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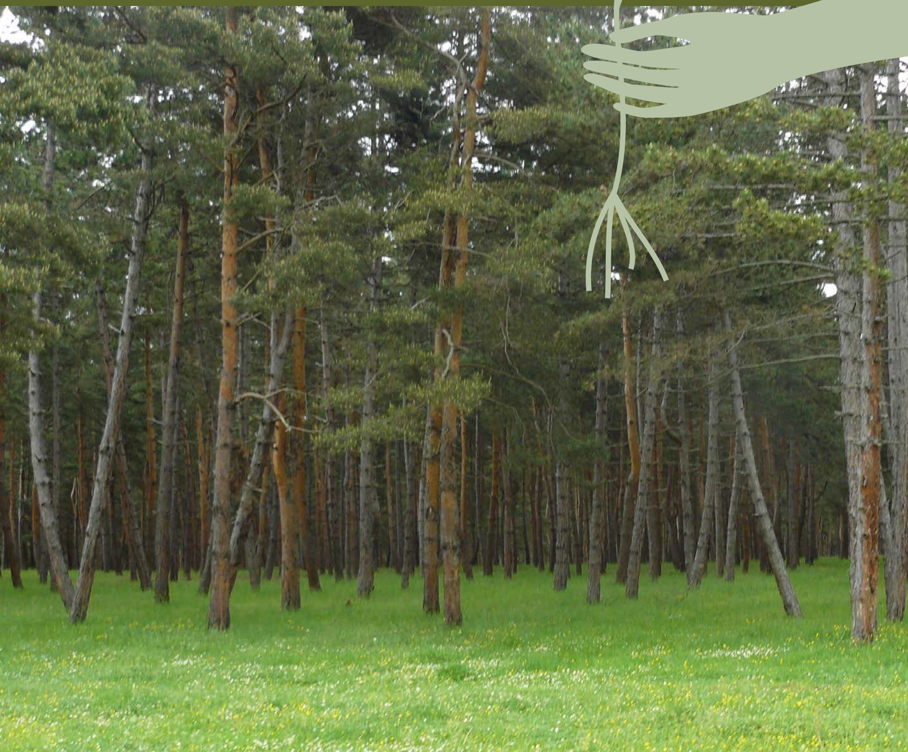
Forest Transformation Guidelines

Transformation of forest plantations in the southern Caucasus to increase their resilience to the impacts of climate change



About this guidelines

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List of abbreviations

BMU	Bundesministerium für Umwelt, Naturschutz und Reaktor sicherheit
WWF-Caucasus	WWF Caucasus Programme Office
ENRTP	Environment and Natural Resources Management includ ing Energy Thematic Programme (of the EU)
EU	European Union
FTSC project	The project “Increasing the resilience of forest ecosystems against climate change in the southern Caucasus through forest transformation”
GCM	General Circulation Model
GHG	greenhouse gas
MNP-AM	Ministry of Nature Protection of Armenia
MENR-AZ	Ministry of Ecology and Natural Resources of Azerbaijan
ha	hectare
UNFCC	United Nations Framework Convention on Climate Change
UNDP	United Nations Development Programme
WWF	Worldwide Fund for Nature

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Foreword

The results of climate modelling indicate that the southern Caucasus region can expect a continuous increase in average annual temperatures and lower average annual precipitation. There will also be more frequent extreme weather events. The geographical ranges in which the region's tree species can thrive will move and in parts of the region where they can no longer thrive the forests which they form will lose their vitally. As a result they will no longer be able to provide the eco-system services on which the people of the region depend, or will provide them in lower amounts.

The purpose of these guidelines is to support the planned adaption of forests in the southern Caucasus countries of Armenia, Azerbaijan and Georgia to climate change. They describe the impacts of predicted climate change on the region's forests and the adaptation strategies that forest managers can implement to mitigate those impacts, thereby helping to sustain the forests' eco-system service functions. The practical measures described in the guidelines are aimed specifically at making artificially established plantation forests more resilient to the impacts of climate change. The guidelines are targeted mainly at forestry practitioners but they will also be of interest to scientists and decision makers. The guidelines are a companion to the Forest Restoration Guidelines which WWF published in 2011 (Forest Restoration Guidelines, 2011).

The guidelines are based on desk research and practical experience obtained from the project "Increasing the Resilience of Forest Ecosystems against Climate Change in the Southern Caucasus through Forest Transformation" which was implemented during 2012-2014. The project was supported by the European Union and implemented by WWF-Germany and its partner organisations - WWF-Caucasus, WWF-Armenia and WWF-Azerbaijan. We express our heartfelt thanks for this support and partnership.

WWF-Germany, WWF-Caucasus, WWF-Armenia and WWF-Azerbaijan will appreciate any comments with respect to further improvement and possible implementation of these guidelines at a wider scale.

Matthias Lichtenberger

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1 Introduction

During 2011-2014 WWF implemented a project "Increasing the resilience of forest ecosystems against climate change in the southern Caucasus through forest transformation" (FTSC project) with funding from the EU in the framework of the Environment and Sustainable Management of Natural Resources including Energy Thematic Programme (ENRTP).

The project piloted methods of transforming forests in six locations in the southern Caucasus - two in Armenia, two in Azerbaijan and two in Georgia. Transformation measures were implemented on a total of 448 hectares. These guidelines have been compiled to pass on those experiences.

First, a short overview is provided on the forest landscapes in the region. This is followed by an account of how the region's climate has been changing and of what the climate might be in the future based on projections from climate models. Then the guidelines describe the impacts of climate change on forests and the effects of projected changes in the climate of the southern Caucasus on the region's forests. Thereafter, the guidelines describe and explain the process of planning forest transformation measures taking into account projected changes in the climate and the suitability of different tree species to future climatic conditions.

As with the companion publication "Forest Restoration Guidelines" it is our hope that these guidelines will be found useful and serve as inspiration for similar efforts in other parts of the Caucasus region or beyond.

2 Forests of the Southern Caucasus

2.1 Types

Forests cover 4 million hectares of the southern Caucasus countries, which makes up 22% of the countries' combined land and inland water surfaces: Armenia 332.33 thousand hectares (11.17%), Azerbaijan 990 thousand hectares (11.4%), Georgia 2,793 thousand hectares (40.7%) (FAO, 2010a). The region's wide variety of climatic zones in combination with variation in soils and relief has provided conditions for the development of a wide variety of forest formations.

Forests dominated by beech (Fagus orientalis) are the largest in hectareage, occupying almost half of the forest area. Oak (Quercus) forests were once widespread have been substantially reduced in range as a result of clearance for agriculture, viticulture and fruit growing and of livestock grazing. Chestnut (Castanea), frequently together with hornbeam (Carpinus) and beech, forms forests in the mountains and foothills of Georgia's Kolkhic region and in some places in the Eastern Greater Caucasus. Chestnut historically has been felled intensively, and this has reduced its area significantly and deteriorated the health of the trees that remain. Dark coniferous forests composed of fir (Abies nordmanniana), spruce (Picea orientalis) and spruce with beech occur in western parts of Eastern Georgia, where they are found in the middle and upper parts of the forest zone. Light coniferous forest formed from pine 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 spp.), maple and elm (Ulmus spp.), lime (Tilia cordata) and alder (Alnus spp.). Birch (Betula spp.), mountain ash (Sorbus caucasigena), high-mountain maple (Acer trautvetteri) form so-called "crooked forests" in the upper margins of the forest zone. In the drier eastern and south-eastern parts of the region arid, sparse forests are formed from juniper (Juniperus spp.) and pistachio (Pistacia mutica), willow-leaf pear (Pyrus salicifolia) and Georgian maple (Acer ibericum). Floodplain forests are found in the lowlands on low river terraces, generally growing on alluvial, swampy or moist soils, and are formed from black poplar (Populus nigra) and white (or silver) poplar (Populus alba), alder (Alnus barbata), ash (Fraxinus excelsior), pedunculate oak (Quercus robur) and field elm (Ulmus foliacea).

In addition to the region's natural forest formations there are about 198 thousand hectares of artificially propagated plantations which were established before the 1990s for various purposes including mitigating the risk of soil erosion, creating a supply of fuel wood for neighbouring

1. Eight species of oak occur in the region. 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 Quercus robur =Q. pedunculiflora. The prevailing species in the Talysh forests is Q. castaneifolia, in the foothills of Kolkhic region Q. hartwissiana, and in Adjara on drier valley slopes Q. imeretina, and Q. dschorochensis prevail. Q. macranthera forms "crooked forests" in the upper forest boundaries in the east and southern Caucasus. The relict and Kolkhic endemic Q. pontica is common in the lower subalpine belt in the western part of Kolkhic region.

communities. In Armenia about 55,000 thousand hectares of plantations were established, in Azerbaijan about 59,000 hectares, and in Georgia about 84 thousand hectares.

2.2 Importance

The region's forests are important for a number of reasons.

Biodiversity. The southern Caucasus is part of 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 region's most important biome for biodiversity, harbouring many endemic and relic species of plants and providing habitats for globally rare and endangered animals.

Carbon storage. In 2010 the forests of the southern Caucasus countries held about 225 million tonnes of carbon in above ground biomass (FAO 2010b), equivalent to about 2.5% of global emissions of carbon dioxide in 2013 (Oliver et al 2013). Preservation of the region's forests therefore makes an important contribution to mitigating climate change.

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. The region's forests are an important source of fuel. According to one study, in 2010 in Armenia 61% of all households still used wood as fuel (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 but locally important wood processing industry.

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

3 Climate change and its impacts on the region's forests

3.1 Changes in the region's climate up to the present day

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. (UNDP 2011).

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). There is an overwhelming scientific consensus that such changes are caused by anthropogenic emissions of carbon dioxide (CO2) and other so-called greenhouse gases (GHG). Climate models make it possible to project, with varying degrees of certainty, changes in the climate as a result of the additional GHGs that have already been emitted into the atmosphere and of future emissions.

3.2 Projected future changes in the climate

In their 2nd national communications to the UNFCC, all three southern Caucasus countries presented projections for changes in precipitation and temperature based on the results of modelling. All the projections indicated that mean annual temperatures will increase significantly by the end of the present century. Projections based on the A2 emission scenario 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. One model projected increases in mean annual precipitation in western Georgia and Azerbaijan, while other models for Georgia project declines. A subsequent study (UNDP 2011) using projections from four General Circulation Models (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.

3.3 How climate change affects forests

Assuming that all other environmental conditions remain constant higher concentrations of CO2 will result in enhanced growth rates. This is because current concentrations of CO2 in the atmosphere are below the levels that are optimum for plant growth. Controlled environment experiments on young trees typically show that biomass production increases by 30–50% when the CO2 concentration is doubled

2. 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

(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. 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 greenhouse gases.

3.3.1 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).

3.3.2 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.

3.3.3 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).

3.3.4 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

capita economic growth and technological change are more fragmented and slower than in other storylines. (IPCC 2000)

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

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). The drought stress of trees will make forests more vulnerable to infestation by insect herbivores and fungal diseases (Kolström, Vilén and Lindner 2011).

3.3.5 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).

3.4 Impacts of climate change on forests in the southern Caucasus

The climate of the southern Caucasus will become less suitable for most of the forest types that occur in the region at present. According to one recent study (Zazanashvili et al 2011), under an ecologically more favourable GHG emissions scenario there could be a reduction of 8% in the area suited to the forest types that occur in the region; under an ecologically less favourable emissions scenario there could be a reduction of 33%. Impacts will vary between bioclimatic zones and between countries; the results of the study suggest that Armenia and Azerbaijan will be affected more than Georgia.

Some forest formations may benefit overall from climate change, but most formations will become stressed and lose vigour. Under the ecologically more favourable GHG emissions scenario 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 for dry woodlands and Zelkova.

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.

Forests and their biological components respond autonomously to long term climate change. The distribution of forests and of different forest types in the southern 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. However, the rate at which tree species migrate is critical. After the last glacial period, tree species migrated a few kilometres per decade or less, compared with a projected rate of shift in climate zones of 50 kilometres per decade. It is therefore a concern 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).

The available evidence suggests strongly 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 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 Kolkhic 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.

4 Strategies for mitigating the impacts of climate change on forests

4.1 Reactive adaptation and planned adaptation

If we want to avoid the consequences of climate change described in the previous chapter we must intervene to help forests adapt. We could intervene reactively - i.e. 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.

The alternative to reactive adaption is planned adaptation, which 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 those uncertainties we need to start now, because the impacts of climate change are likely to be substantial; 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).

4.2 Planned adaptation measures

There are several ways in which we can help forests adapt to climate change:

4.2.1 Increasing the natural adaptive capacity of forests

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, especially by introducing species and provenances that are more resilient, or better adapted to the project future climate, by planting or by promoting them in naturally regenerated stands by selective tending and thinning.

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).

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

4.2.2 Adaptation of fire prevention and control practices

Adaptation of fire prevention and control practices includes 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).

4.2.3 Adaptation of pest and disease prevention and control practices

Adapting pest and disease prevention and control strategies includes: 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).

4.2.4 Adaptation of silvicultural practices to manage declining and disturbed stands

Adaptation of silvicultural practices includes: selectively removing suppressed, damaged, or poor quality individuals to increase light, water, and nutrient availa-

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

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.
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. Build these networks into national and regional planning for large-scale landscape connectivity.

bility 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).

4.2.5 Implementing adaptive management

Forest managers need to plan in the face of uncertainty about the future climate and the response of trees and forest formations to climate change. Adaptive management 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.

The results of scientific research take many years to become applicable and operational on local sites, therefore the concept 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 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).

4.3 Forest transformation 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. This movement towards forest transformation developed even before concern about the impacts of climate change on forest became widespread and 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 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.

The following standard situations and transformation concepts can be distinguished in EU countries:

1. 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):

2. 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).

3. Enrichment of Douglas fir monocultures; e.g. the German State of Hesse (Hessen-Forst 2008).

4. Enrichment of pure beech stands; e.g. the German state of Hesse (Hessen-Forst 2008).

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.

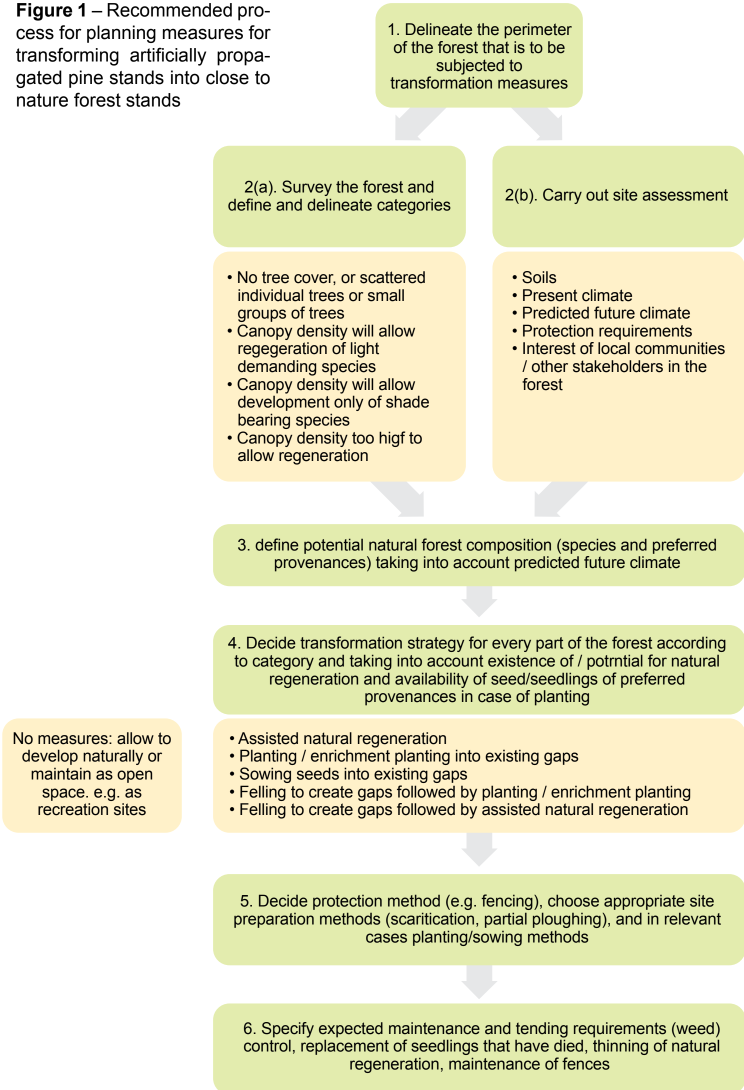
Characteristics of close-to-nature forest management are:

- 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.”

The experience of the German state of Brandenburg is particularly relevant because, as in the Southern Caucasus, the initial situation is usually a mono-cultural 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.

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



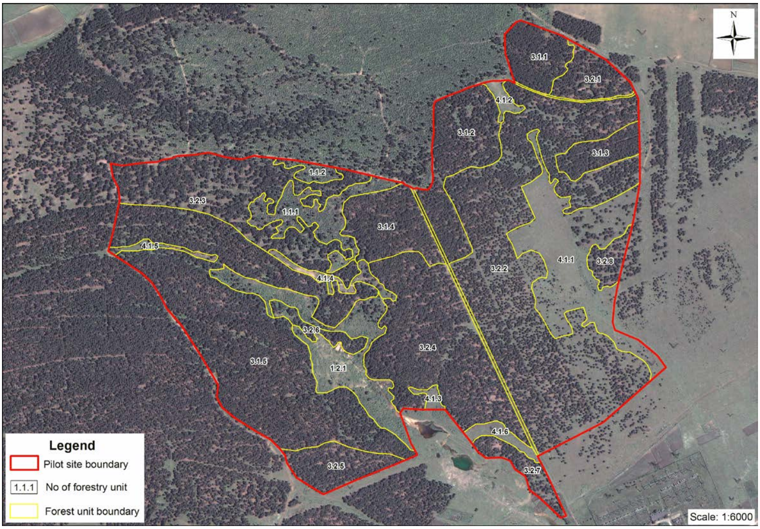
5 Practical guidelines for transforming the region's artificially propagated forests to make them more resilient to climate change

These guidelines focus on the process of elaborating measures to make forests in the southern Caucasus, especially forest plantations, more resilient to climate change. Detailed guidance on specific measures such as fencing, ground preparation, seeding and planting is contained in the companion publication "Forest Restoration Guidelines: restoration of forest landscapes in the southern Caucasus".

The guidelines draw from WWF's experience of the implementing the project "Increasing the Resilience of Forest Ecosystems against Climate Change in the Southern Caucasus through Forest Transformation". The silvicultural focus of the project and of these guidelines is the transformation of monoculture forest stands in the region into highly resilient, "close to nature" forest stands. Thus there are 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".

Resilient in this context means the ability of an 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 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 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

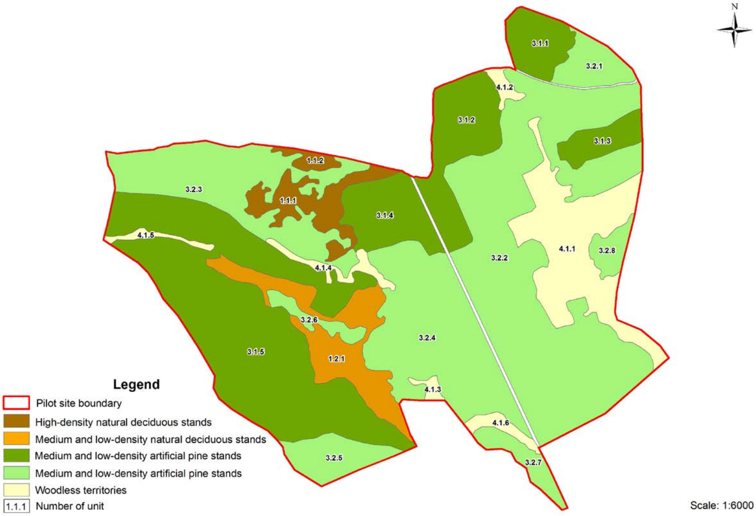
Figure 1 – *Aerial photo showing outer boundary and forest cover. Khashuri pilot site, Georgia*



that are expected in the region. "Close to nature" means 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 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).

Figure 2 – *Map of forest types. Khashuri pilot site, Georgia*



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.

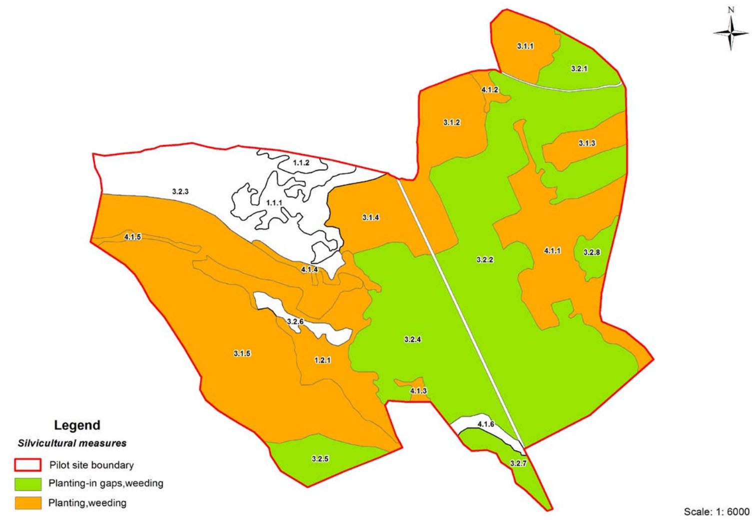
5.1 Process of planning transformation measures

Transformation measures have to be planned taking into account the characteristics of the site (e.g. soil types, pressures such as grazing by livestock), the needs and attitudes of neighbouring communities and of course expected changes in the climate. The FTSC project applied the planning process described in Figure 1.

Step 1 - Delineate the perimeter

The first step in planning transformation measures is to delineate the perimeter of the site on which measures will be implemented. This may seem obvious, but it's important to know the physical boundary within which measures are to planned. In some situations the boundary 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 died, the edges of the plantation are not distinct.; the boundary of a plantation may even be disputed by neighbouring land owners and users and 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 (Figure 1).

Figure 3 – *Map of transformation strategies. Khashuri pilot site, Georgia*



Step 2a - Survey the forest and define and delineate categories

The second step is to divide the territory into categories to provide the basis for planning site- and stand-adapted transformation measures. The categories listed in the diagram in Figure 1 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.

Step 2b - Carry out site assessment

Although the site assessment is presented here as a separate step it can be carried out at the same time as the previous step of defining and delineating categories. The site assessment includes mapping of soils, which is important for deciding which species and the proportions of the chosen species that might be planted in different parts of the stand. 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. A separate and distinct part of this step is to assess how the climate at the site is likely to change. For this the planning team will need to refer to the results of modelling, for example the results presented in the countries' national communications to the Framework Convention on Climate Change. The spatial resolution of climate modelling carried out so far for the southern Caucasus is low, which means that precise predictions cannot be made for individual sites.

Step 3 – Define potential forest composition

After the site assessment the next step is define the potential natural forest composition taking into account the likely changes in the climate at the site. 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 Southern Caucasus in the zone between 500 and 1000 metres oak (Quercus iberica) forests are the dominating natural

forests, while beech (Fagus orientalis) forests form a distinguishably separate zone between 1000 and 1500 metres. However, the projected changes in temperature over the coming decades are large enough to have significant impacts on the functioning of forest ecosystems that are adapted to present day conditions. Therefore serious thought needs to be given to including in the mix of species one or more that are adapted to conditions similar to those projected for the pilot sites and at the very least to using provenances that grow well at the higher end of the temperature range of the species' distribution.

Box 3 – Contents of forest transformation plans prepared for the pilot sites in Armenia, Azerbaijan and Georgia

Technical Statement for Planning Work Design (Client Organization; Planned Area, Planning Organization, Number of Experts Involved etc, Duration of Assignment, linkage with other institutions etc)

Authors and Contributors

Abbreviations

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[Other Attachments if appropriate]

Step 4 – Decide transformation strategy

In this step the transformation strategy for every part of the stand is worked out in terms of 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. As a general rule, existing trees should be felled only when it is necessary to ensure satisfactory establishment of the future trees. The planning team should also consider the option of not implementing any measures in parts of the stand and instead to allow them to develop naturally as future forest or as open space, for example for recreation areas.

Step 5 – Decide protection method and site preparation and sowing/planting 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 (Forest Restoration Guidelines, 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.

The costs of different methods can vary substantially. The planting that WWF did in the FTSC project was very expensive, especially so in Georgia due to the high cost of seedlings. Natural regeneration is a cheaper method when site conditions are suitable and when there are trees of appropriate species that will produce sufficient seed. Fencing to prevent domestic livestock and wild herbivores from eating the young trees is also expensive when the ratio of the perimeter to the area of young trees is large. In such cases engaging with the neighbouring communities that customarily have used the forests for grazing and other resources and getting them to act responsibly may be more cost-effective.

Step 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).

5.2 Forest transformation plan

The final output from the planning process is a forest transformation plan which brings together the information compiled in each of the planning steps and schedules the transformation measures and the resources needed to implement them. The contents of the plans prepared by the FTSC project are shown in Box 3

5.3 Involving local people

All rural communities in the southern Caucasus countries have customarily used their neighbouring forests to help them meet their daily needs. In some cases this use has been allowed or at least tolerated, for example the collection of nuts, berries and mushrooms and sticks cut from shrubs for people's gardens. Such uses affect the forest ecosystem but generally do not threaten the forest's existence. On the other hand the unauthorised cutting of trees for timber or fuelwood and letting domestic livestock into forests so that they can graze are serious threats; but they continue because people often have no alternatives. Rural communities are therefore key actors in the management of forests and WWF's experience with implementing forest conservation projects has demonstrated the importance of involving local people in project planning and in implementing measures. Involving local people in planning helps to identify dependencies of communities on neighbouring forests and pressures which need to be taken into account when planning forestry measures. Involving local people in implementing measures helps to create a sense of ownership and provides some income to people who are often very poor.

It is important to be realistic about the extent to which communities will act responsibility towards their neighbouring forests even if they have been paid to implement measures: sadly, there have been cases of fences being cut and gates opened to allow livestock to be driven into the sites transformed by the FTSC project. Involving local people can help to mitigate the threat of such abuses but will not cancel them completely.

6 Summary and 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. Transforming forest stands into close to nature stands using the approaches described in these guidelines and the techniques described in the Forest Restoration Guidelines will help to make them resilient to predicted climate change. The most difficult aspect of planning transformation is the uncertainty around the predictions of climate change. In addition, the availability of native species and provenances that are well adapted to predicted future climates may be a significant limiting factor for planning transformation measures.

Given the uncertainties surrounding climate change and the responses of species and provenances to climate change it is essential to follow and adaptive management approach. Further measures may need to be implemented many years after the first transformation measures have been implemented in order to reinforce resilience, including planting species that are better adapted to the future climate at the sites.

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