnerable tree species in the formation will lose vigour and may die prematurely; seed production and the formation's capacity for natural regeneration will be reduced.

This does not mean that forests will disappear. Forests and their biological components respond autonomously to long term climate change. The distribution of forests and of different forest types in the south Caucasus 5,000 years ago, before human activity started to cause the deforestation of large areas, was very different from what it was immediately after the end of the last ice age. Sedjo 2010 citing Shugart et al. 2003 notes that forests have responded to past climate change with alterations in the ranges of important tree species. However a critical issue is the rate at which tree species migrate. After the last glacial period, tree species migrated at rates of a few kilometres per decade or less, but the projected rate of shift in climate zones of 50 kilometres per decade could lead to massive loss of natural forests

The capacity for long-distance migration of plants by seed dispersal is particularly important in the event of rapid environmental change. Most, and probably all, species are capable of long-distance seed dispersal, despite morphological dispersal syndromes that would indicate morphological adaptations primarily for short-distance dispersal (Cwyner and MacDonald 1986, Higgins et al. 2003). Assessments of mean migration rates found no significant differences between wind and animal dispersed plants (Wilkinson 1997, Higgins et al. 2003). Long-distance migration can also be strongly influenced by habitat suitability (Higgins and Richardson 1999) suggesting that rapid migration may become more frequent and visible with rapid changes in habitat suitability under scenarios of rapid climate change. The discrepancy between estimated and observed migration rates during re-colonization of northern temperate forests following the retreat of glaciers can be accounted for by the underestimation of long-distance dispersal rates and events (Brunet and von Oheimb 1998, Clark 1998, Cain et al. 1998, 2000). Nevertheless, concerns persist that potential migration and adaptation rates of many tree species may not be able to keep pace with projected global warming (Davis 1989, Huntley 1991, Dyer 1995, Collingham et al. 1996, Malcolm et al. 2002). However, these models refer to fundamental niches and generally ignore the ecological interactions that also govern species distributions.

There is also potential for natural evolutionary change, which has been demonstrated in numerous long term programmes based on artificial selection (Falconer 1989). In the face of rapid environmental change genetic diversity and adaptive capacity of forested ecosystems depends largely on in situ genetic variation within each population of a species (Bradshaw 1991). Populations exposed to a rate of environmental change exceeding the rate at which populations can adapt, or disperse, may be doomed to extinction (Lynch and Lande 1993, Burger and Lynch 1995). Genetic diversity determines the range of fundamental eco-physiological tolerances of a species. It governs inter-specific competitive interactions, which, together with dispersal mechanisms, constitute the fundamental determinants of potential species responses to change (Pease et al. 1989, Halpin 1997).

In the light of the evidence presented in the preceding paragraphs we can conclude that if we take no action to mitigate the impact of climate change on forests we can expect changes in forest health, vitality and productivity caused by changes in climatic variables and the increased risks of damaging events to have significant consequences for people living in the region. Those consequences will include:

- an overall reduction in the quantity of timber and non-wood forest products such as mushrooms, berries and nuts from the forest types present in the region today, though production may increase in the Colchic bio-climatic region;
- an overall reduction in the value of environmental services provided by the region's forests, including regulation of water quality and water flow, prevention of erosion, landslides and avalanches;
- changes in biodiversity and the special values of the region's protected areas;
- changes in the visual landscape.

5. STRATEGIES FOR MITIGATION AND ADAPTATION OF THE IMPACTS OF CLIMATE CHANGE ON THE REGION'S FORESTS

If we want to avoid the consequences of climate change described in Chapter 4.2 we must intervene to help forests adapt. There are two possible approaches open to us: reactive adaptation and planned adaptation.

Reactive adaptation is action taken after climate change impacts have already occurred and been observed; for example changing the tree species after the existing species have shown signs of loss of vigour and early mortality, salvage harvesting after storms, recalculation of allowable cuts in response to declining productivity. Reactive adaptation may lessen some of the long term impacts of climate change on forests that would occur in a no intervention scenario but the long time scales required to bring about changes in forest formations will delay any positive impacts of reactive intervention.

Planned adaptation involves redefining forestry goals and practices in anticipation of climate change-related risks. Planned adaption is made difficult by the fact that our knowledge about the vulnerability of ecosystems and species, and the spatial and temporal resolution of the future climate, are poor and the exact nature and scale of the impacts of climate change on forests impossible to predict. In spite of the high degree of uncertainty it is possible to develop adaptation strategies now, and we need to start now: the impacts are likely to be substantial, and the negative impacts many times greater than any positive impacts (Bernier and Schoene 2009); and adaptation to climate change in forest management requires a planned response well in advance of the impacts of climate change (Spittlehouse and Stewart 2003).

Ways in which we can help forests adapt to climate change include the following:

Increasing the natural adaptive capacity of forests

Adaptation theory suggests that more diverse natural systems are more resilient to short term shocks and long term changes in environmental parameters; e.g. forest ecosystems with greater diversity usually show a greater adaptive capacity (SCBD 2003; Fontaine et al. 2005; Stokes and Kerr 2009), as they are able to adapt in a variety of ways to different changes. Increasing the diversity of species and provenances in forest stands provides insurance against the risk that forest health and productivity will decline as a result of climate change.

While the scientific evidence supports the hypothesis that mixed-species forest ecosystems are more resilient than monotypic stands, some natural monotypic, or nearly monotypic, forests do occur. In the boreal forest zone, natural stands of jack pine (*Pinus banksiana*), Scots pine (*P. sylvestris*), lodgepole pine (*P. contorta*), and Dahurian larch (*Larix gmelinii*) are commonly dominated by single species. These stands self-replace usually following fire over large landscapes, with no change in production over time. Similarly, in wet boreal systems where fire is absent, monotypic stands of a single species of fir (*Abies* spp.) occur and generally self-replace following insect-caused mortality. Generally, these monodominant boreal forest ecosystems tend to be relatively shortlived and are prone to fire or insect infestation. (Thompson et al 2009)

Planting species and provenances that are more resilient or promoting them in naturally regenerated stands by selective tending and thinning. In Germany the use of provenances of native and non-native tree species (e.g. Douglas fir) from regions with a climate corresponding to future climate in Germany is an important element of active adaptation (Bolte and Degen 2010). Species and provenance selection needs to be informed by research into the responses of species and genotypes to climate, for example to identify drought-tolerant genotypes (Spittlehouse and Stewart 2003 citing Farnum 1992). Trees can be bred for pest resistance and for a wider tolerance to a range of climate stresses and extremes in specific genotypes (Spittlehouse and Stewart 2003 citing Namkoong 1984 and Wang et al. 1995).

Alternative provenances or species could be planted to respond positively to the predicted warmer climate (see Cannell et al., 1989). However, the adoption of new varieties or the wider use of some that are already planted will require careful balancing against commitments to the use of native species and origins. Furthermore, where species or provenances originating from hotter, drier climates are planted, performance under a future climate must be balanced with performance under the current climate.

Increasing the resilience and natural adaptive capacity of forests at a landscape level

Reducing fragmentation and creating ecological corridors facilitates the natural movement of species, and strengthens and extends regimes of forest preserves to reduce anthropogenic impacts that compound the negative effects of climate change (Robledo and Forno, 2005).

Adaptation of fire prevention and control practices

Adaptation of fire prevention and control practices include altering forest structure (e.g., tree spacing and density, standing dead trees, or coarse woody debris on the forest floor) to reduce the risk and extent of disturbance (Spittlehouse and Stewart 2003 citing Dale et al. 2001); increasing the use of prescribed burning to minimize fuel loading (Spittlehouse and Stewart 2003 citing Wheaton 2001); developing "fire-smart" landscapes by using harvesting, regeneration, and stand-tending activities that manage fuels to control the spread of wildfire (Spittlehouse and Stewart 2003 citing Hirsch and Kafka 2001 and Climate Change Impacts and Adaptation Directorate 2002); focusing on the protection of areas with high economic or social value, while in other areas allowing fire to run its course (Spittlehouse and Stewart 2003 citing Stocks et al. 1998 and Parker et al. 2000).

Adaptation of pest and disease prevention and control practices

Examples of adapting pest and disease prevention and control strategies include: partial cutting or thinning to increase stand vigour and lower the susceptibility to attack (Spittlehouse and Stewart 2003 citing Wargo and Harrington 1991 and Gottschalk 1995); reducing disease losses through sanitation cuts that remove infected trees; shortening the rotation length to decrease the period of stand vulnerability to damaging insects and diseases (Spittlehouse and Stewart 2003 citing Gottschalk 1995) and facilitating change to more suitable species (Spittlehouse and Stewart 2003 citing Lindner et al. 2000); using insecticides and fungicides in situations where silvicultural activities for insect pest management are ineffective or inappropriate (Spittlehouse and Stewart 2003 citing Parker et al. 2000); controlling undesirable plant species, which become more competitive in a changed climate, through vegetation management treatments (Spittlehouse and Stewart 2003 citing Parker et al. 2000).

Adaptation of silvicultural practices to manage declining and disturbed stands

Adaptation of silvicultural practices include: selectively removing suppressed, damaged, or poor quality individuals to increase light, water, and nutrient availability to the remaining trees (Spittlehouse and Stewart 2003 citing Smith et al.1997 and Papadopol 2000); reducing vulnerability to future disturbances by managing tree density, species composition, forest structure (e.g., under-planting; planting late-successional species), and location and timing of management activities (Spittlehouse and Stewart 2003 citing Dale et al. 2001); reducing the rotation age followed by planting to speed the establishment of better-adapted forest types (Spittlehouse and Stewart 2003 citing Lindner et al. 2000 and Parker et al. 2000).

Implementing adaptive management

Forest managers need to prepare forest management plans in the face of increasing uncertainty about climate and the response of trees and forest formations to climate change. Former certainties underlying classical tools such as yield tables no longer hold true in the face of climate change and the tools are no longer valid (Spittlehouse and Stewart 2003). Adaptive management is a management approach that acknowledges the lack of unequivocal and definitive knowledge about the ways in which forest ecosystems work, and the uncertainty that dominates interactions with them (Robledo and Forno, 2005 citing Borrini-Feyerabend, 2000). It is a formal process for continually improving management policies and practices by learning from their outcomes (Robledo and Forno, 2005 citing Taylor *et al.*, 1997). The key characteristics of adaptive management include (Robledo and Forno, 2005 citing Sit and Taylor, 1998):

- acknowledgement of uncertainty about what policy or practice is “best” for the particular management issue;
- thoughtful selection of the policies or practices to be applied;
- careful implementation of a plan of action designed to reveal critical knowledge;
- monitoring of key response indicators;

- analysis of the outcome in terms of the original objectives;
- incorporation of the results into future decisions.

Since scientific research results take many years to become applicable and operational on local sites, the notion of adaptive management postulates that forest managers themselves integrate applied research and experimentation in their daily work to generate data for immediate use (Robledo and Forno, 2005 citing Nyberg, 1999). This entails local assessments of climate change impacts and vulnerability studies of forest ecosystems, results of which would then feed into the initial stages of the adaptive management cycle, i.e. the problem assessment and the design of implementation measures. An essential element of adaptive forest management is that knowledge generated by learning is reintegrated into the project/working cycle and hence leads to adjustment and improvement of the forest management approach (Robledo and Forno, 2005).

A summary of ecological principles for maintaining the long term resilience of forests ecosystems is presented in Box 1 below.

Box 1 – *Ecological principles to maintain and enhance long term forest resilience (from Thompson et al 2009)*

Thompson et al 2009 suggest the following as ecological principles that can be employed to maintain and enhance long term forest resilience, especially under climate change (a list of adaptation responses similar to these principles can be found on pages 4 and 5 of FAO 2011b):

1. Maintain genetic diversity in forests through practices that do not select only certain trees for harvesting based on site, growth rate, or form, or practices that depend only on certain genotypes (clones) for planting (see e.g., Schaberg et al. 2008) .
2. Maintain stand and landscape structural complexity using natural forests as models and benchmarks.

3. Maintain connectivity across forest landscapes by reducing fragmentation, recovering lost habitats (forest types), and expanding protected area networks (see 8. below).
4. Maintain functional diversity (and redundancy) and eliminate conversion of diverse natural forests to monotypic or reduced species plantations.
5. Reduce non-natural competition by controlling invasive species and reduce reliance on non-native tree crop species for plantation, afforestation, or reforestation projects.
6. Reduce the possibility of negative outcomes by apportioning some areas of assisted regeneration with trees from regional provenances and from climates of the same region that approximate expected conditions in the future.
7. Maintain biodiversity at all scales (stand, landscape, bioregional) and of all elements (genetic, species, community) and by taking specific actions including protecting isolated or disjunct populations of organisms, populations at margins of their distributions, source habitats and refugia networks. These populations are the most likely to represent pre-adapted gene pools for responding to climate change and could form core populations as conditions change.
8. Ensure that there are national and regional networks of scientifically designed, comprehensive, adequate, and representative protected areas (Margules and Pressey 2000). Build these networks into national and regional planning for large-scale landscape connectivity.

6. Increasing the Resilience of the Region's Artificially Propagated Forests to Climate Change (Including General Recommendations for the Selected Pilot Sites)

6.1. Transformation aims

The silvicultural focus of the project is the transformation of monoculture forest stands in the region into highly resilient, "close to nature" forest stands. There are therefore two conditions that the transformation measures have to meet: the transformed stands must be highly resilient to climate change; and they must be "close to nature".

The term "resilient" is used with different meanings in the literature about climate change and forest adaptation[8]. The definition used in the United Kingdom's guidelines on forests and climate change (Forestry Commission, 2011) is probably closest to the meaning that applies in the context of the project: "Resilience [is] the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change". According to this definition a forest, a form of ecological system, can undergo changes in some of its characteristics, for example genetic composition of a species, species composition of a stand, and still meet the definition of resilient provided that the system is still recognisably a forest in terms of its physical structure and the variety of goods and services that it provides. Within the meaning of resilient such scope for change in the genetic character of the forest as has just been described is probably going to be essential: no change or only a small change is almost certainly unrealistic given the increases in temperature and decreases in precipitation that are expected in the region.

"Close to nature forestry" is generally understood to mean a system of forest management which provides continuous regeneration, development and treatment of stands that are similar in species composition, structure and dynamic to forests occurring naturally in the specific site conditions (Box 2).

Thus we can summarise the aims of transformation in the following way:

- **Resilient to climate change.** The stand will continue as a forest formation (i.e it will not transform into another state such as grassland). The stand will continue to provide the range of goods

[8] For example, Holling (1973) defines resilience as "The capacity of an ecosystem to return to the pre-condition state following a perturbation, including maintaining its essential characteristics taxonomic composition, structures, ecosystem functions, and process rates". Gunderson (2000) distinguishes between "ecological resilience" (the ability of a system to absorb impacts before a threshold is reached where the system changes into a different state) and "engineering resilience" (the capacity of a system to return to its pre-disturbance state).

and services that we currently associate with forests but the volumes/quantities of individual goods and services and their volumes/quantities relative to each other may change (e.g. the forest will continue to produce harvestable timber but may do so in smaller amounts than now, and it will continue to provide soil and water regulation services).

- **Close to nature forest stand**. The tree species which form the stand are native to the South Caucasus. The tree species are mixed in proportion to each other and arranged spatially in a way that resembles the structure of the forest that we would expect to develop naturally on the site. The question of how far we should take account of predicted future climate change and our idea of the forest that would develop naturally on the site under those predicted future conditions is discussed later in this report.

Box 2 – *Close to Nature Forestry (adapted from Slovenia Forest Service, 2008)*

The following description of "close to nature forestry" is taken from a publication by the Slovenia Forest Service which is a long standing follower and promoter of the approach:

"*Close to nature forestry uses forest management methods that promote conservation of nature and forests, as its most complex creation, while deriving tangible and intangible benefits from a forest in a way to preserve it as a natural ecosystem of all its diverse life forms and relations formed therein.*

Close to nature forestry is based on forest management plans adapted to individual site and stand conditions as well as forest functions, and considering natural processes and structures specific to natural forest ecosystems.

Natural processes are altered as little as possible, while still maintaining the financial profitability and social sustainability of forest management. Similarly to natural processes, close to nature forestry also contains inbuilt mechanisms for continual internal checks (controls) providing timely response to modify measures adapted in accordance with developmental characteristics of single forest stands and a forest as a whole.

Characteristics of close-to-nature forest management are:

Preservation of the natural environment and the ecological balance of the landscape;

Sustainability of all forest functions;

Integrated approach to a forest ecosystem;

Imitation of natural processes and forms;

Tree species suited to site conditions;

Based on [the adaptive] approach – constant monitoring and learning;

Based on long-term economic efficiency;

Plans designed at a broader and more detailed level.

Close-to-nature forest management is, therefore, a forest management practice where the goals of sustainable and multifunctional forest management are achieved through preservation of natural forest and silvicultural approach mimicking natural disturbances and processes. In this sense, close-to-nature forest management combines the principles of sustainable forest management and the ecosystem approach."

6.2. Experience of transforming forest stands in EU countries

Transformation of forest stands has become increasingly widespread in EU countries during the last 20 years as more and more forest managers have seen that traditional silvicultural practices have resulted in forest stands that are ecologically unstable.

In continental west and central Europe at least 6 to 7 million hectares of pure Norway spruce (*Picea abies*) are located outside the species' natural range; at least 4 to 5 million hectares are located on sites naturally dominated by broadleaved species or mixed tree species. These forests have with time resulted in a higher exposure to forest decline, windthrows, pests, drought and soil deterioration. The transformation of these stands into mixed forests has become one of the most important strategic silvicultural targets and biggest challenges in forest policy and practice in EU countries.

In the UK and Ireland, large areas of forest plantations were established with conifer monocultures using non-native species such as sitka spruce (*Picea sitchensis*), Norway spruce and lodgepole pine (*Pinus contorta*). Now there is an increasing movement towards transforming these plantations into mixed “continuous cover” forests (see section 6.2 below).

It is an interesting point that the movement towards forest transformation in Europe developed before concern about the impacts of climate change on forest became widespread; the movement was inspired more by concerns about resistance to pests and diseases, the long term effects of monoculture silviculture on the site, and aesthetic considerations.

In EU countries we can distinguish the following standard situations and transformation concepts:

Monocultures of Norway spruce (*Picea abies*) – Transformation through underplanting of beech; e.g. the German States of Bavaria and Hesse (Bayerische Landesanstalt für Wald und Forstwirtschaft 2009; Hessen-Forst 2008):

1. Monocultures of Pine (*Pinus sylvestris*) – Transformation through introduction of oak (and other broadleaf species) after opening up the canopy cover of pine; e.g. the German State of Brandenburg (Ministerium für Ländliche Entwicklung, Umwelt und Verbraucherschutz des Landes Brandenburg und Landesforstanstalt Eberswalde 2006).
2. Enrichment of Douglas fir monocultures; e.g. the German State of Hesse (Hessen-Forst 2008).
3. Enrichment of pure beech stands; e.g. the German state of Hesse (Hessen-Forst 2008).

The experience of the German state of Brandenburg is particularly relevant because, as in the South Caucasus, the initial situation is usually a monocultural stand of artificially propagated pine that are not adapted to the site. The experience of the UK is also interesting. Although the initial situation is very different from that in the South

Caucasus, the goal of transformation is the same, and the forestry administration has developed process guidelines for deciding how to transform conifer monocultures into more resilient forests.

German state of Brandenburg

The Brandenburg state forestry administration aims to increase the proportion of broadleaf forests and to reduce the proportion of pine forests significantly in the next decades. The reason behind this policy is the evidence that oak and other broadleaf trees have an comparatively lower risk to get affected by insect pests, forest fires and other negative impacts intensified through climate change. Guidelines published by the Brandenburg state forestry administration provide advice to forest managers on how to transform pine plantations.

The most common silvicultural method for growing oak and other broadleaf species is planting or seeding them under the existing pine stand; the main advantages of this method are:

- with the help of the pine canopy the sensitive young oak and broadleaf seedlings are protected from damaging weather extremes (frost , heat)
- competition of aggressive grass and/or blackberry *(Rubus)* is prevented
- the existing pine stand can be harvested over a longer period producing continuous timber or fuelwood yields

Referring to oak underplanting it is crucial to consider the light requirements of oak seedlings: To ensure a good development of the seedlings the percentage of canopy cover (of the pine stand) should be below 70 %. On the other hand it is recommended to maintain a canopy cover percentage of more than 40 % to safeguard the protection function of the canopy against frost impacts on the seedlings.

United Kingdom

A large proportion of the UK's forest have been created in the last 90 years by planting mainly non-native conifers, mostly as monocultures and sometimes in mixtures.

The main silvicultural system is patch clearfelling followed by planting or occasionally natural regeneration. This system is probably employed in at least 90% of managed forests with an average size of clearfelled coupe of between 5 and 10 hectares, although there is appreciable regional variation (Mason et al., 1999).

The state forest administration now requires forest managers to "*identify areas which are, or will be, managed under a continuous cover forestry system and to build them into the forest design*" (Forestry Commission, 1998). The UK forest certification standard (UKWAS, 2000), which is the standard used in FSC and PEFC certification of UK forests, requires forest managers to favour lower impact silvicultural systems, which include continuous cover forestry.

Continuous Cover Forestry (CCF) is an approach to forest management that results in the development of diverse forests with a range of different structures and often a variety of species (Mason et al., 1999).

Initial interest in CCF was not associated with concerns about the impacts of climate change on forests: the attraction lay in the belief that the CCF approach was suited to an era of multi-purpose forestry where environmental, recreational, aesthetic and other objectives are as important as timber production; in particular, CCF was seen as a means of reducing the impact of clearfelling and the associated changes that it produces in forest landscapes and habitats (Mason et al., 1999). Now, though, CCF is seen as a way of adapting forests to the risks of climate change (Stokes and Kerr 2009).

CCF is not synonymous with close to nature forestry but some forms of CCF can be classed as CNF. CCF does not rule out the use of non-native species and it allows the use of any silvicultural system that does not create large areas that are completely open to the sky. In contrast, generally in CNF only species that are native to the locality are acceptable and there is an emphasis on management mimicking nature.

Therefore irregular silvicultural systems (single stem selection, group selection, irregular shelterwood) are favoured over regular systems (uniform shelterwood, strip shelterwood)[9].

UK guidelines for transforming even-aged conifer and mixed species stands in continuous cover forests (Mason and Kerr 2004) recommend a three stage process (Box 3). Key points of the guidelines are:

- The importance of management objectives in the development of the transformation plan (i.e. forest managers should decide the objectives which the transformed forest will serve before deciding transformation measures).
- Transformation measures that are taken in the stand are decided only after deciding the future stand structure - i.e. simple (one or two storeys) or complex (more than two storeys) - and silvicultural system.
- The guidelines assume that the introduction of young trees will be by natural regeneration and recommend planting only when natural regeneration has failed. This limits the scope for increasing the resilience of the stand by introducing other species and/or different provenances.

  However, the guidelines state that under-planting can also be used, particularly if one aim is to introduce either desired species that are absent from the site or improved genotypes.
- There is no particular emphasis on native species.

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[9] Regular stands are ones where all the trees are of similar height (but not necessarily of the same age) whereas irregular ones contain a mixture of sizes. Systems which promote regular structures require the removal of the overstorey once regeneration is established whereas in irregular systems there will always be some components of the overstorey retained in the stand.

Box 3 – *UK guidelines for transforming even-aged conifer and mixed species stands into continuous cover forests (adapted from Mason and Kerr 2004)*

- Stage 1: Assess the feasibility of transformation.
  - Site appraisal (risk of windthrow, soil fertility and potential vegetation competition, species suitability)
  - Detailed stand appraisal (stand structure and quality, advance regeneration, ground flora, litter, animals, access and topography)
- Stage 2: Select the desired structure and appropriate silvicultural system
  - Decide upon the stand structure (simple or complex) that will best achieve management objectives (a simple structure will be produced by the uniform or group shelterwood systems, whereas a complex structure will result from an irregular shelterwood or a selection system).
- Stage 3: Choose a thinning regime that will favour the desired stand structure, taking into account the current stage of stand development. (The Guidelines provide recommendations for thinning regimes for two age groups of stand (young, 20-40; older, >40) and two desired types of structure (simple and complex).

6.3. Transformation of conifer plantations in the South Caucasus

In contrast to EU countries artificially propagated conifer forests cover only a very limited area in the South Caucasus (data covering, *inter alia*, artificially propagated conifer forests is presented in section 2.1 above). Often these plantations were created in the surroundings of cities in order to protect soil or for recreational purposes. In Armenia artificially propagated pine forests were established in otherwise treeless regions so that they had at least some forest cover. Thus, plantations in the South Caucasus often have positively valued landscape and recreational functions. Nevertheless their transformation into close to nature forests could improve correspondence to the mentioned functions at the same time as increasing their resilience to the impacts of climate change.

General description of the pilot sites

The six pilot sites (see the summary table in Annex I) were selected by the project partners together with the forest administration responsible for assigning the pilot sites to the action. The sites were selected using the criteria that were developed at the initial project planning stage and which later on were adopted at national level in all 3 target countries (through review and conformation during the national introductory workshops with forestry administration staff). The criteria are set out in Annex II.

The site selection preconditions were identified as follows:

- Current leading tree species is not in its natural distribution area
- Current forest stand is a monoculture
- Current forest stand is vulnerable to climate change

As a result the following 6 pilot sites were selected and agreed with national governmental agencies:

In Armenia

Pilot Forest Site N1 – "*KOGHB*" in Tavush Region (Armenia) located on the state forest lands of the Noyemberyan State Forest Enterprise of the State Non-Commercial Organization "Hayantar" (*ArmenForest*) of the Ministry of Agriculture of the Republic of Armenia.

Pilot Forest Site N2 – "*SPITAK*" in Lori Region (Armenia) located on the state forest lands of the Gugarq State Forest Enterprise of the State Non-Commercial Organization "Hayantar" (*ArmenForest*) of the Ministry of Agriculture of the Republic of Armenia.

Detailed location and boundaries of the selected pilot forest sites already agreed with the State Non-Commercial Organization "Hayantar" (*ArmenForest*), as well as relevant agreement with the stakeholder are available at the following web-page:

For the Pilot Forest Sites N1 and N2 :
http://awsassets.panda.org/downloads/memorandum_of_understanding_dec_29_2011.pdf

In Azerbaijan

Pilot Forest Site N1 – "*AGSU*" in Shamalkhi District (Azerbaijan) located on the state forest lands of the Shamakhi Forest Protection and Restoration Enterprise of the Ministry of Ecology and Natural Resources of the Azerbaijan Republic.

Pilot Forest Site N2 – "*YEVLAKH*" in Yevlakh District (Azerbaijan) located on the state forest lands of the Yevlakh Forest Protection and Restoration Enterprise of the Ministry of Ecology and Natural Resources of the Azerbaijan Republic.

Detailed description of locations of the selected pilot forest sites already agreed with the relevant Forest Protection and Restoration Enterprises are available at the following web-pages:

For the Pilot Forest Site N1 :
http://awsassets.panda.org/downloads/mou_shamakhi.pdf

For the Pilot Forest Site N2 :
http://awsassets.panda.org/downloads/mou_yevlakh.pdf

In Georgia

Pilot Forest Site N1 – "*KHASHURI*" in Khashuri Municipality (Georgia) located on the state forest lands of the former Khashuri State Forestry, Forest Unit N.3, Forest Sub-Units NN.5-7 and NN.9-30 - currently under the management of Shida Kartli Service of the Natural Resources Agency of the Ministry of Energy and Natural Resources of Georgia.

Pilot Forest Site N2 – "*TSAVKISI*" in Tbilisi Municipality (Georgia) located on the former state forest lands of Kojori Forest Unit of the former Tbilisi State Forestry - currently under the management of the Municipality of Tbilisi.

Detailed location and boundaries of the selected pilot forest sites already agreed with stakeholders, as well as relevant agreements with the stakeholders are available at the following web-pages:

For the Pilot Forest Site N1 :
http://awsassets.panda.org/downloads/mou_geo_site_khashuri.pdf

For the Pilot Forest Site N2 :
http://awsassets.panda.org/downloads/mou_geo_site_01_tsavkisi.pdf

The pilot sites are located in different natural forest vegetation zones of the South Caucasus and they are mainly represented by artificially propagated non-native pine forests (e.g., by *Pinus nigra* in Georgia).

Currently, transformation plans for the selected sites are being prepared in all 3 countries. These plans will specify in detail the measures to be carried out on each of the pilot forest sites. The measures will include a variety of silvicultural operations: fencing, preparation of sites, seeding and planting, and clearing of competing vegetation from around the seeded and planted trees. The transformation plans will serve as a base for developing best practices and to obtain reliable information about costs and results.

The main silvicultural idea is to transform the pine stands at the pilot sites into close to nature forests by using the existing pine cover as a nurse crop to introduce tree and shrub species by under-planting and, in addition, to reforest open areas. A common example is where a slower-growing, shade-tolerant species forms the lower layer beneath a canopy of a faster-growing, shade-intolerant species.

The factors that have to be considered in planning process include, but are not limited to:

- tree and shrub species that can be used for under-planting (which will depend on species composition natural for the pilot site area, existing vegetation, and existing canopy density;
- soil preparation methods;
- planting and seeding techniques and spacing;

- methods assisting natural regeneration;
- clearing of competing vegetation from around the seeded and planted trees;
- physical protection (fencing of the pilot sites and if necessary single tree protection).

Scenarios for the future climate of the pilot sites

In the time assigned for the preparation of this report it has not been possible to analyse in detail the results of the climate projections for the region prepared by, for example, UNDP (UNDP 2011) and the governments of the three countries (MENR-AZ 2010; MEPNR-GE 2009; MNP-AM 2010). The following projections for temperature and precipitation are interpreted from data presented in a report by Zoï Environment Network (Zoï Network 2011), specifically the maps of current average annual temperature and average annual precipitation on pages 10 and 11 and the maps of forecast average annual temperature and average annual precipitation on pages 22 and 23. The project team should consider whether it would be worthwhile carrying out more precise projections for the purposes of planning transformation measures.

The Armenian pilot sites at Spitak and Noyemberyan lie in a zone in which present day average annual air temperature is 10-13 °C and present day average annual precipitation is between 200-600 mm. The projections presented in the Zoï Network report are that average annual air temperature where the pilot sites are situated will increase by 1.5 °C by 2040, by 3 °C by 2070 and by 5 °C by the end of this century. Average annual precipitation is projected to fall by 5% by 2040, by 5-10% by 2070, and 10-15% by the end of this century.

The Azerbaijan pilot sites at Yevlakhi and Shamlakhi lie in the zone with the highest present day average annual temperature in the South Caucasus (13-16 °C) and lowest average annual precipitation (less than 200 mm). The projections presented in the Zoï Network report are that average annual air temperature where the pilot sites are situated will increase by 1.5 °C by 2040, by 1.5-3 °C by 2070 and by 4-5 °C by the end of this century. Average annual precipitation is projected to fall by 0-5% by 2040, by 5-10% by 2070, and 15-20% by the end of this century.

The Georgian pilot sites lie in zones in which average annual air temperature is 7-10 °C in the case of Khashuri and 10-13 °C in the case of Tsavkisi, and average annual precipitation is 400-600 mm in the case of Khashuri and 200-400 mm in the case of Tsavkisi. The projections presented in the Zoï Network report are that average annual air temperature where the pilot sites are situated will increase by 1.5 °C by 2040, by 3 °C by 2070 and by 5 °C by the end of this century. Average annual precipitation is projected to fall by 0-5% by 2040, by 0-5% by 2070, and 10-15% by the end of this century.

There are huge uncertainties around these projections but all of the studies – the study that produced the data included in the Zoï Network report (UNDP 2011), the national studies that are reported in the countries 2nd national communications to the UNFCC (MENR-AZ 2010; MEPNR-GE 2009; MNP-AM 2010) – predict continuously increasing average annual temperatures and (with one exception) a decrease in annual average precipitation.

General recommendations for the pilot sites

This section of the report provides recommendations on the process for preparing transformation plans for the pilot sites. The report does not make specific recommendations on the species and the provenance of species or on the silvicultural measures that should be used at the pilot sites. These decisions should be taken following a comprehensive site assessment, which is one step in the process described in the rest of this section.

The UK process guidelines described in section 6.2.2. above include references to the objectives of the stands and the silvicultural system which will applied to the stands. These two considerations are not included in the recommendations for the pilot sites. For the purpose of this report its is assumed that the objective for all of the sites is that they will continue to provide the range of goods and services that we currently associate with forests and that no specific objective (e.g. wood production) is favoured over another (e.g. regulation of water resources). The silvicultural system which will be applied to the stands can be decided once the stands have been transformed.

The recommended process for deciding measures for transforming the stands at the pilot sites is pictured in Figure 1 below. The steps in the process are explained in the following paragraphs.

Step 1. Delineate the perimeter of the forest that is to be transformed

In some situations the outer boundary of the area in which transformation measures will be taken will be quite easy to determine. If the plantation has a "hard edge" against land that is not under trees, the plantation edge can be taken as the perimeter. In many situations, where the plantation has been subject to illegal felling, grazing, or trees have simply been unable to establish themselves and have dies, the edges of the plantation are not distinct. The boundary of a plantation may even be disputed by neighbouring land owners and users. In such situations the boundary will have to be negotiated. The output from this step is a map or aerial photo on which an undisputed boundary is marked.

2(a). Survey the forest and define and delineate categories

Dividing the stand into categories is the basis for planning the specific transformation measures that will be carried out. The categories listed in the diagram reflect factors that will be important in deciding the measures that should be taken, i.e the density and distribution of tree cover. The presence of or potential for natural regeneration could be included at this stage in the process but is included in step 4 as a more logical point at which to take it into account.

2(b). Carry out site assessment

The site assessment includes mapping of soils, which is for deciding which species and the proportions of the chosen species that might be planted in different parts of the stand, and the present and predicted future climate. Assessment of protection requirements – in particular whether it will be necessary to erect a fence around the stand to prevent grazing of young trees by livestock – can also be carried out at this stage. The need for protection measures will usually be determined by pressures on the stand from neighbouring communities and it is important to find out the interest of local people in the stand and the products and services that it provides now and could provide in the future.

3. Define potential natural forest composition

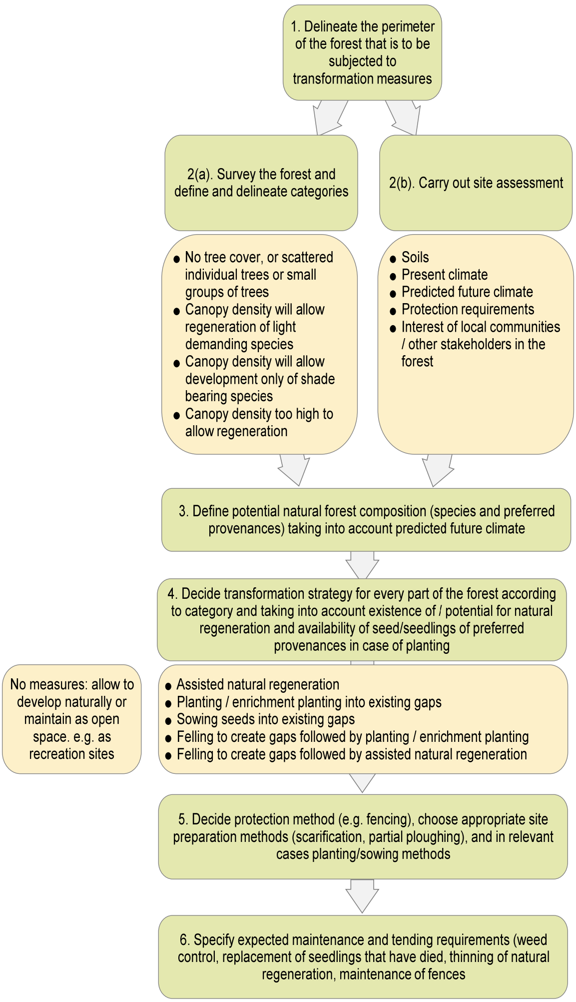
If we consider only the species that would form the natural vegetation under present day conditions we could be guided by the fact that in the South Caucasus in the zone between 350 and 1,800 m hornbeam-oak (*Carpinus betulus*, *Quercus iberica*) forests are the dominating natural forests, while beech (*Fagus orientalis*) forests form a distinguishably separate zone between 1000 and 1500m. However, it is important to consider the future climate in which the trees will be growing.

The projected changes in temperature over the next 30 years discussed in section 6.3.2 above are large enough to have significant impacts on the functioning of forest ecosystems that are adapted to present day conditions. The projected changes by the middle of the century are large enough to raise concerns about the performance of tree species and provenances that are adapted to present day conditions at the sites. Therefore serious thought needs to be given to using species that are adapted to conditions similar to those projected for the pilot sites and at the very least to using provenances that show the greatest tolerance of high temperature; in any case, adaptive management should be implemented – the health and vitality of the species established on the site should be monitored and enrichment with better adapted species considered if health and vitality deteriorate.

4. Decide the transformation strategy

In this step the transformation strategy for every part of the stand is worked out in terms whether to establish the future trees by using natural regeneration, by planting or sowing, or a combination of methods, and whether to open the canopy of the existing trees in order to provide enough light for the future trees.

Figure 1 – *Recommended process for deciding measures for transforming artificially propagated pine stands into close to nature forest stands*



5. Choose appropriate site preparation methods

The specific techniques that will be used to establish the future trees are decided in this step. They include preparation of the site to promote natural regeneration and to provide positions for sowing and planting that are as free as possible from grasses, herbs and other plants that could compete with the future trees for water and nutrients. The Forest Restoration Guidelines published by WWF (WWF 2011) provide detailed advice about choosing site preparation methods. Protection methods should be decided in this step if they have not already been decided in step 2(b); the Forest Restoration Guidelines provide detailed specifications for fencing.

6. Specify expected maintenance and tending requirements

The final step before starting to implement the transformation measures is to specify the maintenance and tending measures that will be necessary to ensure successful establishment and development of the future trees. It is important to know what measures are likely to be necessary so that the work can be planned and budgeted and arrangements made for it to be carried out.

Measures will include removal of competing vegetation, replacing planting seedlings that have died and enriching natural regeneration with planted seedlings. Contingency plans should be made for watering planted seedlings in the event of lengthy hot, dry spells likely to cause a high rate of mortality (watering adds significantly to the costs of establishment and should be used only in exceptional circumstances).

7. OUTLOOK

There is a lot of uncertainty around predictions of the future climate of the South Caucasus; however, the results of climate modelling indicate that we should expect a continuous increase in average annual temperatures and lower average annual precipitation. We should also expect more frequent extreme weather events. The Project will implement measures to transform artificially propagated conifer stands which will become increasingly stressed into close to nature stands that are more resilient to predicted climate change.

Techniques for establishing the trees that will form the future forests stands at the pilot sites have already been tried and tested in the region and are described in detail in the Forest Restoration Guidelines referred to above.

The most difficult aspect of transformation is the choice of species and provenances. That choice must take into account the predicted future climate at the pilot sites. However, the uncertainty around the predictions and the limitations on the availability of native species and provenances that are well adapted to the predicted future climate, will inevitably cause a high level of uncertainty about the resilience of the transformed stands. Further action may need to be taken many years after the transformation measures have been implemented in order to reinforce resilience, including planting species that are better adapted to the future climate at the sites. Those responsible for taking care of the transformed forests after the project has ended will therefore need to implement an adaptive management approach and continuously monitor the health of the stands and be ready to implement further adaptation measures if they become necessary.

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Annex I. Summary Table for Selected Forest Pilot Sites in the South Caucasus Countries

Country	Name of Pilot Site	Land Tenure Status	Owner	Location	Size
			Armenia		
Armenia	1. Koghb FPS (*MoU signed on 29.12.2011*) *http://awsassets.panda.org/downloads/memorandum_of_understanding_dec_29_2011.pdf*	*State Forest Land*	Ministry of Agriculture ⇓ State Organization "Hayantar" (*ArmenForest*) ⇓ Noyemberyan State Forest Enterprise	Tavush Region	78 ha
Armenia	2. Spitak FPS (*MoU signed on 29.12.2011*) *http://awsassets.panda.org/downloads/memorandum_of_understanding_dec_29_2011.pdf*	*State Forest Land*	Ministry of Agriculture ⇓ State Organization "Hayantar" (*ArmenForest*) ⇓ Gugarq State Forest Enterprise	Lori Region	72 ha
TOTAL for ARMENIA					**150 ha**
			Azerbaijan		
Azerbaijan	1. Agsu FPS (*MoU of 20.12.2011*) *http://awsassets.panda.org/downloads/mou_shamakhi.pdf*	*State Forest Land*	Ministry of Ecology and Natural Resources ⇓ Shamakhi Forest Protection and Restoration Enterprise	Shamakhi District	75 ha

Azerbaijan	2. Yevlakh FPS (*MoU of 20.12.2011*) *http://awsassets.panda.org/downloads/mou_yevlakh.pdf*	*State Forest Land*	Ministry of Ecology and Natural Resources ⇓ Yevlakh Forest Protection and Restoration Enterprise	Yevlakh District	75 ha
TOTAL for AZERBAIJAN					**150 ha**
<u>Georgia</u>					
Georgia	1. Tsavkisi FPS (MoU of 11.08.2011) *http://awsassets.panda.org/downloads/mou_geo_site_01_tsavkisi.pdf*	*Muni-cipal Forest Land*	Tbilisi City Mayor's Hall ⇓ Environmental and Green Areas Municipal Service	Municipality of Tbilisi	75 ha
Georgia	2. Khashuri FPS (*MoU of 21.12.2011*) *http://awsassets.panda.org/downloads/mou_geo_site_khashuri.pdf*	*State Forest Land*	Ministry of Energy and Natural Resources ⇓ Natural Resources Agency	Khashuri Municipality	79.9 ha
TOTAL for GEORGIA					**154.9 ha**
<u>South Caucasus</u>					
Grand TOTAL for the South Caucasus					**454.9 ha**

Annex II. Table for Site Selection Criteria

1) **Nature conservation criteria**
   a) Biodiversity indicators occurrence of endemic and/or endangered species
   b) Importance to connect fragmentized habitats (eco-corridor)

2) **Silvicultural/Ecological criteria**
   a) Canopy cover*
   b) Dimension of the forest stand (average height and diameter)
   c) Soil and nutrient situation
   d) Hydrological situation*
   e) Capacity of natural regeneration
   f) Availability of site adapted planting material
   g) Protective function of forest stand
      i) Flood water protection
      ii) Water protection zone
      iii) Erosion Protection
   h) Risk factors
      i) Grazing
      ii) Fire

3) **Legal criteria**
   a) Land tenure
   b) Status of forest land
   c) Legal restrictions for forest transformation measures*

4) **Social- economic criteria**
   a) Support and interest of local population and local government
   b) Possibilities of involvement of local population in work process
   c) Distance to villages
   d) Importance for recreation and environmental education

5) **Other**
   a) Sustainability of the action
      i) Commitment of landowner
      ii) Capacity of land owner
      iii) Possibility of follow-up financing
   b) Visibility

Explanatory notes to site selection criteria for forest transformation:

*Canopy cover: Canopy cover is the foliar cover in a forest stand consisting of one or several layers. It is measured in percentage of full cover. For example a canopy cover more than 30 % would make difficult survival capacity of oak seedlings due to their light requirements.
*Hydrological situation: The Hydrological situation of the site is decisive for the success of seeding or planting. For example extreme dry situations due to exposition or lack of water supply could make impossible survival of plants.
*Legal restrictions for forest transformation measures: For example transformation of forest stands could make necessary felling for opening up of canopy. Possibly measures like this are not covered by national forest legislation.


View of Khashuri Pilot Forest Site, Georgia, Jun-2011 © M.Dzneladze, WWF-Caucasus


View of Agsu Pilot Forest Site, Azerbaijan, Sep-2011 © M.Dzneladze, WWF-Caucasus


View of Koghb Pilot Forest Site, Armenia, Sep-2011 © M.Dzneladze, WWF-Caucasus

WWF Caucasus Programme Office

Merab Aleksidze Str. 11
0193 Tbilisi
Georgia

Tel: + 995 32 237500
Fax: + 995 32 237501

www.panda.org/caucasus
office@wwfcaucasus.ge

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption

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