Strategic Guidelines for Responding to Impacts of Global Climate Change on Forests in the Southern Caucasus (Armenia, Azerbaijan, Georgia)

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Explanation of Main Terms

Forest Type -	type depicted on the forestry maps reflecting actual forest cover by the main dominant species (e.g. beech) or species groups (e.g. oak and other broad-leaved species).
Vegetation Formation -	simplified version of formation type based on the Map of the Natural Vegetation of Europe (Bohn et al., 2000/2003).
Comparable Groups -	grouping of Forest Types and Vegetation Formations in a way they can be analyzed correspondingly.
Climax vegetation -	stable vegetation types with natural structure and species composition relevant to certain biotope (climatic, soil, relief conditions, etc.); "Potential Forest Cover" (see below) is based on this concept.
Actual Forest Cover -	area covered by forests nowadays.
Potential Forest Cover -	forest area according to potential natural vegetation concept; type based on the Map of the Natural Vegetation of Europe (Bohn et al., 2000/2003).
Forest Classes -	unified forest types according to modeling needs.
Forest Landscape Restoration -	for the purpose of this document, it is considered an approach when forest restoration activities are based on climax/potential natural vegetation concepts, considering actual landscape conditions, including socio-economics.
Bioclimatic Regions -	geographical subdivision units defined by general humidity differences reflecting on main vegetation formations' and forest types' ecology and distribution based on subdivision scheme of mountain zoning in the Caucasus (Zazanashvili et al., 2000).

Abbreviations

AFC -	Actual Forest Cover
a.s.l. -	Above sea level
CART -	Classification and Regression Tree Analysis
CBD -	Convention on Biological Diversity
CCCMA -	Canadian Centre for Climate Modeling and Analysis
COP10 -	10th Conference of Parties
DEM -	Digital Elevation Model
GBIF -	Global Biodiversity Information Facility
GIS -	Geographic Information System
IPCC -	Intergovernmental Panel on Climate Change
PFC -	Potential Forest Cover
NDA -	No Data Available
VIF -	Variance Inflation Factor

Executive Summary

Forests in the Caucasus Region

The Caucasus region is one of the most biologically rich regions on earth and is a home to a large number of forest formations of rich typological composition. The region's forest cover today is much less than before human beings started to clear forests on a substantial scale for agriculture and settlements. Comparison of present day forest cover in Armenia, Azerbaijan and Georgia with the potential forest cover determined by the study indicates that 55% of forest cover has been cleared, equivalent to 5 million hectares from a potential former area of 9 million hectares.

Some forest types have suffered greater losses than others: five forest types-eldar pine, juniper-pistachio-hackberry, flood plain oak and poplar-willow, subalpine birch-poplar-ash, and Colchic chestnut-buxus-zelkova-stand at less than 25% of their potential area; four forest types-dark conifers, pitsundian pine, beech-taxus, and Caucasian pine-stand at more than 50% of their potential area.

Absolute and percentage losses vary between bioclimatic region with losses of up to about 90% in the South Uplands and Dry Plains and Ridges regions, between 50% and 75% in the East Caucasus, Southern Lesser Caucasus and the Hyrcan regions, and 42.91% in the Colchic region. Even though the lost of forest cover in the Colchic has the lowest rate, it has the second highest loss in terms of hectares (1,239,671.2 ha) and is just outranked by the East Caucasus region (2,537,467.0 ha). The lost of forest cover in these two regions contribute 75.01% of the total hectares lost in the study area.

Losses also vary between the three countries in the study area. According to the results of the study Georgia has the largest deficit (2,484,784.2 ha) and Armenia the smallest (613,410.2 ha). However, by percentage, Armenia has the highest deficit (68.15%) and Georgia the smallest deficit (46.32%).

Goods and Services Provided by the Region's Forests

The forests that exist in the region today provide a wide variety of goods and services, some of which are essential for people in the daily lives while others contribute to the longer term ecological stability of the region. The most obvious and most used good is the wood from forest trees, which provides construction timber and fire wood; other goods, which may be as important as wood to some people, are the nuts, berries and mushrooms which grow in the forests, and meadows which form part of the forest landscape and which provide pasture and hay.

Environmental services include the regulation of water flow and water quality, stabilization of soils: forests help to mitigate the risk of flash floods, soil erosion and landslides. Forests also help to mitigate greenhouse gas emissions by absorbing and storing carbon dioxide.

Forests and Climate Change

The world is becoming warmer as a result of anthropogenic emissions of carbon dioxide and other greenhouse gases-emissions from power stations, vehicles, domestic wood stoves, and clearance of forests, which alone contributes 30% of total emissions. Global warming has already started to cause changes in the climate, and the climate will continue to change for decades to come even if emissions of greenhouse gases were cut immediately to pre-industrial levels.

The biological components of forest formations will respond to changes in the climate as they have always done: some components of some formations may do better; others do worse; generally, the range of suitability for the present day forest formations will change. The models which were run in the study predict that conditions in the southern Caucasus will become less suitable for most forest classes that occur in the region; overall there could be a reduction of 8% in the area of the southern Caucasus suited to the forest classes that occur in the region today compared with actual forest cover in 2011 under the ecologically more favorable climate scenario and a reduction of 33% under the ecologically less favorable climate scenario. Impacts will vary between bioclimatic zones and countries with Georgia being affected less overall than Armenia and Azerbaijan. The impacts on forests will take many years to show and while some forest formations may benefit overall from climate change, most formations will become stressed and lose vigor. Unless species or genotypes that are better adapted to the changing conditions are able to colonize the site the forest will gradually disappear.

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

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

Responding to the Impacts of Climate Change

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

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

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

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

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

Adapting to Changes in the Forest

Whatever is done to mitigate the impacts of climate change on forests, there will be unavoidable changes in the type, quantity and value of the goods and services which forests provide. Society will have to adjust to these changes: people may have to become less dependent on firewood; they may have to find substitutes for the mushrooms, berries and nuts which they harvest from their local forests; and in extreme cases they may have to develop alternative livelihoods; our societies will be forced to face changes in the region’s biodiversity and in the character of the region’s landscapes; in extreme cases we may have to prepare ourselves to resettle entire communities; and to conserve rare species and species delicate to climate change will demand a big effort from responsible authorities and civil society. Most likely in situ measures for the conservation of forest genetic resources will have to be accomplished ex situ measures as well. A strategy should be developed according to the CBD.

Mitigation and Adaptation Strategies for the Southern Caucasus Countries

The governments of Armenia, Azerbaijan and Georgia are now committed to elaborating and implementing forest adaptation strategies. Those strategies must address research needs, educational needs, information to evaluate how forests respond to climate change, the mitigation and adaptation options that are available, barriers to implementing mitigation and adaptation measures, the policies and instruments that need to be put in place, and monitoring to identify problems and allow an early response.

Different actors are very likely to have different attitudes towards the impacts of climate change in forests, towards mitigation and adaptation goals and therefore towards possible responses. Adaptation could involve large-scale changes in land use, for example restoration of forest on land that has been used as pasture for many generations. An essential part of developing an adaptation strategy is dialogue between policy makers, people who use or depend on forests, people who manage forests, and researchers.

We conclude the report with some suggestions for objectives and targets for the forest adaptation strategies, which Azerbaijan, Armenia and Georgia must soon start to prepare. We suggest targets for the process of developing the strategies and targets for measures, which are incorporated into the strategies. We consider the objectives and the targets to be appropriate and feasible, though challenging. We offer them as a starting point for the dialogues on forest adaptation, which should precede the adoption of the national strategies, keeping in mind the regional strategic context.

1. Introduction

1.1. The Caucasus Ecoregion

The Caucasus region[1] covers a total area of some 580,000 km^2 in the nations of Armenia, Azerbaijan and Georgia, the North Caucasus portion of the Russian Federation, the north-eastern part of Turkey, and a relatively small part of north-western Iran (Fig. 1). One of the most biologically rich regions on Earth, especially in the temperate context, the Caucasus is ranked among the planet's 34 most diverse and endangered hotspots by Conservation International (Mittermeier et al., 2004). The Caucasus, as part of the newly defined Greater Black Sea region, is one of WWF's 35 Priority Places, identified as focal among globally outstanding Ecoregions (WWF, 2008).

Fig. 1: Caucasus Ecoregion/Hotspot (Zazanashvili et al., 1999; CEPF 2003; Williams et al; 2006)

In terms of its origin, the Caucasus isthmus is part of the huge mountain belt, formed during the Alpine Orogeny that embraces the whole of Eurasia from the Pyrenees and the Atlas Mountains in the west to the Malay Peninsula and Vietnam in the East. The Caucasus is a region of natural contrasts, and is composed of several prominent elements, including the Greater Caucasus Range, the South Caucasian Depression (from the Black Sea coastal, Colchic lowlands in the west to Absheron peninsula on the Caspian), the Lesser Caucasus Mountain Chain and the South Caucasian Uplands (covering parts of the Asia Minor, the Armenian and Iranian Upland, with the highest point being Great Ararat at 5,165 m). There is relief, with erosional-tectonic and accumulation forms being sequenced by volcanic, glacier, and karst (limestone) forms. Glaciers are concentrated mainly in the Greater Caucasus Range, with over 2,000 of them covering 1,450

[1] The definition of the region is as was presented in Zazanashvili et al. (1999), in CEPF Ecosystem Profile for the Caucasus Biodiversity Hotspot (2003) and Ecoregional Conservation Plan for the Caucasus (Williams et al., 2006).

km^2, without considering constant melting process during the last 20 years. Not surprisingly, the climate is very variable. Mean annual rainfall in the south-western part of the region is quiet high, exceeding 2,000 mm in the coastal area of the Black Sea (up to 4,500 mm), while in the south-eastern part of the Caspian coast it rarely exceeds 200 mm. Mean annual temperature in the Southern Caucasus part of the Black Sea coats and the Caspian Sea coast is 15^{0}C, declining from south to north, from the seacoasts to inland and with increasing altitude.

1.2. Forests of the Southern Caucasus

Before men made serious changes to the distribution of vegetation, medium and low mountains of the Caucasus were primarily covered by forests. In some locations forests also covered large areas of lowlands. That was mainly due to climatic factors. Forests usually come down to the sea level in areas where the annual precipitation exceeds 1,000 mm, for instance, as in Colchic and the Hyrcan (Tallish) regions. In arid (dry) mountains of the Arax river basin, forests retreat up almost to the subalpine zone. Fluctuations of the natural upper limits of forests occurred in a smaller range: in most of the cases those changed within 2,200-2,650 m above the sea level (a.s.l.).

The rather small territory of the Caucasus is a home to a large number of forest formations of rich typological composition. Species composition of tree stratum dominants is not as complex as their phyto-sociologic diversity; most formations are mono-dominant or with several dominants (with 2-3 dominant species); poly-dominant forest types are rare and occupy smaller areas.

Floro-genetically, the composition of the trees and the understory shrubs is quite diverse, reflecting different stages of the complex history of the Caucasus vegetation. There are two Tertiary refugia in the region–centres of plant endemism: the Colchic in the catchment's basin of the Black Sea and the Hyrcanian at the extreme south-eastern end of the Caucasus, covering the eastern slopes of the Talysh Mountains (and northern slopes of the Alborz Mountains) at the southern coastal area of the Caspian Sea. Even now, many relicts, including evergreen, forms still appear as dominants or co-dominants in a number of plant communities. These include *Quercus pontica*, *Betula medwedewii, Epigaea gaultherioides, Rhododendron ungernii,* and *Rh. smirnowii* in the Colchic; and *Quercus castaneifolia, Albizia julibrissin, Gleditsia caspia, Parrotia persica,* and *Danae racemosa* in the Hyrcan.

At the same time these unique forests can mostly be classified as temperate rainforests, due to the same principal reasons as for other temperate rainforest regions: relevant slopes of barrier-mountains located along coastlines that trap a large portion of the humidity from oceanic air masses. In the Caucasus, these barriers are formed by a topographical triangle created by the intersection of the western part of the Greater Caucasus Mountain Range (Georgia, Russia), western part of the Lesser Caucasus Mountain Chain (Turkey, Georgia) and Likhi ridge (bridge ridge between Greater and Lesser Caucasus, Georgia) at the Black Sea, and by the Talysh-Alborz Mountain Range at the southern and south-western coast of the Caspian (Iran, Azerbaijan). Montane barriers also contribute to a warm and humid climate that has been present since the late Tertiary and is the primary reason that the Caucasus has acted as a shelter for humid- and warm-requiring (hygro-thermophilous) relicts during the previous ice age. Consequently, Colchic and Hyrcan forests are the oldest forests in Western Eurasia in terms of their origin and evolutionary history, the most diverse in terms of relict and endemic woody species and tree diversity, and the most natural in terms of transformation of historic structure (Nomination, 2009).

The hemixerophilous element of the forest flora is diverse in species, ages and origin. Most species are associated with continental areas of the southern and eastern part of the Southern Caucasus.

Some form forests, other are components of dry open woodlands. Widespread European forest species or their close relatives from the Caucasus may not be most numerous but indeed are most important in terms of their forest-forming capacity. Both main species of the Caucasus dark coniferous forest-Caucasian fir (*Abies Nordmanniana*) and Orinetal spruce (*Picea orientalis*) are taxonomically somewhat isolated from contemporary European species, but to some extent are similar to them in ecological properties and areas occupied in mountain landscapes.

The region is bioclimatically divided as follows (Fig. 2):

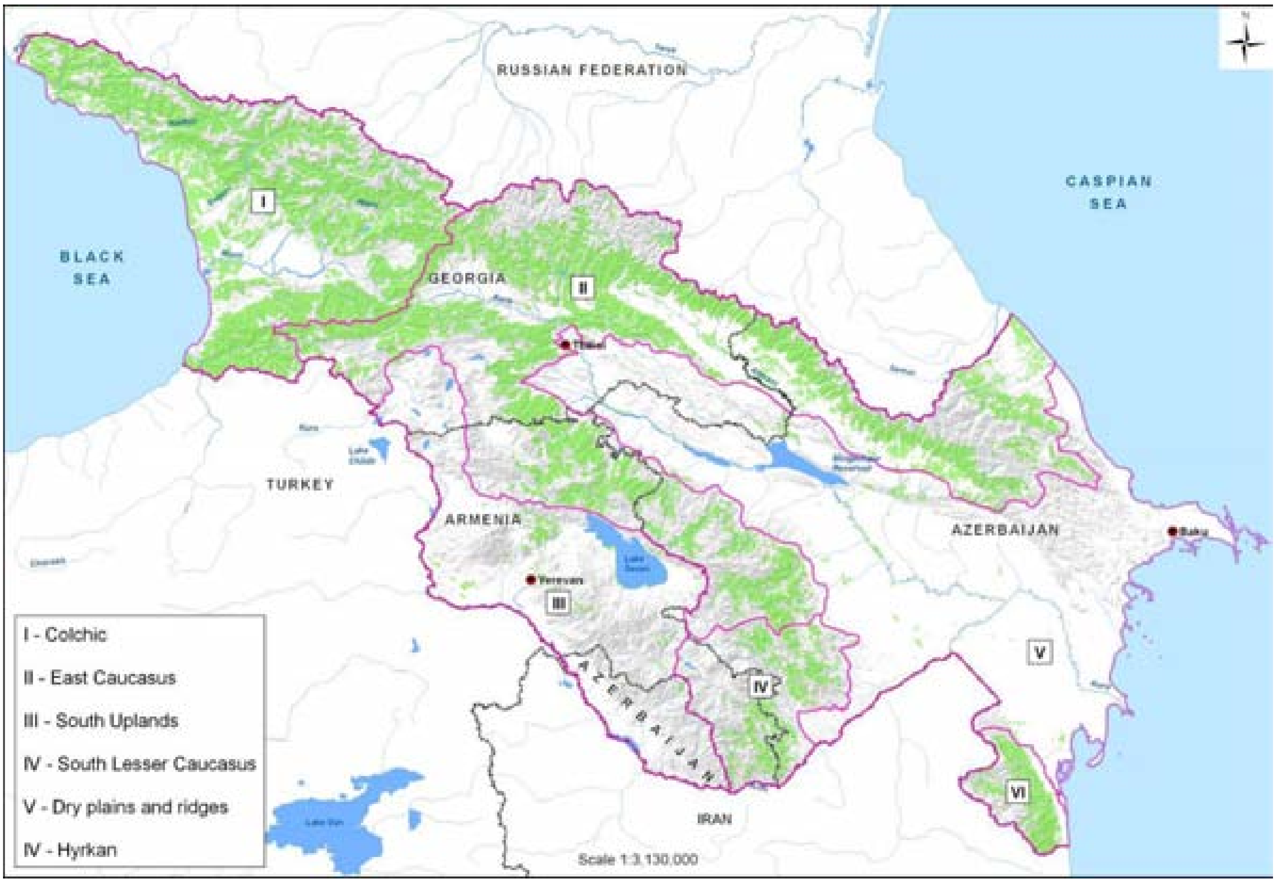

Fig. 2: Bioclimatic regions in the Southern Caucasus (after Zazanashvili et al., 2000)

I. Colchic (West Caucasus) type

This type is characteristic of the western sections of the Great Caucasus range and of the Lesser Caucasus mountain chain, mainly where the Caucasus embraces the Black Sea catchment's basin, (i.e. to that region, where one of the refugia of hygro-thermophilous representatives of the Tertiary flora existed during the ice-age). This type was formed under humid conditions (mean annual precipitation is mostly more than 2,000 mm, in certain places it even exceeds 4,000 mm). The main characteristic of this type is a wide distribution of Colchic relicts along the whole zonal altitudinal profile, almost from sea level up to 2,300 m. Mostly Colchic relicts either form a 2-4 m tall dense understorey in different forest types, or they occur as independent shrub communities in certain habitats. Here, in the Southern Caucasus (lower subalpine belt) endemic oak and birch elfin woods are found, with *Quercus pontica*, *Betula medwedewii* and *B. megrelica*; other endemic relicts include *Rhododendron ungernii, R. smirnowii*, *Epigaea gaultherioides* and *Corylus colchica*. (For a description of the typical zonal altitudinal profiles for this forest, check Appendix A, Table A1).

II. East Caucasus type

This type is characteristic of the eastern section of the Great Caucasus range and north-eastern part of the Lesser Caucasus mountain chain. The climate has continental features over most of the area: mean annual precipitation varies from 600 to 1,000 mm limits. Besides, the northern slope of the Eastern Great Caucasus and the Lesser Caucasus are drier than the southern slope of the Eastern Great Caucasus, which is reflected on the zonation sub-type level. Furthermore, in comparison with the humid Colchis, corresponding zones are located 100-200 m higher here. Due to the absence of refugia the zonation is relatively simple. (For a description of the typical zonal altitudinal profiles for this forest, check Appendix A, Table A2).

III. South Uplands type

This type is characteristic of the uplands/plateaus and mountains of the Southern Caucasus mainly composed of volcanic sediments. Here representatives of the Caucasian relict flora do not occur: Anatolian-Iranian components predominate in the plant communities' floristic composition; the typical forest zones are not characteristic of the zonal altitudinal profile which is formed in xerothermic, continental conditions: the mean annual precipitation varies within 250-500 mm limits and increases in high-mountain regions. In comparison with humid regions in the Caucasus the corresponding zone limits are situated 300-400 m higher. Forests here are located in higher mountain zones only. (For a description of the typical zonal altitudinal profiles for this forest, check Appendix A, Table A3).

IV. Southern Lesser Caucasus type

This type is characteristic of southern part of the Lesser Caucasus Mountains. From northern part of the Lesser Caucasus the main differentiating feature here is absence of beech forests, which is indicated drier conditions as well. In comparison with humid regions in the Caucasus the corresponding zone limits are situated approximately 200 m higher. (For a description of the typical zonal altitudinal profiles for this forest, check Appendix A, Table A4).

V. Dry Plains and Ridges type

This type is characteristic of dry chain of low mountain ridges and plains located between the Greater and Lesser Caucasus in the east part of the region. The climate has continental features with very hot and dry summer and dry and mild winter. Mean annual precipitation varies from 400 to 600 mm limits, which together with historical development of vegetation cause existence of open dry woodlands of juniper species and pistachio as main landscape type. Forest zonation is one of the simplest in the Caucasus. Differential tree species is relict and endemic *Pinus eldarica* survived only on 800 ha in Eldar pine reserve in Azerbaijan at the border with Georgia. (For a description of the typical zonal altitudinal profiles for this forest, check Appendix A, Table A5).

VI. Hyrcan type

This type is characteristic of the extreme southeastern part of the Caucasus, southeast Azerbaijan and the northwest Iranian mountains along the Caspian Sea coast. Here the other refuge from the Tertiary flora, the Hyrcanian refuge, occurs. There is more difference than similarity between the Colchic and Hyrcanic refugia. In the Hyrcanic area evergreen species are less widely distributed and are of less phytocoenotic importance. Besides, if relicts are spread from sea level to alpine belt in Colchis, communities in Hyrcanic area, where relicts appear as dominants and co-dominants, reach only up to 800-1000 (1,200) m. Due to local climatic peculiarities, the lower zones of the mountains are more humid than the upper zones: the mean annual precipitation in the lower mountain area is 1700 mm (expressed by summer minimum), while the mean annual precipitation above 2,000 m is 300-400 mm. (For a description of the typical zonal altitudinal profiles for this forest, check Appendix A, Table A6).

Broad-leaved forests (mainly with beech, oak, oak-hornbeam, chestnut, etc.) form the picturesque forest landscapes of the Caucasus. Beech (*Fagus orientalis*) forests growing on brown mountain-forest soils are the biggest in area and timber stock, and play a leading role in the forest industry of countries of the Southern Caucasus. In Colchis, these spread almost from the sea level to the upper forest boundary. At 1,000-1,400 m a.s.l., beech is partially substituted with dark conifers, but in areas where no fir and spruce are found, the middle and upper belts of the forest zone are mainly formed by beech. In less humid areas of the Southern Caucasus the lower boundary of the beech forests moves higher in mountains. In these cases beech mainly grows on northern slopes, leaving more lighted slopes to oak, oak-hornbeam, and hornbeam forests. Beech forests of the Greater Caucasus are primarily all-aged. In regions where proper forest management is in place, there are satisfactory rates of forest natural regeneration.

Oak forests growing on grayish brown and brown mountain soils used to be among the most widespread forests in the Caucasus. Yet land farming has significantly areas under them, as they occupied territories favorable for crops, fruit and grapes. Shrinking of the oak forests is also due to grazing that prevents natural regeneration. Oak forests have primarily survived to date in hard-to-access ravines or comparatively poor soils and steep rocky slopes where the oak trees have low production rates. The Caucasus forests where oak prevails are very diverse in typology and structure. Floristic composition of the trees, understory and grass there is richer than in other forest formations. These forests are rich in widespread nemoral species; also involve a lot of Caucasus endemic species. *Quercus iberica* is the main species of oaks in the lower and middle parts of the forest zone in the Southern Caucasus. In the eastern part lowland/riverside and flood plain forests mainly include typical *Q. pedunculiflora*; *Q. castaneifolia* prevails in Talysh forests, *Q. hartwissiana* and *Q. imtretina*–in foothills of Colchic region, and *Q. dschorochensis* prevails in Adjara drier slopes of valleys. Old relict and Colchic endemic *Q. pontica* is common species for 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*). In areas where these types are felled, there are secondary growths with prevailing hornbeam or even dense hornbeam stands. The oak to hornbeam ratio depends not only on environmental conditions and age. The oak and hornbeam forests and secondary hornbeam stands are of low productivity are typical in the lower mountain belts of the eastern Southern Caucasus (especially in the Kura river basin), but are also found in some other areas. The hornbeam is frequently prone to degradation and substituted by Christ's-thorn shrubs (*Paliurus spina-christi*).

Chestnut, frequently together with hornbeam and beech, forms forests growing on mountain yellow soils and acidic mountain-forest brown soils in 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 m a.s.l., and in Eastern Southern Caucasus between 500 and 1,100 m a.s.l., avoiding carbonate soils. 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. Trees of seed origin are rather few, and stem wood prevails, which poses a threat of mass chestnut forest loss due to fungus diseases. Restoration of this unique precious species in favorable soil and climate conditions should be identified as one of the most urgent forest management objectives in many regions of the Caucasus, especially in Colchis.

Dark coniferous forests (fir, fir-spruce, beech-spruce) are spread 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 m a.s.l.). These forests mainly grow on acidic and typical brown mountain forest soils. The most optimum level for dark coniferous forests ranges from 1,400 to 1,750 m a.s.l. Some fir trees reach 60-65 m in height. Yet these are rare exclusions. Average reserves even in best stands unaffected by felling do not exceed 900 m^3 per ha. Dark coniferous forests have been the most important source of timber supply for forest-related industries (mainly paper production) of the Caucasus. Yet cutting for local needs and forced shelter wood cuts have exhausted the timber reserves, strongly reduced productivity by deteriorating the growth of industrial wood and have affected the health of a number of forests.

Pine forest consisting of the Caucasus mountain race of the *Pinus sylvestris* (*P. kochiana*) is most widespread mainly in the upper reaches of the Kura river catchment. Small islets of pine trees are found far outside the main massifs of their contemporary development.

In addition to the above-listed types of mountain forests, there are many other types found in the Caucasus, including maple and maple-elm forests, lime tree forests, and alder forests; different mixed forests are spread in mountain ravines, on rocky and stony slopes.

At timberline the trees form crooked-steam forests, open woodlands and low forests. Crooked-steam forests are common in mountains with very snowy winters; in drier and more continental climate the natural timberline consists mainly of shrublands and low open woodlands.

Tree species at the upper boundaries include birch (*Betula* spp.,), mountain ash (*Sorbus caucasigena*), beech (*Fagus orientalis* in the western Caucasus), oriental oak (*Quercus macranthera* in the east and southern Caucasus), high-mountain maple (*Acer trautvetteri*), here and there pine (*Pinus kochiana*).

Eastern spruce (*Picea orientalis*) and Caucasus spruce (*Abies nordmanianna*) grow in the western part of the Caucasus; there are also relic species, including Colchis endemic species that even prevail in some areas.

In the Southern Caucasus that has no forest-steppe zone, lower boundaries of the forest zone usually consist of Georgian oak of low growth class, with a storey of hornbeam or hemixerophilous shrubs and small trees: hawthorn (*Crataegus*), medlar (*Mespilus*), dogwood (*Cornus*), everlasting thorn (*Pyracantha*), quince (*Cydonia*), fustic (*Cotinus*), spiraea (*Spiraea*), and others.

In the eastern and southeastern parts of the Southern Caucasus, elements of arid sparse forests appear on dry and stony slopes with brown and grayish brown, frequently detritus soils, including willow-leaf pear (*Pyrus salicifolia*), Georgian maple (*Acer ibericum*), species of hackberry (*Celtis*), here and there squamous plants, including *Juniperus spp.* and aleppo (*Quercus araxina*), and the underwood consists of the Christ's thorn, Cotoneaster, brier, bladder fern (*Cystopteris*), jasmine and sumac (*Rhus*). Open dry woodlands are mainly represented by juniper (*Juniperus spp.)* and pistachio (*Pistacia mutica*). Representative species of mountain-xerophytic and mountain-steppe species prevail in underwood and grass cover in the juniper forests. Occasionally open woodlands primarily consist of willow-leaf peers; there are also *Celtis*, *Acer iberica*, and

Amygdalus fenzliana. In Zangezur there are also sparse forests consisting of *Quercus araxina*. In Eastern Southern Caucasus *Punica granatum* is a typical species forming sparse formations.

There are few arid sparse forests left today. They are most frequently substituted by mountain xerophytes, sparse dry shrublands or secondary beard grass (*Botriochloca*) steppes, semi-deserts and even deserts. In the past, open dry woodlands used to occupy larger areas, being one of the leading components in phytolandscapes of arid regions in the Eastern and Southern parts of Southern Caucasus.

Plain forests on alluvial, bogged and marsh soils of floodplain and river terraces very much differ from mountain forests in their composition, structure, and ecoprofile. There are almost no areas of these forests that would be in satisfactory condition today. Plain forests of the Colchis lowlands and the Alazani-Agrichay valley are most interesting in terms of their origin and typological composition. Their common typical feature is presence of lianas that are especially exuberant in windows, sparse forests, at forest edges, along roads and riverbanks (Dolukhanov, 1966).

2. Forests and Climate Study

It is well recognized that even though climate has been always changing, human activities have been a disruptive force that has been accelerating this process (Eeley, Lawes and Piper, 1999; Iverson and Prasad, 2001). This has mainly been caused by increase concentration of so called greenhouse gases, which in turn might be leading to changes in climate, such as temperature rise, changes in seasonality and precipitation patterns, as well as accelerated sea level rise (Boompragob and Santisirisomboon, 1996). According to Iverson and Prasad (2001, p. 186), “this warming trend would cause major changes in all living systems, including forests.” For instance, Melillo (1999) and Shriner and Street (1998) estimated that one third of Earth’s forest cover could be clearly altered because of climate change (as cited in Iverson and Prasad, 2001).

Paleo-ecological studies, as well as mechanistic and statistic models have been used as approaches to predict potential forest response to climate change (Hamann and Wang, 2006; Iverson and Prasad, 2001). In this strategic document, outputs from a ‘statistical model’[2] on the study area forest cover provide the data to estimate its potential extirpation rate due to changes in climate based on emission sceneries A2a and B2a (see below).

Using the same modeling approach to predict forest response to climate change and in some cases even at the same biodiversity level (i.e., species level), similar studies have been done around the world, mainly at country level or within its boundaries. For example, Iverson and Prasad (2001), and Thompson et al. (1998) respectively evaluated the distribution of 80 eastern tree species and 16 western tree species for the United States of America. Also, Hamann and Wang (2006) assessed potential climate change impacts on forest communities and 48 tree species in British Columbia, Canada. In South Africa, Eeley et al. (1999) determined the influence of climate change on the distribution of forest subtypes in the KwaZulu-Natal. Similarly, Boompragob and Santisirisomboon (1996) and Ravindranath et al. (2006) modeled the potential impact of climate change on forest in Thailand and India, respectively. Meanwhile, Sykes et al. (1996) modeled the response of 19 North European tree species to climate change for the whole continent using a mechanistic modeling approach.

[2]Statistical models, also know as envelop analysis or envelop modeling, “… generally use empirical data to define relationships between current species distribution and environmental [especially climate drivers]” (Iverson & Prasad, 2001, p. 187).

Like in Iverson and Prasad (2001), classification and regression tree analysis (CART) was used to model habitat suitable areas of forest classes in the Southern Caucasus, also referred as study area. CART was chosen because (a) its algorithm is simple to understand and interpret, (b) it captures non-linear relationships between dependent and independent variables without prior transformations of variables, (c) it's able to handle both numerical and categorical data, (d) the explanation for the results is easy to understand (i.e. 'white box model' vs. 'black box model' such as artificial neural networks), (e) it's possible to validate a model using statistical tests, and (f) it performs well with large data in a short time.

This extract of similar studies between forest cover and climate change show the relevance of such similar effort for Armenia, Azerbaijan and Georgia. Likewise, it was directly or indirectly concluded in the above listed examples that even though these studies have been laden with assumptions, they do provide a picture on how species and forest types might react if the climate continues to change. According to Spittlehouse (2005), this kind of studies constitutes one of the steps needed for integrating climate change adaptation into forestry management or as Noss (2001) sees it, one of the areas that need to be researched to refine recommendations (strategies for adapting to climate change).

The relevance of these studies have been stipulated in recent international agreements/conferences as well, such as the 10th Conferences of the Parties (COP 10) of the Convention on Biological Diversity (CBD), which in its Decision 33, point 8, literal 'a' invites parties and other governments to "identify, monitor and address the impacts of climate change … and assess the future risks for biodiversity and the provision of ecosystem services using the latest available vulnerability and impact assessment frameworks and guidelines" (CBD, 2010, p. 2, at https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf).

2.1. Methods

This section includes a description (a) of what and from where needed information was collected (Background Information), (b) the tools and procedure used to model habitat suitability of forest classes (Habitat Suitability Modeling), and (c) how the amount of lost area and under threat due to climate change were estimated, as well as the altitudinal shift of forest classes (Spatial Trend Analysis).

Basic mapping and analysis scale was 1:500,000.

2.1.1. Background Information

Existing needed information was collected from different sources to develop this strategic document. Among these sources, it can be listed:

(a) Map and database of actual forest cover compiled by WWF-GIS unit depicting actual distribution of dominant forest species, based on GIS information and paper maps provided by partners and contributors from Armenia, Azerbaijan and Georgia;
(b) GIS map and database of natural potential forests prepared using Map of Natural Vegetation of Europe (Bohn et al., 2000/2003);
(c) Global occurrence data on each forest class downloaded from the Global Biodiversity Information Facility (GBIF);

(d) Global climatic layers (spatial resolution of 1-km cells) and the future climatic layers (spatial resolution: 30 arc-seconds = ~1km) based on climate model CCCMA (Flato et al., 2000) and emission scenarios A2a and B2a (IPCC, 2007) for year 2080 downloaded from WorldClim version 1.4 (WorldClim, 2010).

Although not used to develop the habitat suitability model of forest classes, the Map of the Bioclimatic Regions of the Caucasus was developed (based on existing relevant maps) and used to divide the study area into another level of analysis (bioclimatic regions). Therefore, information on boundaries of each bioclimatic region were just digitalized and used to group the information collected in maps and forest cover distribution models.

2.1.2. Habitat Suitability Modeling of Forest Classes

ArcGIS (ESRI, 2008), ERDAS imagine (Leica Geosystems Geospatial Imaging, 2005), and SPSS v. 16 (SPSS, 2007) were used to model the habitat suitability of forest classes. The first two softwares were used to sample, mapped and managed layers of global climatic variables and forest classes. Meanwhile, the last software was used to conduct statistical analyses and collinearity diagnostics.

It is important to stress out that modeling suitable habitats from a set of many predictors (i.e., independent variables) has to be considered with caution. Inclusion of all available variables in the modeling usually results in high predictive power at local spatial and temporal scales. However, this all-variable approach fails to reflect realistic species-specific tolerance limits and interactions between predictor variables that make sense for the response of the independent variable at broader spatial and temporal scales.

Moreover, any modeling method assumes tolerance limits and correlations among independent variables measured at training locations to be true underlying ecological relationships. Models based on these assumptions may perform well within the extent of training locations but prove wrong outside the extent. The exclusion of redundant or collinear predictor variables is highly recommended to avoid an artificial increase in model explanatory power. Therefore, before modeling the habitat suitability of forest classes, one point per square kilometer was firstly created within each polygon of the forest class layer in order to avoid repeated sampling of climatic variables (Table 1). Secondly, these sampling points were used to extract values of climatic variables from global climatic layers. Subsequently, multicollinearity of predictor variables was diagnosed by checking a variance inflation factor (VIF)[3].

Table 1: Predictor variables used for modeling forests throughout the Caucasus

Variable	Description
Bio1	Annual Mean Temperature (^{0}C* 10)
Bio2	Mean Diurnal Range (Mean of monthly (max temp - min temp))
Bio3	Isothermality (Bio2/Bio7) (* 100)
Bio4	Temperature Seasonality (standard deviation *100)
Bio5	Max Temperature of Warmest Month (^{0}C* 10)

[3]The variables with a VIF value > 10 were removed from the subsequent analyses (Bowerman and O'Connell, 1990).

Variable	Description
Bio6	Min Temperature of Coldest Month (^{0}C* 10)
Bio7	Temperature Annual Range (Bio5 - Bio6)
Bio8	Mean Temperature of Wettest Quarter (^{0}C* 10)
Bio9	Mean Temperature of Driest Quarter (^{0}C* 10)
Bio10	Mean Temperature of Warmest Quarter (^{0}C* 10)
Bio11	Mean Temperature of Coldest Quarter (^{0}C* 10)
Bio12	Annual Precipitation (mm)
Bio13	Precipitation of Wettest Month (mm)
Bio14	Precipitation of Driest Month (mm)
Bio15	Precipitation Seasonality (Coefficient of Variation) (mm)
Bio16	Precipitation of Wettest Quarter (mm)
Bio17	Precipitation of Driest Quarter (mm)
Bio18	Precipitation of Warmest Quarter (mm)
Bio19	Precipitation of Coldest Quarter (mm)
Bio10_Bio11	Temperature Range between Warmest and Coldest Quarters (Bio10 - Bio11)
Heat_sum	Sum of monthly positive temperatures (MPT), where MPT = (monthly min + monthly max)*10/2, if monthly min >= 0, otherwise MPT = 0
Wb_sum	Sum of monthly Water balance (WB): monthly WB = MP–PET Where MP = Monthly precipitation, PET = Potential Evapotranspiration PET = Potential Evapotranspiration as defined by Thornthwaite 1948 and Thornthwaite and Mather 1957

The Habitat Suitability Model of Forest Classes, hereafter referred as niche model, was derived using classification and regression tree analysis (Breiman et al., 1984). Apart from presence training locations, classification and regression tree analysis (CART) requires use of absence training locations for model development. Absence of a species from a given area could result not only from the impact of climate, but also from isolation by distance (or history of species distribution) and human impact. For example, severity of competition with other species could well be a function of isolation by distance. In other words, distance from the species distribution range.

As the modeling output was to be a realistic niche model per forest class, predictors other than climatic variables had to be controlled. To rule out the influence of isolation by distance, absence locations for each forest class were randomly selected from areas that did not support this class but that were not too far to be colonized by the nearby forest class. To control for human impact, absence locations were selected from areas with very limited human access such as historically protected areas and areas too rugged to be exploited by humans in terms of forest over-harvesting. Thus, using training locations of presences and absences per forest class, CART models were developed.

Instead of completely trusting the CART algorithm with selecting a set of the most important predictor variables per forest class from a set of all variables (Table 1), various cross-validation and pruning settings were used to build each CART model. The predictive power of each model was tested using global occurrence data on each forest class. As a result, a set of predictor variables per forest class that resulted in the smallest omission error on a global scale was considered the best (Table 2).

Over-fitting, as well as untrue interactions and importance of predictor variables for forest classes' distribution, issues typical of models validated within or near a training geographic extent, were minimized using the above-mentioned approach. The derived best CART models were applied to the study area to generate a predictive map of forest distributions for present (from 1950 to 2000) and in future (2080).

Table 2: CART model per forest class in the Southern Caucasus[4]

Class	Description	CART model predicting each class
Dry woodlands	Juniperus spp., Pistacia mutica, Pinus eldarica, Carpinus orientalis, Paliurus spina-christi, in combination with steppe and semidesert	[heat_sum] >= 150 & (([bio_12] * 10) / [heat_sum]) <= 4
Betula_etc	Betula spp., Populus spp., etc	[heat_sum] >= 177 & [heat_sum] <= 573 & (([bio_12] * 10) / [heat_sum]) >= 4.314607
Buxus	Buxus spp.	[heat_sum] >= 700 & [bio_7] < 360 & [bio_17] >= 100 & (([bio_12] * 10) / [heat_sum]) >= 6
Carpinus	Carpinus caucasica	[heat_sum] >= 687 & [bio_7] < 360 & [bio_17] >= 42 & (([bio_12] * 10) / [heat_sum]) >= 3
Castanea	Castanea sativa	[heat_sum] >= 914 & [bio_7] < 360 & [bio_17] >= 60 & (([bio_12] * 10) / [heat_sum]) >= 5.731707
Fagus	Fagus orientalis	[heat_sum] >= 687 & [bio_7] < 360 & [bio_17] >= 60 & (([bio_12] * 10) / [heat_sum]) >= 4.02486
Parrotia	Parrotia persica	[heat_sum] >= 1012 & [bio_7] < 360 & [bio_17] >= 51 & (([bio_12] * 10) / [heat_sum]) >= 3.32079
Picea_Abies	Abies nordmanniana, Picea orientalis	[heat_sum] >= 500 & [heat_sum] <= 1165 & [bio_7] < 360 & [bio_17] >= 80 & (([bio_12] * 10) / [heat_sum]) >= 5.264798
Pinus_pts	Pinus pithyusa	[heat_sum] >= 1742 & [bio_7] < 360 & (([bio_12] * 10) / [heat_sum]) >= 8
Quercus_Pinus	Quercus spp., Pinus kochiana	[heat_sum] >= 480 & (([bio_12] * 10) / [heat_sum]) >= 3.36
Quer_casta	Quercus castaneifolia	[heat_sum] >= 885 & [bio_7] < 360 & (([bio_12] * 10) / [heat_sum]) >= 3.544061
Quer_pedun	Quercus pedunculiflora	[heat_sum] >= 1229 & [bio_7] < 360 & (([bio_12] * 10) / [heat_sum]) >= 2.051282

[4] Although CART models did well with land forest species, they failed to perform reasonably well on riparian forests (e.g., communities of Alder, Willow, Salix, Poplar and Flood plain oak), because riparian forests do not really depend on climate as long as they're in close proximity to streams, rivers, lakes and flood-plains. Therefore, this kind of community can occur alongside permanently flowing streams even in semi-desert.

Class	Description	CART model predicting each class
Taxus	Taxus baccata	[heat_sum] >= 753 & [bio_7] < 360 & [bio_17] >= 60 & (([bio_12] * 10) / [heat_sum]) >= 5.784314
Zelkova	Zelkova carpinifolia	[heat_sum] >= 1355 & [bio_7] < 360 & [bio_17] >= 60 & (([bio_12] * 10) / [heat_sum]) >= 4.776632

For the two models in future, data on emission scenario A2a and emission scenario B2a of greenhouse gases were used to predict forest cover distribution. Both emission scenarios assume economically and culturally heterogeneous world.

Scenario A2 family implies more economic development with a likely surface temperature increase by 2.0-5.4 °C for the next 100 years. Scenario B2 family assumes a more ecologically friendly world with a likely surface temperature increase by 1.4-3.8 °C for the next 100 years.

2.1.3. Spatial Trend Analyses

Three separate spatial trend analyses were conducted for developing this strategic document. For the first two analyses, area values came from the GIS databases used to develop the Actual Forest Cover Map, Potential Forest Cover Map, and three models maps. As for the first analysis both datasets were based on different descriptive data-species and vegetation types-it was necessary to group them in a way that both levels of data can be compared (Table 3).

Table 3: Outline of possible combinations for assembling comparable groups between forest species and vegetation formations

ACTUAL FOREST COVER (Forest Species)	POTENTIAL FOREST COVER (Formation)	Code as on the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003)
(1) Alder_Poplar_Willow* (located in the Colchic)	(1) Alnus	T3
(2) Beech	(2) Fagus (3) Fagus Colchic (4) Fagus Hyrcanian	F164, 165 F163 F166
(3) Birch_Poplar_Ash-tree	(5) Betula	C42, 43, 45, northern part of C44
(4) Caucasian Pine	(6) Pinus kochiana	D64
(5) Chestnut, (6) Buxus, (7) Zelkova	(7) Colchic polydominant	H1
(5) Chestnut, (7) Zelkova		Not Reflected**
(8) Chestnut-leaved oak, (9) Iron-tree	(8) Quercus castaneifolia	H2, 3
(10) Dark conifers	(9) Picea-Abies Colchic (10) Picea-Abies	D32 D33
(11) Eldar pine	(11) Pinus eldarica formation has been reconstructed according to National maps	Not Reflected**
(12) Flood plain oak, (13) Poplar_Willow_Plains* (located in the East Caucasus plains)	(12) Flood plain vegetation (13) Quercus pedunculiflora	U22 F171

ACTUAL FOREST COVER (Forest Species)	POTENTIAL FOREST COVER (Formation)	Code as on the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003)
(14) Juniper_Pistachio_Hackberry	(14) Dry mixed woodlands (15) Juniperus (16) Quercus iberica & Juniperus	K34 K33 Part of F170
(15) Oak and other broad-leaved species, (16) Hornbeam	(17) Quercus iberica (18) Quercus iberica Colchic (19) Quercus iberica Hyrcanian (20) Quercus macranthera (21) Quercus macranthera sub-alpina	Main part of F170 F169 Hyrcanian part of F170 F172 C46, 47, southern part of C44
(17) Pitsundian pine	(22) Pinus pityusa	K24
(18) Poplar_Willow_Mountain-valleys* (located in the East Caucasus mountain-valleys)		Not Reflected**
(19) Taxus		Not Reflected**

Note: *Area values of these three forest types came from separating the area value of Poplar_Willow_Alder, original forest type in the database, by its geographic location.
**This inconvenience could have been caused by differences in mapping scales between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003), where some larger scale-mapping units have been omitted (i.e., peculiarities of generalization during mapping exercises in different scales).

Subsequently, the above listed comparing groups (e.g., Beech vs. Fagus, Fagus Colchic and Fagus Hyrcanian) were used to identify the difference in area (hectares) between actual forest cover and potential forest cover at three unit levels of analysis (study area, bioclimatic regions, and countries). These differences were calculated subtracting the total hectares of each comparing group (actual forest cover minus potential forest cover).

Meanwhile, data needed for conducting the second spatial trend analysis came from the three models of forest classes' distribution, developed by Dr. Alexander Gavashelishvili (see sections 2.2.). The model developed in present climatic conditions, hereafter referred as modeled present, served as landmark for analyzing the impact of climate change based on emission scenario A2a and B2a (Model A2a and Model B2a, respectively). Moreover, the extent of extirpated forest due to climate change was only estimated in percentage, and for only two levels of analysis (study area, and countries).

In addition, the shift or 'altitudinal migration' of forest classes was also taken into account. In order to do so, the outputs of the above listed three models were combined with a 90 m Digital Elevation Model (DEM) to identify the lowest and highest altitudinal points of each forest class. The data obtained was also compared at the same two levels of analysis used in the previous spatial trend analyses explained. Middle altitudinal points were calculated from the lowest and highest altitudinal points depicted in each of the three climatic models developed for this document. This spatial trend was also carried out at two levels of analysis (study area and south Caucasian countries), and the outputs from modeled present model were used as landmark for estimating the percentage of shift under both emission scenarios.

3. Results

In this section, the difference between actual forest cover (AFC) and potential forest cover (PFC) (Appendix B, Figures B1 and B2), as well as between Modeled Present and Future Models are presented. The former analysis essentially helps identifying the amount of area by forest species that might have been lost (Potential Extend of Lost Forest). Meanwhile, the last analysis provides information on how much area of forest species might be extirpated due to climate change (Potential Rate of Extirpated Forest).

3.1. Actual Forest Cover vs. Potential Forest Cover

3.1.1 Study Area Level

The study area, which includes the territories of Armenia, Azerbaijan and Georgia, extends over 18,566,894.4 ha. Forests actually cover 22.10% of the study area (4,105,475.4 ha), although the PFC should be its 49.24% (9,141,593.1 ha). Therefore, there is an actual negative difference of 5,036,117.7 ha between AFC and PFC (Table 4).

Table 4: Difference between AFC and PFC at study area level

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Alder_Poplar_Willow	96,055.3	Alnus	76,026.0	20,029.3	26.35%
Beech	1,805,483.4	Fagus + Fagus Colchic + Fagus Hyrcanian	2,183,054.6	-377,571.2	-17.30%
Birch_Poplar_Ash-tree	108,013.0	Betula	949,979.2	-841,966.2	-88.63%
Caucasian pine	112,020.3	Pinus kochiana	155,932.7	-43,912.4	-28.16%
Chestnut + Buxus + Zelkova	163,899.1	Colchic polydominant	664,711.4	-500,812.2	-75.34%
Chestnut + Zelkova	1,008.7	Not Reflected	NDA	1,008.7	---
Chestnut-leaved oak	81.0	Quercus castaneifolia	33.9	47.1	139.29%
Chestnut-leaved oak + Iron-tree	77,426.8	Quercus castaneifolia	198,470.8	-121,044.0	-60.99%
Dark conifers	392,431.8	Picea-Abies + Picea-Abies Colchic	717,974.6	-325,542.8	-45.34%
Eldar pine	187.3	Pinus eldarica	5,819.9	-5,632.6	-96.78%
Flood plain oak + Poplar_Willow_Plains	81,184.8	Flood plain + Quercus pedunculiflora	749,226.4	-668,041.6	-89.16%
Juniper_Pistachio_ Hackberry	32,994.0	Dry mixed woodlands + Juniperus + Quercus iberica & Juniperus	910,430.2	-877,436.1	-96.38%
Oak and other broad-leaved species + Hornbeam	1,159,474.2	Quercus iberica + Q. iberica Colchic + Q. iberica hyrcanic + Q. macranthera + Q. macranthera sub-alpina	2,526,570.8	-1,367,096.6	-54.11%

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Pitsundian pine	1,855.2	Pinus pityusa	3,362.7	-1,507.5	-44.83%
Poplar_Willow_Mountain-valleys	71,855.8	Not Reflected	NDA	71,855.8	---
Poplar_Willow_Plains	1,274.4	Not Reflected	NDA	1,274.4	---
Taxus	230.2	Not Reflected	NDA	230.2	---
TOTAL	**4,105,475.4**	**TOTAL**	**9,141,593.1**	**-5,036,117.7**	**-55.09%**

Four forest types (beech, oak and other broad-leaved species, and hornbeam-which were grouped into two comparing groups) currently cover nearly 3 million hectares. However, the composition of these four forest dominants within these 3 million hectares is not proportionally equal. For example, whereas hornbeam covers 552,959.2 ha, beech does it for 1,805,483.4 ha–the most widespread (Appendix C, Table C1).

Like in the case of the AFC, eight vegetation formations (Fagus, Fagus Colchic, Fagus Hyrcanian, Quercus iberica, Q. iberica Colchic, Q. iberica Hyrcanian, Q. macranthera, and Q. macranthera sub-alpina-which are grouped in two comparing groups) should be covering a bit more than 50% of the study area (4,709,625.8 ha). Like in the AFC case, the distribution of these 8 formations is also not proportionally equal. For instance, Fagus and Q. iberica respectively extends over 1,603,587.9 and 1,305,161.7 ha, whereas Fagus Hyrcanian should be 43,986.9 ha (Appendix C, Table C2).

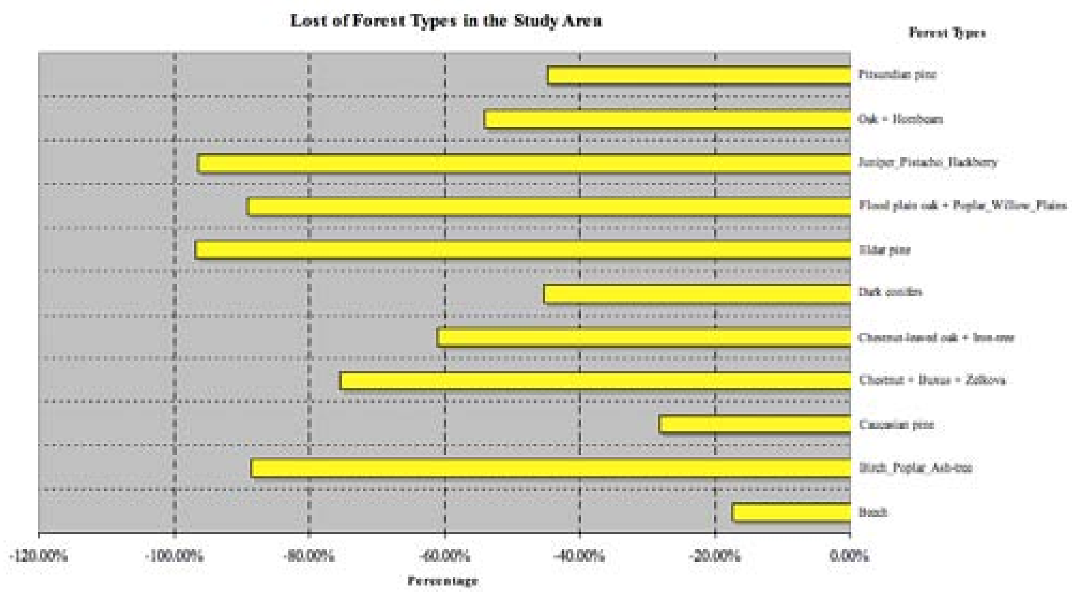

Fig. 3: Lost of forest types in the study area, including only those values that resulted in a negative difference

There are five forest types comparing groups that have lost more than 75% of their potential area (eldar pine with 96.78%, juniper_pistachio_hackberry with 96.38%, flood plain oak and poplar_willow_plains with 89.16%, birch_poplar_ash-tree with 88.63%, and chestnut-buxus-zelkoca with 75.34%), which represent 2,893,888.8 ha of lost forest cover. Meanwhile, there are four comparing groups that have lost no more than 50% of their potential area (Dark conifers with 45.34%, pitsundian pine with 44.83%, Caucasian pine with 28.16%, and beech with 17.30%). The remaining two forest types (chestnut-leaved oak with iron-tree, and oak-hornbeam) have respectively lost 60.99% and 54.11% of their potential areas (Fig. 3).

There are two comparing group that has a positive difference between the AFC and PFC (alder_poplar_willow comparing group with 20,029.3 ha, and chestnut-leaved oak with 47.1 ha). This inconvenience could have been caused by differences in approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003), which could have resulted from overlapping with nearby formations (e.g., Caucasian pine). Likewise, the difference for Chestnuts with Zelkova, Poplar_willow_mountain-valleys, Poplar_willow_plains, and Taxus could not be calculated because of lack of data (NDA–No Data Available). These inconveniences could have been caused by the reason mentioned above, as well as by differences in mapping between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003).

3.1.2 Bioclimatic Region Level

COLCHIC

The Colchic bioclimatic region covers 3,262,645.5 ha. 50.55% of its area is currently covered by forest types (1,649,379.5 ha). In this region, there is a total lost of 1,239,050.2 ha of potential area (Table 5). Alder_poplar_willow, and beech are the forest types that exceed the PFC by 20,029.3, and 261,847.3 ha, respectively. Likewise, the difference for Poplar_willow_mountain-valleys and Poplar_willow_plains could not be calculated because of lack of data (NDA–No Data Available). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003).

Table 5: Difference between AFC and PFC at the Colchic bioclimatic region

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Alder_Poplar_Willow	96,055.3	Alnus	76,026.0	20,029.3	26.35
Beech	799,964.7	Fagus + Fagus Colchic	538,117.4	261,847.3	48.66
Birch_Poplar_Ash-tree	45,077.9	Betula	517,173.0	-472,095.2	-91.28
Caucasian pine	21,665.5	Pinus kochiana	24,932.0	-3,266.4	-13.10
Chestnut + Buxus + Zelkova	163,899.1	Colchic polydominant	664,711.4	-500,812.2	-75.34
Dark conifers	275,527.5	Picea-Abies + Picea-Abies Colchic	603,402.5	-327,875.1	-54.34
Oak and other broad-leaved species + Hornbeam	185,874.3	Quercus iberica + Q. iberica Colchic	461,325.7	-275,451.5	-59.71
Pitsundian pine	1,855.2	Pinus pityusa	3,362.7	-1,507.5	-44.83
Poplar_Willow_Mountain	58,232.6	Not Reflected	NDA	58,232.6	---

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE Ha	%
Poplar_Willow_Plains	1,227.4	Not Reflected	NDA	1,227.4	---
TOTAL	**1,649,379.5**	**TOTAL**	**2,889,050.7**	**-1,239,050.2**	**-42.91**

In Table 5, there are two comparing groups that have lost more than 75% of their potential area (birch_poplar_ash-tree with 92.53%, and chestnut-buxus-zelkoca with 75.34%), which together equal to 972,907.4 ha. Dark conifers, oak with hornbeam, and pitsundian pine comparing groups have respectively lost 54.34%, 59.71% and 44.83% of their potential areas (Table 5, and Appendix D, Figure D1), which equals to 604,834.1 ha. Meanwhile, Caucasian pine has lost 13.10% of its potential cover.

EAST CAUCASUS

The East Caucasus bioclimatic region extends over 5,937,980.5 ha. 34.79% of its area is covered by forest (2,066,069.3 ha). Likewise, eleven out of the fifteen comparing groups used in this analysis can be found in the East Caucasus region (Table 6). However, there are four differences that cannot be calculated due to the lack of data on the vegetation formation parameter. Likewise, there is a positive difference between AFC and PFC (dark conifers exceed by 2,332.3 ha). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003).

Table 6: Difference between AFC and PFC at the East Caucasus bioclimatic region

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE Ha	%
Beech	973,807.1	Fagus + Fagus Colchic	1,529,073.7	-555,266.6	-36.31%
Birch_Poplar_Ash-tree	62,596.1	Betula	414,370.1	-351,774.0	-84.89%
Caucasian Pine	79,742.5	Pinus kochiana	114,734.6	-34,992.1	-30.50%
Chestnut + Zelkova	1,008.7	Not Reflected	NDA	1,008.7	---
Chestnut-leaved oak	81.0	Quercus castaneifolia	NDA	81.0	---
Dark Conifers	116,904.3	Picea-Abies + Picea-Abies Colchic*	114,572.1	2,332.3	2.04%
Flood plain oak + Poplar_Willow_Plains	57,175.3	Flood plain + Quercus pedunculiflora	555,693.6	-498,518.3	-89.71%
Juniper_Pistachio_ Hackberry	4,956.2	Juniperus + Q. iberica & Juniperus	317,603.5	-312,647.3	-98.44%
Oak and other broad-leaved species + Hornbeam	756,347.5	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	1,557,488.8	-801,141.3	-51.44%
Poplar_Willow_Mountain-valleys	13,220.4	Not Reflected	NDA	13,220.4	---

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Taxus	230.2	Not Reflected	NDA	230.2	---
TOTAL	**2,066,069.3**	**TOTAL**	**4,603,536.4**	**-2,537,467.0**	**-55.12%**

Note: *It is a figurative name that depicts the main location of this forest type. Hence, it does not make it exclusive to the Colchic region. However, its distribution limits coincide with extreme western part of the Eastern Greater Caucasus and north-western part of the Lesser Caucasus (Appendix C, Table C2).

Juniper_pistachio_hackberry, flood plain oak with poplar_willow_plains, and birch_poplar_ash-tree forest types have lost more than 75% of the potential area (Table 6), which together add up to 1,162,939.6 ha. Meanwhile, even though Caucasian pine, oak with hornbeam and beech have respectively lost 30.50%, 51.44%, and 36.31% of their potential areas (Table 6 and Appendix D, Figure D2), their deficit by hectares (1,390,939.6 ha.) is higher than the firstly mentioned forest types in this paragraph.

SOUTH UPLANDS

Couple with the Southern Lesser Caucasus and the Dry Plains and Ridges bioclimatic regions, the South Uplands is one of the driest regions in the study area. It extends over 2,629,395.7 ha and is currently covered by just 20,992.3 ha of forests, which represents 0.80% of its territory. However, it should have 219,240.2 ha of forest (Table 7). This means that the South Uplands region has a forest area lost of 198,247.9 ha.

Table 7: Difference between AFC and PFC at the South Uplands bioclimatic region

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Beech	0.0	Fagus	15,535.6	-15,535.6	-100.00%
Birch_Poplar_Ash-tree	339.1	Betula	18,436.1	-18,097.0	-98.16%
Caucasian Pine	10,285.5	Pinus kochiana	16,266.1	-5,980.6	-36.77%
Flood plain oak	0.0	Flood plain	921.7	-921.7	-100.00%
Juniper_Pistachio_ Hackberry	4,227.4	Juniperus	22,475.2	-18,247.8	-81.19%
Oak and other broad-leaved species + Hornbeam	6,131.6	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	145,605.5	-139,473.9	-95.79%
Poplar_Willow_Mountain-valleys	347.8	Not Reflected	NDA	347.8	---
Poplar_Willow_Plains	46.9	Not Reflected	NDA	46.9	---
TOTAL	**20,992.3**	**TOTAL**	**219,240.2**	**-198,247.9**	**-90.42%**

Although there are eight comparing groups in this climatic region, two differences cannot be calculated due to lack of information in the formation area field (Table 7). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003). From the remaining 6 comparing groups, Caucasian pine has lost 36.77% of its potential areas, whereas the other five forest types have lost more than 75% of it (Table 7 and Appendix D, Figure D3), which add up to 192.276.0 ha. From this last group of forest classes, only Beech and Flood-plain oak have lost all their covering areas (100% lost rate). This total lost rate should be considered with caution, because differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003) could also have hindered the analysis of these forest types for this region.

SOUTHERN LESSER CAUCASUS

The South Lesser Caucasus bioclimatic region extends over 1,014,424.7 ha, but just 17.14% of its area is covered by forests (173,849.9 ha). Its potential forest cover should be 624,214.8 ha (Table 8). Hence, there is a lost of 450,364.9 ha in this region, and most of the lost area comes from juniper_pistachio_hackberry comparing group (336,781.4 ha).

Table 8: Difference between AFC and PFC at the Southern Lesser Caucasus bioclimatic region

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Beech	859.3	Fagus	2,105.1	-1,245.8	-59.18%
Juniper_Pistachio_ Hackberry	8,478.5	Dry mixed woodlands + Juniperus + Q. iberica & Juniperus	345,259.9	-336,781.4	-97.54%
Oak and other broad-leaved species + Hornbeam	164,457.0	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	276,849.7	-112,392.8	-40.60%
Poplar_Willow_Mountain-valleys	55.0	Not Reflected	NDA	55.0	---
TOTAL	**173,849.9**	**TOTAL**	**624,214.8**	**-450,364.9**	**-72.15%**

Like in the previous bioclimatic regions, one difference could not be calculated due to lack of data on the vegetation formation parameter. This inconvenience could have been caused by reasons mentioned in above paragraphs. From the remaining two forest types, even though beech has lost 59.18% of their potential areas, oak with hornbeam has lost much more hectares than beech (Table 8, and Appendix D, Figure D4).

DRY PLAINS AND RIDGES

The area of the Dry Plains and Ridges bioclimatic region -the driest in the Caucasus- is 5,365,992.2 ha. Even though forests should cover 8.86% of this region (475,415.5 ha), the AFC is just 1.00% (53,844.2 ha). Two groups have lost all their covering areas (beech and chestnut-leaved oak). Like in the South Uplands, these two figures should be considered with caution, because differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003) could also have hindered the analysis of these forest types for this region.

Table 9: Difference between AFC and PFC at the Dry Plains and Ridges bioclimatic region

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Beech	0.0	Fagus	5,448.3	-5,448.3	-100.00%
Caucasian Pine	326.7	Pinus kochiana	NDA	326.7	---
Chestnut-leaved oak	0.0	Quercus castaneifolia*	33.9	-33.9	-100.00%
Eldar pine	187.3	Pinus eldarica	5,819.9	-5,632.6	-96.78%
Flood plain oak + Poplar_Willow_Plains	24,009.5	Flood plain + Quercus pedunculiflora	192,611.2	-168,601.7	-87.53%
Juniper_Pistachio_ Hackberry	15,331.9	Juniperus + Quercus iberica & Juniperus	225,091.5	-209,759.6	-93.19%
Oak and other broad-leaved species + Hornbeam	13,988.7	Quercus iberica	46,410.6	-32,421.9	-69.86%
TOTAL	**53,844.2**	**TOTAL**	**475,415.5**	**-421,571.3**	**-88.67%**

Note: *This figure appears here because of differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003).

From the remaining five comparing groups, Caucasian pine does not have comparable vegetation formation value (Table 9). This inconvenience could have been caused by reasons mentioned in above paragraph. Oak with hornbeam has lost 69.86% of its covering area, whereas eldar pine, juniper_pistachio_hackberry, and flood plain oak with poplar_willow_plains have lost more than 75% of their covering areas (Table 9 and Appendix D, Figure D5). Adding up the lost areas for the last two comparing groups, 89.75% of forest cover lost in this region comes from these two forest types. By percentage, eldar pine type has the highest forest area lost (96.78%), whereas juniper-pistachio-hackberry is the comparing group that has the highest deficit by hectares (209,759.6 ha).

HYRCAN

The Hyrcan bioclimatic region (within the study area) extends over 356,215.3 ha. Its PFC should spread over 92.68% of this area (330,135.6 ha). However, just 140,954.2 ha of forest types are actually covering this regions (39.57%). Two forest types have lost around 60% of their covering areas (beech, and chestnut-leaved oak with iron-tree). They together add up to 182,966.2 ha, which represents 96.71% of the total forest cover lost in this region. Meanwhile, oak with hornbeam has lost 15.98% of its potential area (Table 10 and Appendix D, Figure D6).

Table 10: Difference between AFC and PFC at the Hyrcan bioclimatic region

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Beech	30,852.3	Fagus + Fagus Hyrcanian	92,774.4	-61,922.2	-66.74%
Chestnut-leaved oak + Iron-tree	77,426.8	Quercus castaneifolia	198,470.8	-121,044.0	-60.99%

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Oak and other broad-leaved species + Hornbeam	32,675.1	Quercus iberica hyrcanian + Q. macranthera + Q. m. sub-alpina	38,890.4	-6,215.3	-15.98%
TOTAL	**140,954.2**	**TOTAL**	**330,135.6**	**-189,181.4**	**-57.30%**

ANALYSIS ACROSS BIOCLIMATIC REGIONS

Pitsundian pine, chestnut with buxus and zelkova, alder_poplar_willow, eldar pine, and chestnut-leaved oak with iron-tree comparing groups cannot be found in at least two bioclimatic regions (Table 11), and therefore, not important for this part of the analysis. Likewise, chestnut with zelkova (Table 6), poplar_willow_mountain-valley (Tables 5–8), poplar_willow_plains (Tables 5 and 7), taxus, and chestnut-leaved oak (Table 6 and 9) comparing groups were not taken into account either. This was because the first four groups did not have formation to compare with, which could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003). In addition to this issue, chestnut-leaved oak lacked of data in the area value of PFC, resulting in a positive difference (Table 6). As a result, seven comparing groups were analyzed across bioclimatic regions.

Table 11: Summary of hectares lost by bioclimatic region based on results from Tables 5–10

Forest Types	Bioclimatic Region						Total Area Lost by Species
	Colchic Ha.	East Caucasus Ha.	South Uplands Ha.	Southern Lesser Caucasus Ha.	Dry Plains and Ridges Ha.	Hyrcan Ha.	
Alder-Poplar-Willow (Colchic)	20,029.3						20,029.3
Beech	261,847.3	-555,266.6	-15,535.6	-1,245.8	-5,448.3	-61,922.2	-377,571.2
Birch_Poplar_Ash-tree	-472,095.2	-351,774.0	-18,097.0				-841,966.2
Caucasian pine	-3,266.4	-34,992.1	-5,980.6		326.7		-43,912.4
Chestnut + Buxus + Zelkova	-500,812.2						-500,812.2
Chestnut + Zelkova		1,008.7					1,008.7
Chestnut-leaved oak		81.0			-33.9		47.1
Chestnut-leaved oak + Iron-tree						-121,044.0	-121,044.0
Dark conifers	-327,875.1	2,332.3					-325,542.8
Eldar pine					-5,632.6		-5,632.6
Flood plain oak + Poplar_Willow_Plains		-498,518.3			-168,601.7		-667,119.9

Forest Types	Bioclimatic Region						Total Area Lost by Species
	Colchic Ha.	East Caucasus Ha.	South Uplands Ha.	Southern Lesser Caucasus Ha.	Dry Plains and Ridges Ha.	Hyrcan Ha.	
Juniper_Pistachio_Hackberry		-312,647.3	-18,247.8	-336,781.4	-209,759.6		-877,436.1
Oak and other broad-leaved species + Hornbeam	-275,451.5	-801,141.3	-139,473.9	-112,392.8	-32,421.9	-6,215.3	-1,367,096.6
Pitsundian pine	-1,507.5						-1,507.5
Poplar_Willow_Mountain-valleys	58,232.6	13,220.4	347.8	55.0			71,855.8
Poplar_Willow_Plains	1,227.4		46.9				1,274.4
Taxus		230.2					230.2
Total Area Lost by Bioclimatic Region	-1,239,671.2	-2,537,467.0	-196,940.2	-450,364.9	-421,571.3	-189,181.4	**-5,035,196.1**

Note: *The figures presided by the minus sign (-) refers to the negative difference between AFC and PFC (lost hectares), where as the figures without the minus sign-and within the light-blue cells-refers to the positive difference that exists between AFC and PFC. Meanwhile, the cells in gray means that a forest type is not distributed within a bioclimatic region

Likewise, it is important to point out that forest cover has decreased in all regions (Tables 6–10). In the South Uplands and Dry Plains and Ridges regions, forest cover could decrease in 90.42% and 88.67%, respectively. Meanwhile, the lost rates in the East Caucasus, Southern Lesser Caucasus and the Hyrcan regions are between 50% and 75% (Tables 6, 8 and 10), leaving the Colchic with a lost rate of 42.91%. Even though the lost of forest cover in the Colchic has the lowest rate, it is the second region that has lost the most amounts of hectares (1,239,671.2 ha). It is just outranked by the lost of forest cover in the East Caucasus region (2,537,467.0 ha). The lost of forest cover in these two regions contribute with 75.01% of the total hectares lost in the study area.

Oak with hornbeam and beech comparing groups can be found in the six bioclimatic regions (Tables 5–10), The former has lost 1,367,096.6 ha of its potential cover (Table 11). It has lost more than 90% of its covering area in the South Uplands (Table 7), which represents only 10.20% of this class total lost in the study area. However, this comparing group has lost more hectares in the East Caucasus (820,535.9). Event though the lost rate of oak-hornbeam in the East Caucasus and the Colchic regions is between 50% and 60% (Appendix D, Figures D1 and D2), they respectively contribute with 58.60% and 20.15% of its total lost area, which equals to 1,076,592.7 ha. In the Dry Plains and Ridges, the Southern Lesser Caucasus, and the Hyrcan regions, this type has respectively lost 69.86%, 40.60%, and 15.98% of its potential area.

Even though beech has a positive hectare value (261,847.3 ha) in the Colchic region, this forest type has lost 377,571.2 ha of its potential cover when seeing at the study area level. In the other five regions, beech has lost between 1,245.8 and 555,266.6 ha (Table 11). However, its lost rates were around 60% in the Southern Lesser Caucasus and the Hyrcan regions and 100% in the South Uplands and the Dry Plains and Ridges regions (Tables 7–10 and Appendix D, Figures D3–D6). In the East Caucasus region, even though this forest type has lost the biggest amount of hectares

(555,266.6 ha), it equals to 36.31% lost rate. The smallest percentage lost of this forest type across regions. Caucasian pine and juniper_pistachio_hackberry appear in four bioclimatic regions. Even though Caucasian pine has a positive hectare value (326.7 ha) in the Dry Plains and Ridges region, it has lost 43,912.4 ha of its potential cover (Table 11). This type has the highest lost rate in the South Uplands region (36.76%), but the biggest amount of lost hectares in the East Caucasus region (34,992.1 ha), which represents 79.69% of its total cover lost.

Juniper_pistachio_hackberry has lost a total of 877,436.1 ha of its potential cover (Table 11). In three regions, it has lost more than 75% of its potential area (Tables 6–9 and Appendix D, Figures D2–D5), which equals to 859,188.4 ha. By percentage, this type has the highest lost rate in the East Caucasus (98.44%), whereas it has lost the most amounts of hectares in Southern Lesser Caucasus (336,781.4 ha). However, the difference in hectares between these regions is no more than 24,134.1 ha. In the South Uplands region, juniper_pistachio_hackberry has lost only 81.19% of its covering area, representing 18,247.8 ha or 2.08% of the total cover lost for this forest type.

Birch_poplar_ash-tree can be found in three bioclimatic regions. Like in juniper_pistachio_ hackberry comparing group, birch_poplar_ash-tree, has lost more than 75% in the three regions that can be found, which equals to 841,966.2 of lost hectares (Table 11). The highest lost rate happens in the South Uplands (Appendix D, Figure D3), even though it only represents 18,097.0 ha (Table 11). Meanwhile, the biggest amounts of lost hectares happen in the Colchic, which represent 56.07% of its total cover lost in the study area. The hectares lost in the East Caucasus contribute with 41.78% of the total cover lost of this type in the East Caucasus Region.

Finally, dark conifer and flood plain oak with poplar_willow_plains can be found in two bioclimatic regions. Even though the former forest type has a positive difference (Table 6), it has lost 325,542.8 ha of its potential area in the study area (Table 11). Meanwhile, flood plain oak with poplar_willow_plains has lost 667,119.9 ha. Both the highest lost rate and biggest amounts of hectares lost happen in the East Caucasus region (Table 6). The hectares lost in this region contribute with 74.73% of cover lost for this forest type.

3.1.3. Country Level

ARMENIA

Armenia has an area of 2,964,408.8 ha. Potentially, 30.36% of its territory should be covered by forest (900,046.8 ha). However, just the 9.67% of its territory has forest nowadays (286,636.6 ha). Hence, Armenia has a forest deficit of 613,410.2 ha (Table 12).

Table 12: Difference between AFC and PFC in Armenia

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Beech	94,305.7	Fagus	302,237.7	-207,932.0	-68.80
Birch_Poplar_Ash-tree	1,089.2	Betula	3,570.5	-2,481.3	-69.49
Caucasian pine	757.9	Pinus kochiana	NDA	757.9	---
Chestnut	1.1	Not Reflected	NDA	1.1	---

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Oak and other broad-leaved species + Hornbeam	178,120.7	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	434,603.2	-256,482.5	-59.02
Poplar_Willow_Plains	58.0	Flood plain + Quercus pedunculiflora	NDA	58.0	---
Juniper_Pistachio_ Hackberry	12,068.3	Dry mixed woodlands + Juniperus + Quercus iberica & Juniperus	159635.4	-147,567.1	-92.44
Poplar_Willow_Mountain-valleys	235.7	Not Reflected	NDA	235.7	---
TOTAL	**286,636.6**	**TOTAL**	**900,046.8**	**-613,410.2**	**-68.15**

There are four differences that cannot be calculated because of lack of data on the vegetation formation area value. These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003), as it was mentioned in the analysis at the bioclimatic level. Juniper_pistachio_hackberry is the only comparing group that has lost more than 75% of its PFC (Table 12 and Appendix E, Figure E1). However, the covering area lost by both oak with hornbeam, and beech forest types contribute with 75.71% of the total lost of forest cover in Armenia (464,414.5 ha, together).

AZERBAIJAN

Azerbaijan has an area of 8,632,958.0 ha. Currently, 10.88% of Azerbaijan is covered by forest species (939,074.8 ha). However, 33.32% of its territory should have forest cover (2,879,770.2 ha). Therefore, Azerbaijan has a 67.36% forest lost (1,937,773.7 ha).

Table 13: Difference between AFC and PFC in Azerbaijan

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Beech	297,696.7	Fagus + Fagus hyrcanian	725,641.2	-427,944.5	-58.97
Birch_Poplar_Ash-tree	776.6	Betula	13315.4	-12,538.8	-94.17
Caucasian pine	373.6	Pinus kochiana	NDA	373.6	---
Chestnut	868.1	Not reflected	NDA	868.1	---
Chestnut-leaved oak + Iron-tree	77,507.8	Quercus castaneifolia	198,467.0	-120,959.2	-60.95
Eldar pine	187.3	Pinus eldarica	2,287.6	-2,100.3	-91.81
Flood-plain oak + Poplar_Willow_Plains	63,671.8	Flood plain + Quercus pedunculiflora	492,804.0	-429,132.2	-87.08
Oak and other broad-leaved species + Hornbeam	483,003.9	Quercus iberica + Q. iberica hyrcanian + Q. macranthera + Q. macranthera sub-alpina	855,077.4	-372,073.5	-43.51

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Juniper_Pistachio_ Hackberry	13,974.9	Dry mixed woodlands + Juniperus + Quercus iberica & Juniperus	589,255.9	-575,281.0	-97.63
Poplar_Willow_Mountain-valleys	1,014.1	Not Reflected	NDA	1,014.1	---
TOTAL	**939,074.8**	**TOTAL**	**2,876,848.5**	**-1,937,773.7**	**-67.36**

There are three differences that cannot be calculated because there is no data on the vegetation formation area value (Table 13). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003), as well as by overlapping of their nearby formation types.

From the seven remaining comparing groups, there are four forest types that have lost more than 75% of their potential cover (juniper_pistachio_hackberry with 97.63%, birch_poplar_ash-tree with 94.17%, eldar pine with 91.81%, and flood plain oak and poplar_willow_plains with 87.08%), which together equal to 1,019,052.3 ha. Beech, and oak with hornbeam comparing groups contribute with 41.29% of the forest deficit in Azerbaijan (i.e., 800,018.0 ha), even though they have respectively lost 58.97% and 43.51% of their potential area (Table 13 and Appendix E, Figure E2).

GEORGIA

The territory of Georgia extends across 6,669,288.8 ha. 43.18% of Georgia is covered by forest, even though its forest should spread over 80.44% of its territory (5,364,548.9 ha). This results in a forest deficit of 2,484,784.2 ha. There are two positive differences between AFC and PFC (Table 14). Likewise, two comparing groups lacked of data in the vegetation field (poplar_willow_mountain-valleys, and taxus). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003), as well as by overlapping of their nearby formation types.

Table 14: Difference between AFC and potential forest cover in Georgia

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE	
				Ha	%
Alder_Poplar_Willow	96,055.3	Alnus	76,026.0	20,029.3	26.35%
Beech	1,413,481.7	Fagus + Fagus colchic	1,155,171.9	258,309.8	22.36%
Birch_Poplar_Ash-tree	106,147.3	Betula	933,093.4	-826,946.1	-88.62%
Chestnut + Buxus + Zelkova	164,038.6	Colchic polydominant	664,711.4	-500,672.8	-75.32%
Caucasian pine	110,888.8	Pinus kochiana	155,932.7	-45,043.9	-28.89%
Dark conifers	392,431.8	Picea-Abies Colchic + Picea-Abies	717,974.6	-325,542.8	-45.34%

ACTUAL COVER (Plants)	AREA Ha	POTENTAIL COVER (Formation)	AREA Ha	DIFFERENCE Ha	%
Eldar pine	0.0	Pinus eldarica	3,532.2	-3,532.2	-100.00%
Flood plain oak + Poplar_Willow_Plains	18,729.4	Flood plain + Quercus pedunculiflora	256,422.5	-237,693.1	-92.70%
Juniper_Pistachio_Hackberry	6,950.8	Juniperus + Quercus iberica & Juniperus	161,538.9	-154,588.1	-95.70%
Oak and other broad-leaved species + Hornbeam	498,349.5	Quercus iberica + Q. iberica Colchic + Q. macranthera + Q. macranthera sub-alpina	1,236,782.6	-738,433.1	-59.71%
Pitsundian pine	1,855.2	Pinus pityusa	3,362.7	-1,507.5	-44.83%
Poplar_Willow_Mountain-valleys	70,606.1	Not Reflected	NDA	70,606.1	---
Taxus	230.2	Not Reflected	NDA	230.2	---
TOTAL	**2,879,764.7**	**TOTAL**	**5,364,548.9**	**-2,484,784.2**	**-46.32%**

Five forest comparing groups have lost more than 75% of their potential area (Table 14 and Appendix E, Figure E3), which together add up to 1,723,432.3 ha. From this group, eldar pine has entirely disappeared from Georgia. There are two comparing groups (oak with hornbeam, and dark conifers) that even with smaller lost rate, their total deficit by area is over 1 million hectares (1,063,975.9 ha). Both Caucasian pine and pitsundian pine have respectively lost 28.89% and 44.83% of their covering areas in Georgia, which equals to 46,551.4 ha.

ANALYSIS ACROSS COUNTRIES

By amount of hectares, Georgia is the country with the highest deficit of forest cover (2,484,784.2 ha), whereas Armenia has the smallest cover deficit (613,410.2 ha). However, if the deficit of forest cover is analyzed by percentage, Armenia is the country with the highest deficit (68.15%), whereas Georgia has the smallest deficit (46.32%).

Six comparing groups (alder_poplar_willow, chestnut with buxus and zelkova, chestnut-leaved oak with iron-tree, dark conifers, and pitsundian pine, for which there is comparable data in the formation field) cannot be found in at least two climatic regions (Table 15), and therefore, not important for this part of the analysis. Likewise, chestnut, poplar_willow_mountain-valleys, poplar_willow_plains, and taxus were not taken into account for this part of the analysis because there were no vegetation formation data to compare with. These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003). Hence, seven comparing groups were analyzed across South Caucasian countries.

Five comparing groups can be found in the three South Caucasian countries (Table 15). Both birch_poplar_ash-tree, and oak with hornbeam biggest amounts of lost hectares happened in Georgia (826,946.1 ha and 738,433.1 ha, respectively), whereas for juniper_pistachio_hackberry it happened in Azerbaijan (575,281.0 ha). For these three types, the forest area lost in only one country ranged from 55% to 99% of the total lost area for each comparing group (98.22% for birch_poplar_ash-tree, 65.56% for juniper_pistachio_hackberry, and 54.02% for oak with hornbeam).

Table 15: Summary of hectares lost by country based on results from Tables 12–14

Forest Types	South Caucasian Countries			Total Forest Area by Species
	Armenia Ha.	Azerbaijan Ha.	Georgia Ha.	
Alder-Poplar-Willow (Colchic)			20,029.3	20,029.3
Beech	-207,932.0	-427,944.5	258,309.8	-377,566.6
Birch_Poplar_Ash-tree	-2,481.3	-12,538.8	-826,946.1	-841,966.3
Caucasian pine	757.9	373.6	-45,043.9	-43,912.4
Chestnut	1.1	868.1		869.2
Chestnut + Buxus + Zelkova			-500,672.8	-500,672.8
Chestnut-leaved oak + Iron-tree		-120,959.2		-120,959.2
Dark conifers			-325,542.8	-325,542.8
Eldar pine		-2,100.3	-3,532.2	-5,632.5
Flood plain oak + Poplar_Willow_Plains		-429,132.2	-237,693.1	-666,825.3
Juniper_Pistachio_Hackberry	-147,567.1	-575,281.0	-154,588.1	-877,436.2
Oak and other broad-leaved species + Hornbeam	-256,482.5	-372,073.5	-738,433.1	-1,366,989.1
Pitsundian pine			-1,507.5	-1,507.5
Poplar_Willow_Mountain-valleys	235.7	1,014.1	70,606.1	71,855.8
Poplar_Willow_Plains	58.0			58.0
Taxus			230.2	230.2
Total Forest Area by Bioclimatic Region	**-613,410.2**	**-1,937,773.7**	**-2,484,784.2**	**-5,035,968.1**

Note: *The figures presided by the minus sign (-) refers to the negative difference between AFC and PFC (lost hectares), where as the figures without the minus sign-and within the light-blue cells- refers to the positive difference that exists between AFC and PFC. Meanwhile, the cells in gray means that a forest type is not distributed within a bioclimatic region.

Based on the lost rate of these species (Tables 12, 13 and 14), Birch_poplar_ash-tree and juniper_pistachio_hackberry have the highest lost rate in Azerbaijan (Table 13 and Appendix E, Figure E2). Meanwhile, oak with hornbeam comparing group has suffered the highest lost rate in Georgia (Table 14 and Appendix E, Figure E3). It is needed to point out that juniper-pistachio-hackberry has suffered similar high lost-rate in Armenia and Georgia (92.44%, and 95.70%, respectively), like it happened in Azerbaijan (97.63%). In addition to these three forest types, beech and Caucasian pine groups are distributed in Armenia, Azerbaijan and Georgia. Even though beech has a positive hectare difference (258,309.8 ha) in the Colchic region, it has lost 377,566.6 ha in the study area. This represents 7.50% of lost forest cover. Meanwhile, Caucasian pine has a positive difference in Armenia and Azerbaijan (Table 15). However, this forest type ended up with a lost of 43,912.4 ha, which represent only 0.87% of the total forest cover lost in the study area.

The remaining three forest types can be found in two countries. Beech can be found in Armenia and Azerbaijan, whereas eldar pine, and flood plain oak with poplar_willow_plains spread over Azerbaijan and Georgia (Table 15). Both eldar pine, and flood plain oak with poplar_willow_plains have lost more than 90% of their potential area in Georgia (Table 14 and Appendix E, Figure E3). Meanwhile, the highest lost rate for beech happened in Armenia (68.80%). By hectares, beech, and flood plain oak with poplar_willow_plains have lost the biggest amount in Azerbaijan, whereas for eldar pine happened but in Georgia (Table 15). For these three forest types, the amount of hectares lost in only one country contribute with around 60% of the total deficit for each forest type (beech–67.30% in Azerbaijan, flood plain oak with poplar_willow_plains–64.35% in Azerbaijan, and eldar pine–62.71% in Georgia).

3.2. Modeled Present vs. Modeled Futures

The Modeled Present of forest classes' distribution yielded a total of 69,478,447.0 ha, which is almost four times the extent of the study area (i.e., 18,566,894.4 ha). This output happened because, in contrast to both datasets used in the first analysis, three are overlaps of forest classes. Also, overlapping did happen between forest classes for A2a Models and B2a Models (Check appendix F for habitat suitability maps of forest classes for each model).

3.2.1. Modeled Present vs. A2a Model[5]

Study Area Level

In the study area, distribution of "forest cover"[6] could shrink 33.25% from its modeled present value (Table 16). Dry woodlands and zelkova could be the only two forest classes that could increase their covering area (70.89% and 33.12%, respectively). From the remaining twelve, both pinus_pts and betula_etc could each suffer extirpations of more than 75% of their modeled present covering area (94.70% and 85.89%, respectively).

Table 16: Impact of climate change on forest classes at the study area level based on Modeled Present and A2a Model outputs

MODELED PRESENT Forest Classes	AREA Ha	A2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Dry woodlands	7,091,200.8	Dry woodlands	12,117,839.8	70.89
Betula_etc	2,199,902.6	Betula_etc	310,324.5	-85.89
Buxus	3,014,052.3	Buxus	2,247,509.3	-25.43
Carpinus	9,006,472.7	Carpinus	3,950,797.7	-56.13
Castanea	2,846,612.8	Castanea	2,156,060.4	-24.26

[5] For this analysis, area figures from overlapping forest classes were not subtracted. In other words, the areas (hectares) used to estimate the potential extirpation rate for all forest classes include their overlapping area figures.
[6] Forest cover refers to the total number of forest classes and their area found within regional, bioclimatic, or political boundaries (e.g., South Caucasus Region, referred as study area; Colchic climatic region; and Armenia, respectively).

MODELED PRESENT Forest Classes	AREA Ha	A2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Fagus	7,105,570.4	Fagus	3,883,510.9	-45.35
Parrotia	5,225,200.6	Parrotia	2,934,438.9	-43.84
Picea_Abies	3,211,861.8	Picea_Abies	1,699,508.0	-47.09
Pinus_pts	198,800.4	Pinus_pts	10,542.8	-94.70
Quercus_Pinus	10,868,656.0	Quercus_Pinus	7,250,644.3	-33.29
Quer_casta	6,131,592.0	Quer_casta	3,275,910.0	-46.57
Quer_pedun	7,294,403.9	Quer_pedun	2,253,126.4	-69.11
Taxus	4,008,502.9	Taxus	2,590,892.2	-35.37
Zelkova	1,275,617.8	Zelkova	1,698,074.5	33.12
TOTAL	**69,478,447.0**	**TOTAL**	**46,379,179.7**	**-33.25**

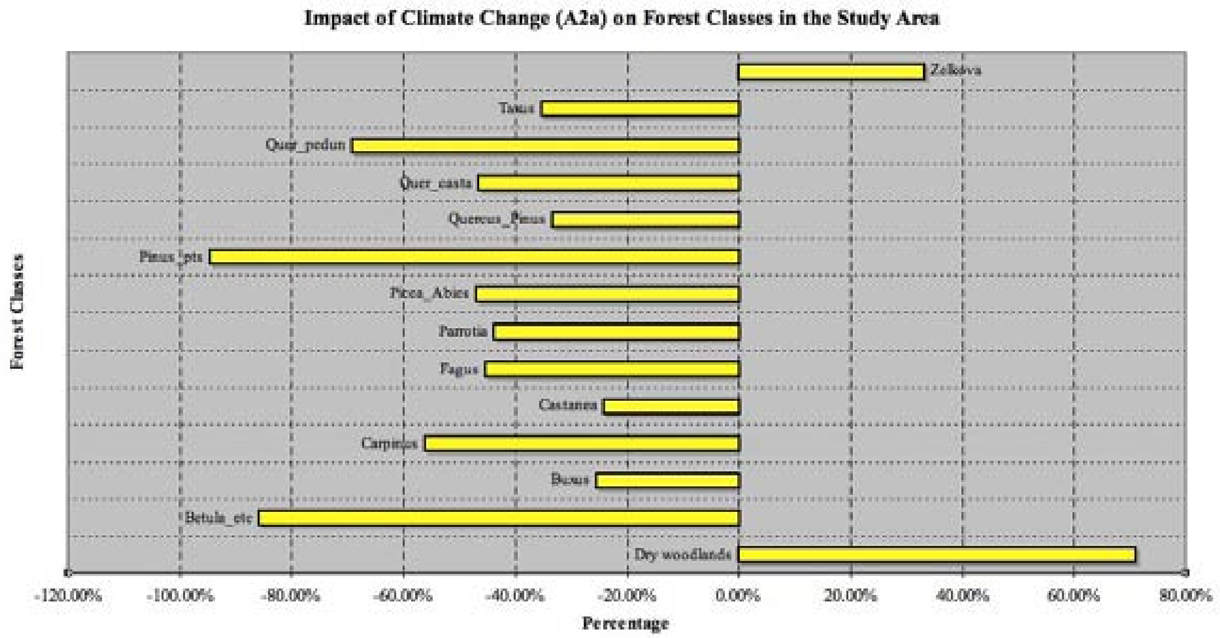

Fig. 4: Lost of forest classes in the study area, based on values from Table 16

Eight forest classes might decrease their covering area in less than 50% from its modeled present value (Table 16, and Fig. 4). From this group, castanea could be the forest class facing the smallest extirpation rate within the study area (24.26%), whereas picea_abies could suffer the highest extirpation rate (47.09%). Meanwhile, carpinus and quer_pedun could respectively suffer 56.13% and 69.11% extirpation rates (Fig. 4).

Country Level

ARMENIA

In Armenia, the distribution of forest classes could decrease in 52.08% from its modeled present value (Table 17). Dry woodlands could increase in 286.90% (Appendix G, Figure G1). From the remaining ten forest classes, only quercus_pinus and betula_etc might appear in Armenia by 2080, even though betula_etc could join carpinus, castanea, fagus, parrotia, picea_abies, quer_casta, Quer_pedun, and taxus as the forest classes that might disappear from the territory of Armenia (Table 17).

Table 17: Impact of climate change on forest classes in Armenia based on Modeled Present and A2a Model outputs

MODELED PRESENT Forest Classes	AREA Ha	A2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Dry woodlands	587,789.1	Dry woodlands	2,274,154.2	286.90
Betula_etc	569,749.0	Betula_etc	4,149.8	-99.27
Carpinus	1,223,451.6	Carpinus	0.0	-100.00
Castanea	72,094.9	Castanea	0.0	-100.00
Fagus	1,079,820.0	Fagus	0.0	-100.00
Parrotia*	249,461.8	Parrotia	0.0	-100.00
Picea_Abies*	84,534.6	Picea_Abies	0.0	-100.00
Quercus_Pinus	2,087,152.2	Quercus_Pinus	1,063,561.3	-49.04
Quer_casta*	498,449.1	Quer_casta	0.0	-100.00
Quer_pedun	135,659.1	Quer_pedun	0.0	-100.00
Taxus	385,493.4	Taxus	0.0	-100.00
TOTAL	**6,973,654.8**	**TOTAL**	**3,341,865.3**	**-52.08**

Note: *These forest classes are not historically recorded within this country. They appear in the modeled present outputs because the model just took into account climatic variables for identifying suitable habitats. Other ecological process (e.g., intraspecific and interspecific competition), and geographic features (e.g., natural migratory barriers) that determine the distribution that could increase accuracy were left out due to time and data constraints.

AZERBAIJAN

In Azerbaijan, 62.08% of its forest cover could disappear by 2080 (Table 18). Only buxus, picea_abies, and zelkova could suffer 100% potential extirpation rate each (Appendix G, Figure G2). From the remaining seven forest classes, only quercus_pinus could decrease its covering area in less than 75%. Meanwhile, Quer_casta, parrotia, betula_etc, carpinus, fagus, quer_pedun, taxus, and castanea could lessen their covering areas in more than 90% (Table 18), being castanea the forest class threatened with the highest potential extirpation rate (98.86%).

Table 18: Impact of climate change on forest classes in Azerbaijan based on Modeled Present and A2a Model outputs

MODELED PRESENT Forest Classes	**AREA Ha**	**A2a MODEL Forest Classes**	**AREA Ha**	**EXTIRPATED %**
Dry woodlands	5,997,687.9	Dry woodlands	8,031,356.9	33.91
Betula_etc	312,487.7	Betula_etc	14,561.9	-95.34
Buxus	3,271.0	Buxus	0.0	-100.00
Carpinus	3,184,930.6	Carpinus	122,704.1	-96.15
Castanea	295,122.7	Castanea	3,375.0	-98.86
Fagus	1,848,704.1	Fagus	61,755.7	-96.66
Parrotia	2,044,605.9	Parrotia	100,133.7	-95.10
Picea_Abies*	93,132.1	Picea_Abies	0.0	-100.00
Quercus_Pinus	3,188,509.1	Quercus_Pinus	806,735.6	-74.70
Quer_casta	2,095,652.9	Quer_casta	109,586.3	-94.77
Quer_pedun	4,861,751.1	Quer_pedun	75,146.2	-98.45
Taxus	550,681.1	Taxus	8,042.1	-98.54
Zelkova	139,364.4	Zelkova	0.0	-100.00
TOTAL	**24,615,900.6**	**TOTAL**	**9,333,397.5**	**-62.08**

Note: * See above note for previous Table 17.

GEORGIA

In Georgia, its forest cover could decrease in 11.05% from its modeled present value (Table 19). Both dry woodlands and zelkova could increase their covering areas in 258.36% and 49.44%, respectively. Only pinus_pts, and betula_etc could decrease their covering areas in more than 75% (Table 19 and Appendix G, Figure G3), being pinus_pts the forest class threatened with the highest potential extirpation rate (94.70%). The remaining ten forest classes could also suffer extirpations but no higher than 50%. From this group, picea_abies and quer_pedun could respectively suffer the highest and the lowest potential extirpation rates (Table 19).

Table 19: Impact of climate change on forest classes in Georgia based on Modeled Present and A2a Model outputs

POTENTAIL COVER (Formation)	AREA Ha	A2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Dry woodlands	505,723.5	Dry woodlands	1,812,328.6	258.36
Betula_etc	1,317,667.7	Betula_etc	291,612.7	-77.87
Buxus	3,010,781.3	Buxus	2,247,509.4	-25.35
Carpinus	4,598,089.6	Carpinus	3,828,093.8	-16.75
Castanea	2,479,395.0	Castanea	2,152,684.0	-13.18
Fagus	4,177,046.9	Fagus	3,821,755.3	-8.51
Parrotia*	2,931,133.1	Parrotia	2,834,305.5	-3.30
Picea_Abies	3,034,194.8	Picea_Abies	1,699,508.1	-43.99
Pinus_pts	198,800.4	Pinus_pts	10,542.8	-94.70
Quercus_Pinus	5,592,994.5	Quercus_Pinus	5,380,349.2	-3.80
Quer_casta*	3,537,490.8	Quer_casta	3,166,322.5	-10.49
Quer_pedun	2,296,993.9	Quer_pedun	2,177,980.3	-5.18
Taxus	3,072,328.4	Taxus	2,582,850.3	-15.93
Zelkova	1,136,255.9	Zelkova	1,698,074.4	49.44
TOTAL	**37,888,895.8**	**TOTAL**	**33,703,916.9**	**-11.05**

Note: * See above note for previous Table 17.

ANALYSIS ACROSS COUNTRIES

Based on modeled present outputs, the fourteen forest classes could be found in Azerbaijan and Georgia, whereas buxus and zelkova could not appear in Armenia. Moreover, the first two listed countries could respectively suffer the highest (62.08%) and lowest (11.05%) extirpation rates of forest cover (Tables 18 and 19). In Armenia, Azerbaijan and Georgia, betula_etc could lessen its covering area more than 75% (Appendix G, Figures G1–G3). Carpinus, castanea, fagus, parrotia, picea_abies, Quer_casta, Quer_pedun, and taxus could shrink more than 75% their covering areas in Armenia and Azerbaijan (Appendix G, Figures G1 and G2). Meanwhile, quercus_pinus could decrease its covering area but in less than 75% in the three Caucasian countries (Table 17, 18, and 19).

Moreover, some forest classes could suffer 100% potential extirpation rates in at least one Caucasian country. In Armenia and Azerbaijan, picea_abies could disappear by 2080 (Tables 17, and 18). Buxus and zelkova could also vanish from Azerbaijan (Appendix G, Figure G2). Meanwhile, carpinus, Castanea, fagus, parrotia, quer_casta, quer_pedun, and taxus could suffer the same future but in Armenia (Appendix G, Figure G1). Conversely, dry woodlands could increase its covering areas in these three Caucasian countries; however, only in Armenia and Georgia this forest class could suffer expansion rates higher than 100% (Table 17, and 19).

3.2.2. Modeled Present vs. B2a Model[7]

Study Area Level

In the study area, distribution of "forest cover"[8] could decrease in 7.85% from its modeled present value (Table 20). Zelkova, dry woodlands, buxus, castanea, and parrotia could respectively increase their covering area in 47.83%, 46.38%, 5.54%, 0.20% and 0.08%.

Table 20: Impact of climate change on forest classes at the study area level based on Modeled Present and B2a Model outputs

MODELED PRESENT Forest Classes	AREA Ha	B2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Dry woodlands	7,091,200.8	Dry woodlands	10,380,106.1	46.38
Betula_etc	2,199,902.6	Betula_etc	587,670.2	-73.29
Buxus	3,014,052.3	Buxus	3,181,080.1	5.54
Carpinus	9,006,472.7	Carpinus	7,809,286.7	-13.29
Castanea	2,846,612.8	Castanea	2,852,346.3	0.20
Fagus	7,105,570.4	Fagus	5,862,868.0	-17.49
Parrotia	5,225,200.6	Parrotia	5,229,641.8	0.08
Picea_Abies	3,211,861.8	Picea_Abies	2,435,865.8	-24.16
Pinus_pts	198,800.4	Pinus_pts	88,347.1	-55.56
Quercus_Pinus	10,868,656.0	Quercus_Pinus	8,965,709.2	-17.51
Quer_casta	6,131,592.0	Quer_casta	5,768,835.5	-5.92
Quer_pedun	7,294,403.9	Quer_pedun	5,341,120.9	-26.78
Taxus	4,008,502.9	Taxus	3,632,661.1	-9.38

[7] For this analysis, area figures from overlapping forest classes, discussed in section 3.2., were not subtracted. In other words, the areas (i.e., hectares) used to estimate the potential extirpation rate for all forest classes include their overlapping area figures.
[8] Forest cover refers to the total number of forest classes and their area found within regional, bioclimatic, or political boundaries (e.g., South Caucasus Region, referred as study area; Colchic climatic region; and Armenia, respectively).

MODELED PRESENT Forest Classes	AREA Ha	B2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Zelkova	1,275,617.8	Zelkova	1,885,778.1	47.83
TOTAL	**69,478,447.0**	**TOTAL**	**64,021,316.9**	**-7.85**

From the remaining nine forest classes, quer_pedun, picea_abies, quercus_pinus, fagus, carpinus, taxus, and quer_casta could lessen their covering areas in less than 30% each (Table 20 and Fig. 5), leaving betula_etc and pinus_pts with potential extirpation rates between 50% and 75% (Table 20). Moreover, quer_casta could be facing the smallest potential extirpation rate within the study area (i.e., 5.92%), whereas betula_etc could be suffering the highest potential extirpation rate (73.24%).

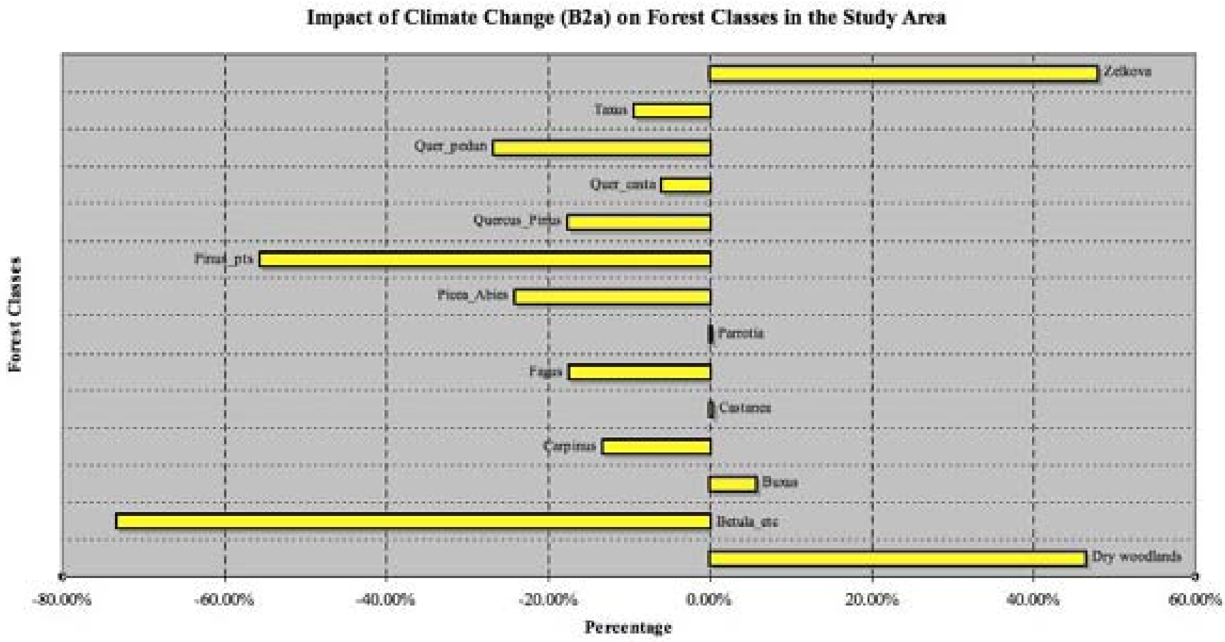

Fig. 5: Lost of forest classes in the study area, based on values from Table 16

Country Level

ARMENIA

In Armenia, the distribution of forest classes could decrease in 2.37% from its modeled present value. Dry woodlands, parrotia, quer_pedun, and Quer_casta could increase their covering area (Appendix H, Figure H1). From the remaining seven forest classes, only betula_etc and castanea could suffer extirpation rates higher than 75%, but up to 96.87% (Table 21). Meanwhile, fagus, quercus_pinus, carpinus, and picea_abies could decrease their covering areas in less than 50% each, leaving taxus with 58.60% potential extirpation rate (Table 21).

Table 21: Impact of climate change on forest classes in Armenia based on Modeled Present and B2a Model outputs

MODELED PRESENT Forest Classes	AREA Ha	B2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Dry woodlands	587,789.1	Dry woodlands	1,541,071.7	162.18
Betula_etc	569,749.0	Betula_etc	17,849.6	-96.87
Carpinus	1,223,451.6	Carpinus	1,084,141.2	-11.39
Castanea	72,094.9	Castanea	5,549.4	-92.30
Fagus	1,079,820.0	Fagus	626,877.5	-41.95
Parrotia*	249,461.8	Parrotia	564,395.9	126.25
Picea_Abies*	84,534.6	Picea_Abies	81,754.6	-3.29
Quercus_Pinus	2,087,152.2	Quercus_Pinus	1,756,500.6	-15.84
Quer_casta*	498,449.1	Quer_casta	692,507.4	38.93
Quer_pedun	135,659.1	Quer_pedun	278,085.0	104.99
Taxus	385,493.4	Taxus	159,602.9	-58.60
TOTAL	**6,973,654.8**	**TOTAL**	**6,808,335.8**	**-2.37**

Note: * See above note for previous Table 17.

AZERBAIJAN

In Azerbaijan, 36.59% of its forest cover could disappear by 2080 (Table 22). Only buxus could suffer 100% potential extirpation rate, and dry woodlands could increase in 25.27% its covering area (Appendix H, Figure H2). Castanea, betula_etc, zelkova, and taxus could lessen their covering area in more than 75% of their modeled present value. Meanwhile, fagus, quer_pedun, picea_abies, quer_casta, and quercus_pinus could decrease their covering areas in less 75%, but only parrotia and carpinus could suffer potential extirpation rates lower than 50% (Table 22).

Table 22: Impact of climate change on forest classes in Azerbaijan based on Modeled Present and B2a Model outputs

MODELED PRESENT Forest Classes	AREA Ha	B2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Dry woodlands	5,997,687.9	Dry woodlands	7,513,143.8	25.27
Betula_etc	312,487.7	Betula_etc	59,071.0	-81.10
Buxus	3,271.0	Buxus	0.0	-100.00

MODELED PRESENT Forest Classes	AREA Ha	B2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Carpinus	3,184,930.6	Carpinus	1,708,582.2	-46.35
Castanea	295,122.7	Castanea	23,535.4	-92.03
Fagus	1,848,704.1	Fagus	634,361.8	-65.69
Parrotia	2,044,605.9	Parrotia	1,048,636.3	-48.71
Picea_Abies*	93,132.1	Picea_Abies	39,680.5	-57.39
Quercus_Pinus	3,188,509.1	Quercus_Pinus	1,591,347.8	-50.09
Quer_casta	2,095,652.9	Quer_casta	995,519.7	-52.50
Quer_pedun	4,861,751.1	Quer_pedun	1,833,034.4	-62.30
Taxus	550,681.1	Taxus	132,882.3	-75.87
Zelkova	139,364.4	Zelkova	28,174.7	-79.78
TOTAL	**24,615,900.6**	**TOTAL**	**15,607,969.9**	-36.59

Note: * See above note for previous Table 17.

GEORGIA

In Georgia, its forest cover could increase in 9.81% from its modeled present value. This could happen, because eleven forest classes could increase their covering area (Table 23 and Appendix H, Figure H3). This rise in covering are could range from less than 1% to 162.17%, such it could be the cases of quercus_pinus and dry woodlands, respectively. Likewise, pinus_pts and betula_etc could suffer extirpation rates lower than 75%, and picea_abies lower than 50% (Table 23).

Table 23: Impact of climate change on forest classes in Georgia based on Modeled Present and B2a Model outputs

MODELED PRESENT Forest Classes	AREA Ha	B2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Dry woodlands	505,723.5	Dry woodlands	1,325,846.6	162.17
Betula_etc	1,317,667.7	Betula_etc	511,739.8	-61.16
Buxus	3,010,781.3	Buxus	3,181,080.0	5.66
Carpinus	4,598,089.6	Carpinus	5,016,562.7	9.10
Castanea	2,479,395.0	Castanea	2,823,261.5	13.87
Fagus	4,177,046.9	Fagus	4,601,628.8	10.16

MODELED PRESENT Forest Classes	AREA Ha	B2a MODEL Forest Classes	AREA Ha	EXTIRPATED %
Parrotia*	2,931,133.1	Parrotia	3,616,609.7	23.39
Picea_Abies	3,034,194.8	Picea_Abies	2,314,432.4	-23.72
Pinus_pts	198,800.4	Pinus_pts	88,347.1	-55.56
Quercus_Pinus	5,592,994.5	Quercus_Pinus	5,617,863.2	0.44
Quer_casta*	3,537,490.8	Quer_casta	4,080,809.1	15.36
Quer_pedun	2,296,993.9	Quer_pedun	3,230,000.8	40.62
Taxus	3,072,328.4	Taxus	3,340,175.9	8.72
Zelkova	1,136,255.9	Zelkova	1,857,603.5	63.48
TOTAL	**37,888,895.8**	**TOTAL**	**41,605,961.1**	**9.81**

Note: * See above note for previous Table 17.

ANALYSIS ACROSS COUNTRIES

Like in the analysis across countries for the A2a model outputs, Armenia, Azerbaijan and Georgia could have the same forest cover composition (14 forest classes for both Azerbaijan and Georgia, and same 12 forest classes for Armenia). Armenia and Azerbaijan could decrease their forest covers but in much less than 75% (2.37% and 36.59%, respectively); whereas the forest cover in Georgia could increase in 9.81%.

Picea_abies could decrease its covering area in Armenia, Azerbaijan and Georgia (Appendix H, Figures H1–H3). However, its extirpation rates could be less than 75% in all these three Caucasian countries. In Armenia and Azerbaijan, betula_etc and castanea could suffer extirpation rates higher than 75% (Appendix H, Figures H1 and H2), whereas carpinus, fagus, and quercus_pinus could also decrease their covering areas but in less than 75%.

Additionally, taxus could decrease its covering area in Armenia and Azerbaijan. However, only in Armenia its extirpation rate could be higher than 75% (Appendix H, Figure H1). Buxus and Zelkova could be found in Azerbaijan and Georgia. In Georgia, both forest classes could respectively increase their covering areas in 5.66% and 63.48% (Table 23), whereas in Azerbaijan their covering areas could lessen more than 75% (Table 22). However, only buxus could entirely disappear from Azerbaijan by 2080 (Appendix H, Figure H2). Moreover, parrotia, quer_casta, and Quer_pedun could increase their covering areas in Armenia and Georgia. These three forest classes could suffer the highest expansion rates in Armenia (i.e., 126.25%, 38.93% and 104.99%, respectively).

ANALSYS BETWEEN A2a and B2a MODELS

As the impact of both models showed to be different for each forest class at the three units of examination, analysis between the outputs of each model at the same unit of analysis (e.g., A2a model outputs vs. B2a model outputs in the Colchic climatic region) were performed to determine the impact of these two possible climate change sceneries on forest classes.

Study Area

Both models outputs showed that forest cover of the study area could decrease due climate change regardless the emission scenery used to determine its potential impact on forest cover. However, this outcome could be more drastic if a more extreme change of climate (i.e., emission scenery A2a) happened (Table 16). In Contrast to A2a model outputs, where only dry woodlands and zelkova could increase their covering area, three more forest classes (buxus, castanea, and parrotia) could suffer expansion rates under emission scenery B2a, although these rises in covering areas could be less than 6% (Table 20).

In addition, even though dry woodlands and zelkova could increase their covering areas under both emission sceneries conditions, only dry woodlands could maintain increasing its covering area under a more extreme change in climatic conditions (emission scenery A2a). In other words, zelkova could reduce its expansion rate from 47.83% under emission scenery B2a to 33.12% under emission scenery A2a. Moreover, buxus, castanea, parrotia, and zelkova could not be able to maintain the same tendency when comparing both emission sceneries, like it could happen to the other nine forest classes.

Caucasian Countries

In Armenia, forest cover could decrease under both emission sceneries, but it could only reach higher extirpation rate under emission scenery A2a (Table 17). Although dry woodlands, parrotia, quer_casta, and quer_pedun could suffer expansion rates under emission scenery B2a (Table 21), only the first forest class could also do it under emission scenery A2a. Meanwhile, parrotia, quer_casta, and quer_pedun could be entirely extirpated from Armenia if emission scenery A2a happened. Moreover, even though the remaining seven forest classes could only reach the highest extirpation rate under emission scenery A2a, only betula_etc and quercus_pinus could not suffer 100% extirpation rate under such emission scenery.

In Azerbaijan, forest cover could decrease under both emission sceneries. However, higher extirpation rate could only happen under emission scenery A2a. Buxus could disappear from Armenia if any of emission sceneries happened, whereas dry woodlands could increase its covering area. Moreover, even though the remaining eleven forest classes could only reach the highest extirpation rate under emission scenery A2a, only picea_abies and zelkova could suffer 100% extirpation rate under such emission scenery.

In Georgia, Forest cover could either increase under emission scenery B2a or decrease under a more extreme change in climatic conditions (i.e., emission scenery A2a). Dry woodlands could also suffer expansion rates under both emission sceneries. Additionally, ten forest classes could suffer expansion rates under emission scenery B2a (Table 23), whereas only zelkova could also do it under emission scenery A2a (Table 19). However, the expansion rate of zelkova could only be higher under emission scenery B2a. Excluding these two forest classes, the ten remaining forest classes could suffer higher extirpation rates under emission scenery A2a than under B2a. This includes forest classes that could increase their covering areas under emission scenery B2a but decrease them under emission scenery A2a.

3.3. Vertical Shift of Forest Classes

Although the previous analysis of climate change on forest classes showed their area distribution trends, as either increasing or decreasing, it is also important to estimate forest classes' likely vertical distribution. In doing so, middle altitudinal points were calculated from the minimal and maximal altitudinal points depicted in each of the three climatic models developed for this document. Like in the previous analysis, this spatial trend was seen at two levels of analysis (study area and south Caucasian countries), and the outputs from modeled present model were used as landmark for estimating the percentage of shift.

3.3.1. Study Area Level

In the Southern Caucasus, the middle altitudinal point of forest cover, which includes 14 forest classes, goes from 175 to 2,450 m a.s.l. (Table 24). When comparing modeled present middle altitudinal points with A2a model middle altitudinal points, only pinus_pts could decrease its vertical distribution in 11.43%. From the remaining 13 forest classes, only zelkova could shift up to more than 50% from its present modeled middle altitudinal point (Table 24). The lasting 12 forest classes could increase their vertical distribution between 6.67% (carpinus and fagus) and 47.37% (parrotia).

Under the most environmentally friendly scenario (B2a), the fourteen forest classes could shift up their vertical distribution (Table 36). Only pinus_pts could increase in 114.29% its altitudinal distribution, whereas the remaining thirteen forest classes could do so but in less than 50%, ranging between 13.33% (carpinus and fagus) and 46.15% (Zelkova).

Table 24: Modeled altitudinal shifts per forest classes in the study area*

Forest Classes	Modeled Present** Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage (%)	B2a Model Vertical Shift Percentage (%)
Dry woodlands	1,150	+39.13	+17.39
Betula_etc	2,450	+30.61	+22.45
Buxus	1,100	+40.91	+27.27
Carpinus	1,500	+6.67	+13.33
Castanea	1,150	+26.09	+21.74
Fagus	1,500	+6.67	+13.33
Parrotia	950	+47.37	+42.11
Picea_Abies	1,500	+43.33	+40.00
Pinus_pts	175	-11.43	+114.29
Quercus_Pinus	1,600	+25.00	+18.75
Quer_casta	1,300	+11.54	+11.54

Forest Classes	Modeled Present** Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage (%)	B2a Model Vertical Shift Percentage (%)
Quer_pedun	900	+27.78	+27.78
Taxus	1,400	+10.71	+21.43
Zelkova	650	+69.23	+46.15

Note: *The plus sign '+' indicates that the altitudinal distribution of a forest class has increased from its modeled value, whereas the minus sign '-' indicates that the altitudinal distribution of a forest class has decreased from its modeled value.
**Modeling exercise did not specifically consider altitudinal ranges; this is why the middle points for certain classes do not reflect current distributions; however, we think that the possible vertical shifts showing in the table in percentage value can be useful for interpretation when developing national strategies, considering realities.

In addition and only at the study area level, the shift of each forest class based on cardinal points was identified in order to determine general horizontal 'migratory' tendencies. From this analysis it was seen that carpinus, castanea, fagus, parrotia, quer_casta, and taxus seem to migrate North and South under both emission sceneries (A2a and B2a). Likewise, four forest classes seem to follow the same migratory tendency under both emission scenarios. However, each of these four forest classes could follow different directions (dry woodlands–Northwest, betula_etc–North, pinus_pts–South, and zelkova–Southwest). Meanwhile, the remaining forest classes could follow different trajectories depending upon the emission scenery. Under emission scenery A2a, buxus, picea_abies and quercus_pinus could migrate North from their modeled present position, whereas quer_pedun could move North and Southeast. If predictions from emission scenery B2a stand true, buxus, quercus_pinus, and quer_pedun could migrate North and South, whereas picea_abies could move North and Southeast from its modeled present position.

3.3.2. Country Level

ARMENIA

In Armenia, the middle altitudinal point of forest cover, which includes eight forest classes—based on modeled present outputs, goes from 1,100 to 2,750 m a.s.l. Under emission scenery A2a, five forest classes (carpinus, castanea, fagus, quer_pedun, and taxus) could decrease its altitudinal distribution, and even disappear from this country (Table 25). Meanwhile, the remaining forest classes could shift up their altitudinal modeled present distribution between 23.64% (betula_etc.) and 50.00% (dry woodlands).

Table 25: Lowest and highest altitudinal points per forest classes in Armenia*

Forest Classes	Modeled Present Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage (%)	B2a Model Vertical Shift Percentage (%)
Dry woodlands	1,200	+50.00	+29.17
Betula_etc	2,750	+23.64	+18.18
Carpinus	1,700	-100.00	+23.53

Forest Classes	Modeled Present Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage (%)	B2a Model Vertical Shift Percentage (%)
Castanea	1,550	-100.00	+32.26
Fagus	1,750	-100.00	+28.57
Quercus_Pinus	1,900	+36.84	+18.42
Quer_pedun	1,100	-100.00	+27.27
Taxus	1,800	-100.00	+38.89

Note: *See notes for Table 24.

When comparing modeled present with B2a model, the altitudinal distribution of forest classes could be completely different than the one depicted in the above paragraph. The eight forest classes could actually increase their altitudinal ranges (Table 25), ranging from 18.18% (betula_etc.) to 38.89% (Taxus). In other words, even the five forest classes that could disappear if emission scenery A2a stands true, they could shift up their modeled present distribution under a more ecological friendly projections (B2a).

AZERBAIJAN

The modeled present middle altitudinal points of forest cover in Azerbaijan, which includes twelve forest classes, goes from 600 to 2,750 m a.s.l. Buxus, and zelkova could have no altitudinal range to use under emission scenario A2a, whereas castanea could shift up to 100% its altitudinal distribution (Table 26). From the remaining eight forest classes, only taxus could increase its altitudinal range in more than 75%. Meanwhile the lasting forest classes could increase their vertical distribution, ranging from 3.33% (carpinus) to 47.37% (parrotia).

Table 26: Lowest and highest altitudinal points per forest classes in Azerbaijan*

Forest Classes	Modeled Present Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage (%)	B2a Model Vertical Shift Percentage (%)
Dry woodlands	1,150	+34.78	+17.39
Betula_etc	2,750	+27.27	+20.00
Buxus	1,000	-100.00	-100.00
Carpinus	1,500	+3.33	+13.33
Castanea	1,150	+100.00	+73.91
Fagus	1,500	+36.67	+13.33
Parrotia	950	+47.37	+42.11
Quercus_Pinus	1,550	+22.58	+22.58

Forest Classes	Modeled Present Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage (%)	B2a Model Vertical Shift Percentage (%)
Quer_casta	1,250	+16.00	+16.00
Quer_pedun	900	+27.78	+27.78
Taxus	1,300	+84.62	+80.77
Zelkova	600	-100.00	+50.00

Note: *See notes for Table 24.

When comparing modeled present with B2a model, only buxus could also decrease in 100% its altitudinal range, and taxus could increase its vertical distribution in more than 75% (Table 26). Conversely to what was mentioned in the above paragraph, zelkova could increase their ranges in 68.97% and 50.00%, respectively. Eight out of the remaining nine forest classes could also shift up but in less than 50% increase, ranging from 13.33% (fagus) to 42.11% (parrotia). Meanwhile, the lasting forest class (castanea) could increase up to 73.91% its altitudinal range.

GEORGIA

In Georgia, the modeled present middle altitudinal point of forest cover, which includes twelve forest classes, goes from 175 to 2,250 m a.s.l. Comparing modeled present with A2a model showed that only pinus_pts could decrease its altitudinal distribution (Table 27). Meanwhile, the remaining forest classes could shif up. Dry woodlands could shift its altitudinal range up to 100%, whereas quer_pedun and zelkova could also significantly shift their vertical distribution (Table 27). The lasting eight forest classes could shift up between 35.71% (quercus_pinus) and 47.37% (castanea).

Table 27: Lowest and highest altitudinal points per forest classes in Georgia*

Forest Classes	Modeled Present Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage	B2a Model Vertical Shift Percentage
Dry woodlands	550	+100.00	+72.73
Betula_etc	2,250	+42.22	+28.89
Buxus	1,100	+40.91	+27.27
Carpinus	1,150	+39.13	+26.09
Castanea	950	+47.37	+36.84
Fagus	1,150	+39.13	+26.09
Picea_Abies	1,500	+43.33	+33.33
Pinus_pts	175	-11.43	+114.29
Quercus_Pinus	1,400	+35.71	+21.43

Forest Classes	Modeled Present Altitude (m a.s.l.) Middle Point	A2a Model Vertical Shift Percentage	B2a Model Vertical Shift Percentage
Quer_pedun	700	+57.14	+57.14
Taxus	1,100	+40.91	+27.27
Zelkova	650	+69.23	+46.15

Note: *See notes for Table 24.

When comparing modeled present with B2a model, both, dry woodlands and quer_pedun could still drastically shift upper their modeled present altitudinal distributions (72.73% and 57.14%, respectively); whereas zelkova could also shift up but in around 46.15%. In addition, pinus_pts could shift 114,29% its altitudinal range, conversely to what could happened under emission scenery A2a. The lasting eight forest classes could also shift up, ranging from 21.43% (quercus_pinus) and 36.84% (castanea).

3.4. Estimation of Restoration Potential

This part of the analysis sought to determine the amount of hectares that could be restored for each comparing group of forest types at three levels of analysis (Bioclimatic Regions, South Caucasian countries, and Bioclimatic Regions within each South Caucasian Country). Ten percent of the total lost area was used as threshold for calculating the amount of hectares that need to be restored. This fixed figure was chosen based on (a) our experience in managing natural resources in the Caucasus, and (b) the assumption that the remaining 90% of the lost area has been transformed either into pastures, agriculture lands or urbanized areas.

3.4.1. Bioclimatic Regions

There are 17 comparing groups of forest types (Table 11). Three comparing groups did not have formation to compare with, and therefore, their differences resulted in no area lost (1,298.0 ha for chestnut with zelkova, 52,576.8 ha for poplar_willow_mountain-valleys, and 230.2 ha for taxus). Moreover, only alder_poplar_willow has a positive hectares difference in both the study area and its bioclimatic region (Colchic). Meanwhile, chestnut-leaved oak has lost hectares in at least one of its climatic regions, but still ended up with differences that indicate no hectares lost (Table 11).

As explained along this document, these inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003). Hence, the restoration potential were calculated for all those forest types that have one negative difference in at least one climatic region, which excluded alder_poplar_willow, chestnut with zelkova, poplar_willow_mountain-valleys, poplar_willow_plains and taxus from this part of the analysis (Table 28).

Likewise, positive differences values were excluded from this part of the analysis in order to have an accurate figure on how many hectares need to be restored. Nevertheless, these intentional exclusions do not mean that any of these forest types do not need restoration efforts. It just means that due to the constraints mentioned above we were not able to estimate how many hectares could be restored.

Table 28: Forest restoration potential based on the 10% of lost hectares in each bioclimatic region (Table 11)*

Forest Types	Bioclimatic Region						Total of Potentially Restorable Hectares by Species
	Colchic Ha.	East Caucasus Ha.	South Uplands Ha.	Southern Lesser Caucasus Ha.	Dry Plains and Ridges Ha.	Hyrcan Ha.	
Alder-Poplar-Willow (Colchic)							---
Beech		55,526.7	1,553.6	124.6	544.8	6,192.2	63,941.8
Birch_Poplar_Ash-tree	47,209.5	35,177.4	1,809.7				84,196.6
Caucasian pine	326.6	3,499.2	598.1				4,423.9
Chestnut + Buxus + Zelkova	50,081.2						50,081.2
Chestnut + Zelkova							---
Chestnut-leaved oak					3.4		3.4
Chestnut-leaved oak + Iron-tree						12,104.4	12,104.4
Dark conifers	32,787.5						32,787.5
Eldar pine					563.3		563.3
Flood plain oak + Poplar_Willow_Plains		49,851.8			16,860.2		66,712.0
Juniper_Pistachio_Hackberry		31,264.7	1,824.8	33,678.1	20,976.0		87,743.6
Oak and other broad-leaved species + Hornbeam	27,545.1	80,114.1	13,947.4	11,239.3	3,242.2	621.5	136,709.7
Pitsundian pine	150.8						150.8
Poplar_Willow_Mountain-valleys							---
Poplar_Willow_Plains							---
Taxus							---
Total of Potentially Restorable Hectares by Bioclimatic Region	**158,100.8**	**255,434.0**	**19,733.5**	**45,042.0**	**42,189.8**	**18,918.1**	**539,418.2**

Note: *The cells in blue refer to the forest type that ended up with positive value. As mentioned at the beginning of this section, these forest types and/or their values were not used for this part of the analysis. Meanwhile, the cells in gray means that a type is not distributed within a bioclimatic region. For checking the amount of hectares used to calculate the figures in this table, check Table 11.

For forest types comparing groups confined to a specific geographic area (chestnut with buxus and zelkova, chestnut-leaved oak with iron-tree, eldar pine, and pitsundian pine), the restoration potential add up to 62,899.6 ha, which represents 11.66% of the total hectares that need to be restored in the study area. Chestnut with buxus and zelkova, and chestnut-leaved oak with iron-tree will need the biggest amounts of hectares to be restored (50,081.2 ha in the Colchic, and 12,104.4 ha in the Hyrcan, respectively). Meanwhile, eldar pine and pitsundian pine will only need to restore 563.3 ha and 150.8 ha, respectively (Table 28).

A total of 136,709.7 ha of oak with hornbeam will need to be restored in six bioclimatic regions (Table 28). 58.60% and 20.15% of this total should be planted in the East Caucasus and the Colchic regions, respectively. The remaining 29,050.4 ha will require restoration efforts in the other regions.

For beech, 86.84% of its restoration potential will be needed in the East Caucasus, whereas the remaining 8,415.2 ha will have to be restored along the South Uplands, the Southern Lesser Caucasus, the Dry Plains and Ridges, and the Hyrcan bioclimatic regions, being the former the area that will required more of the restoration efforts (6,192.2 ha).

Juniper_pistachio_hackberry will need to be restored in four bioclimatic regions. It has the major amounts of hectare needs in the Southern Lesser Caucasus and the East Caucasus regions (Table 28). The restoration of these hectares will respectively contribute with 38.38% and 35.63% the total hectares that need to be restored for this forest type.

Birch_poplar_ash-tree and flood plain oak with poplar_willow_palins can respectively be found in three and two bioclimatic regions. Both comparing groups need to restore more than 50% of these types' cover in one region (birch_poplar_ash-tree 56.07% in the Colchic, and for flood plain oak with poplar_willow_palins 74.73% in the East Caucasus). Even more drastic it will be the impact of restoration efforts within one climatic region for Caucasian pine (79.10% in the East Caucasus).

3.4.2. Countries

Like in the restoration analysis at bioclimatic level, forest types and/or their positive difference values were excluded of this part of the analysis, as well. The purpose was to have accurate figures on how many hectares need to be restored in each bioclimatic region for twelve out of sixteen forest types (Table 29). Nevertheless, these intentional exclusions do not mean that any of these forest types do not need restoration efforts. It just means that due to the constraints mentioned above we were not able to estimate how many hectares could be restored.

Table 29: Forest restoration potential based on the 10% of lost hectares in each Caucasian country (Table 15)*

Forest Types	South Caucasian Countries			Total of Potentially Restorable Hectares by Species
	Armenia Ha.	Azerbaijan Ha.	Georgia Ha.	
Alder-Poplar-Willow (Colchic)				---
Beech	20,793.2	42,794.4		63,587.6
Birch_Poplar_Ash-tree	248.1	1,253.9	82,694.6	84,196.6
Caucasian pine			4,504.4	4,504.4

Forest Types	South Caucasian Countries			Total of Potentially Restorable Hectares by Species
	Armenia Ha.	Azerbaijan Ha.	Georgia Ha.	
Chestnut			0.0	---
Chestnut + Buxus + Zelkova			50,067.3	50,067.3
Chestnut-leaved oak + Iron-tree		12,095.9		12,095.9
Dark conifers			32,554.3	32,554.3
Eldar pine		210.0	353.2	563.2
Flood plain oak + Poplar_Willow_Plains		42,913.2	23,769.3	66,682.5
Juniper_Pistachio_Hackberry	14,756.7	57,528.1	15,458.8	87,743.6
Oak and other broad-leaved species + Hornbeam	25,648.3	37,207.4	73,843.3	136,698.9
Pitsundian pine			150.8	150.8
Poplar_Willow_Mountain-valleys				---
Poplar_Willow_Plains				---
Taxus				---
Total of Potentially Restorable Hectares by Bioclimatic Region	**61,446.3**	**194,002.9**	**283,396.0**	**538,845.2**

Note: *The cells in blue refer to the forest type that ended up with positive value. As mentioned at the beginning of this section, these forest types and/or their values were not used for this part of the analysis. Meanwhile, the cells in gray means that a type is not distributed within a country. For checking the amount of hectares used to calculate the figures in this table, check Table 15.

For the forest types comparing groups confined to one South Caucasian country (chestnut with buxus and zelkova, dark conifers, and pitsundian pine in Georgia, as well as chestnut-leaved oak with iron-tree in Azerbaijan), the restoration potential add up to 82,772.3 ha, which represents 15.36% of the total hectares that need to be restored in the study area. Chestnut with buxus and zelkova, and dark conifers will need the biggest amounts of hectares to be restored (50,067.3 ha and 32,554.3 ha, respectively), whereas pitsundian pine will need to restore 150.8 ha.

Four forest types can be found in the three countries (Table 29). Both birch_poplar_ash-tree and oak with hornbeam need to restore more than 50% of their cover in Georgia (98.22% and 54.02%, respectively). Similar restoration efforts will be needed by juniper_pistachio_hackberry, but in Azerbaijan (65.56%). The restoration of these three forest types only in the countries mentioned in this paragraph can contribute with 39.73% (214,066.0 ha) of the total hectares needs for the study area.

Beech is distributed in all the three countries. However, it could only be estimated its restoration potential in Armenia and Azerbaijan (Table 29). Beech, and flood plain oak with poplar_willow_plains will need to restore similar amount of hectares in Azerbaijan (42,794.4 ha and 42,913.2 ha, respectively). Just the restoration of these two forest types in Azerbaijan will contribute with 67.30% for beech, and 64.35% for flood plain oak with poplar_willow_plains of their total restoration potential. Although the amount of hectares for eldar pine are not as big as any of the forest types discussed above (Table 29), their single restoration in Georgia will contribute with 62.71% of its total reforestation potential.

3.4.3. Bioclimatic regions within Countries

The previous two restoration-needs analyses projected slightly different values. In order to make sense of the above information under a landscape approach, forest species found in bioclimatic regions were clipped within the boundaries of each South Caucasian country. In doing so, both landscape management issues and political aspects will be able to be targeted when developing the recommendations (strategic actions).

ARMENIA

In Armenia, four bioclimatic regions can be found (Table 30). It has eight comparing groups of forest type. Like it happened in the other previous analysis, there are forest types that resulted in positive differences when comparing their AFC to PFC (Appendix I, Tables I1, I2 and I3). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003). Hence, the restoration potential were calculated for all those forest types that have one negative difference in at least one bioclimatic region, which excluded Caucasian pine, chestnut, poplar_willow_mountain-valleys, and poplar_willow_plains from this part of the analysis (Table 30).

Positive differences values were excluded in order to have an accurate figure on how many hectares for each forest type can be restored in Armenia based on their bioclimatic distribution. Nevertheless, these intentional exclusions do not mean that any of these forest types do not need restoration efforts. It just means that due to the constraints mentioned above we were not able to estimate how many hectares could be restored.

A total of 61,565.2 ha will need to be restored in Armenia (Table 30). 52.71% of this restoration effort will be needed in the East Caucasus, whereas only 0.26% will be required in the Dry Plains and Ridges region of Armenia. In the East Caucasus, the entire restoration of beech and juniper_pistachio_hackberry will respectively contribute with 59.29% and 49.36% of these regions' restorations needs (19,239.6 ha, and 7,284.0 ha, respectively).

In the South Uplands and the Southern Lesser Caucasus, the restoration of their forest types will respectively help to overcome with 26.98% and 20.04% of the total restored hectares needed for Armenia. The entire restoration of oak with hornbeam in the South Uplands will be able to contribute with 50.19% of this region's restoration potential (12,877.5 ha). Meanwhile, the restoration of juniper_pistachio_hackberry will contribute with 44.46% of the Southern Lesser Caucasus' restoration potential, which leaves the remaining 55.54% of restoration to be covered by oak with hornbeam in this region.

By forest types across bioclimatic regions in Armenia, the forest restoration potential for juniper_pistachio_hackberry are mainly concentrated in two climatic regions (7,284.0 in the East Caucasus, and 5,486.6 ha in the Southern Lesser Caucasus), which together represent 86.54% of the total hectares needs for this type. The biggest amount of restored hectares for oak with hornbeam is located in the South Uplands (Table 30), which represents 50.19% of its restoration potential. Meanwhile, the restoration of beech in the East Caucasus and birch_poplar_ash-tree in the South Uplands will respectively help overcoming with 92.53% and 100% of their restoration potential, which respectively represent 19,239.6 ha and 357.0 ha.

Table 30: Forest restoration potential based on the 10% of lost hectares for each bioclimatic region existing in Armenia*

Forest Types	Bioclimatic Regions in Armenia				Total of Potentially Restorable Hectares by Types
	East Caucasus	South Uplands	Southern Lesser Caucasus	Dry Plains and Ridges	
	Restored Ha	Restored Ha	Restored Ha	Restored Ha	
Beech	19,239.6	1,553.6			20,793.2
Birch_Poplar_Ash-tree		357.0			357.0
Caucasian pine					---
Chestnut					---
Juniper_Pistachio_Hackberry	7,284.0	1,824.8	-5,486.6	-161.3	14,756.7
Oak and other broad-leaved species + Hornbeam	5,926.6	12,877.5	-6,854.1		25,658.3
Poplar_Willow (Mountain valleys)					---
Poplar_Willow (Plains)					---
Total of Potentially Restorable Hectares by Bioclimatic Region	**32,450.3**	**16,612.9**	**12,340.7**	**161.3**	**61,565.2**
Size of Bioclimatic Regions in Armenia (ha)	714,854.0	1,802,452.5	445,489.2	1,613.1	

Note: *The cells in blue refer to the forest type that ended up with positive value. As mentioned in this section, these forest types and/or their values were not used for this part of the analysis. Meanwhile, the cells in gray means that a type is not distributed in Armenia. For checking the amount of hectares used to calculate the figures in this table, check Appendix I, Tables I1–I4.

AZERBAIJAN

Five out of six bioclimatic regions can be found in Azerbaijan (Table 31). It has 10 comparing groups. However, there are forest types that resulted in positive differences when comparing their AFC to PFC (Appendix J, Tables J1 and J2). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003). Hence, the restoration potential was calculated for all those forest types that have one negative difference in at least one climatic region. This excluded Caucasian pine, chestnut, chestnut-leaved oak, and poplar_willow_mountain-valleys from this part of the analysis (Table 31). Nevertheless, these intentional exclusions do not mean that any of these forest types do not need restoration efforts. It just means that due to the constraints mentioned above we were not able to estimate how many hectares could be restored.

Table 31: Forest restoration potential based on the 10% of lost hectares for each bioclimatic region existing in Azerbaijan*

Forest Types	Bioclimatic Regions in Azerbaijan					Total of Potentially Restorable Hectares by Types
	East Caucasus	South Uplands	Southern Lesser Caucasus	Dry Plains and Ridges	Hyrcan	
	Restored Ha	Restored Ha	Restored Ha	Restored Ha	Restored Ha	
Beech	35,933.3		124.6	544.8	6,191.8	42,794.5
Birch_Poplar_Ash-tree	1,253.9					1,253.9
Caucasian pine						---
Chestnut						---
Chestnut-leaved oak						---
Chestnut-leaved oak + Iron-tree					12,104.0	12,104.0
Eldar Pine				210.0		210.0
Flood plain oak + Poplar_willow_plains	32,214.7	92.2		10,606.4		42,913.2
Juniper_Pistachio_Hackberry	16,527.8		28,191.5	12,808.8		57,528.1
Oak and other broad-leaved species + Hornbeam	28,506.3		4,385.1	3,706.0	620.8	37,218.2
Poplar_Willow (Mountain valleys)						---
Total of Potentially Restorable Hectares by Bioclimatic Region	**114,435.8**	**92.2**	**32,701.3**	**27,876.1**	**18,916.6**	**194,022.0**
Size of Bioclimatic Regions in Azerbaijan (ha.)	2,404,931.0	542,580.5	568,935.5	4,760,295.7	356,215.3	

Note: *The cells in blue refer to the forest type that ended up with positive value. As mentioned in this section, these forest types and/or their values were not used for this part of the analysis. Meanwhile, the cells in gray means that a type is not distributed in Azerbaijan. For checking the amount of hectares used to calculate the figures in this table, check Appendix J, Tables J1–J5.

The reforestation needs of this South Caucasian country equals to 194,022.0 ha (Table 31). 58.98% of the reforestation needs for Azerbaijan are concentrated in the East Caucasus region, whereas the restoration of forest cover in the South Uplands will only contribute 0.05% of the total restoration potential for this country. More than 75% of the restoration potential for beech, flood plain oak with poplar_willow_plains, and oak with hornbeam will be accomplished if their entire restored hectares in the East Caucasus region are planted (83.97% for beech, 75.07% for flood plain oak with poplar_willow_plains, and 76.59% for oak with hornbeam). Meanwhile, achieving 100% of the restoration potential in the South Uplands region will only need planting 230.4 ha of flood plain oak with poplar_willow_plains (Table 31).

In the Southern Lesser Caucasus, Dry Plains and Ridges, and the Hyrcan regions, the restoration of their forest covers will respectively help to overcome with 16.85%, 14.37% and 9.75% of the total restored hectares needed for Azerbaijan. These percentages represent a total of 79,494.0 ha. The restoration of juniper_pistachio_hackberry in the Southern Lesser Caucasus (28,191.5 ha) and chestnut-leave oak with iron-tree in the Hyrcan (12,104.0 ha) will respectively help overcome 86.21% and 63.99% of each of these two regions' reforestation needs. Meanwhile, the restoration of two forest types (juniper_pistachio_hackberry and flood-plain oak with poplar_willow_plains) will contribute with 84.00% of the Dry Plains and Ridges region reforestation needs, which equal to 23,415.2 ha.

Juniper_pistachio_hackberry, flood plain oak with poplar_willow_plains, and beech need to be restored more than 40,000 ha each (Table 31). They together represent 73.08% of the total forest cover restoration potential in Azerbaijan. For the last two forest types, the biggest amounts of hectares that need to be restored are in the East Caucasus region (Table 31). Meanwhile, the restoration potential of juniper_pistachio_hackberry are mainly concentrated in the Southern Lesser Caucasus region (28,191.5 ha), which represent 49.00% of this forest type restoration potential in Azerbaijan.

Like flood plain oak with poplar_willow_plains, and beech forest types, the biggest amount of restored hectares for oak with hornbeam is concentrated in the East Caucasus region (Table 31), which represents 76.59% of this type restoration potential. Meanwhile, even though the restoration of the remaining three forest types (birch_poplar_ash-tree, chestnut-leaved oak with iron-tree, and eldar pine) will not imply an important impact when compared to other forest types either by percentage or amount of hectares, their restoration will have a significant impact on the forest cover of Azerbaijan as these forest types are located within just one climatic region (Table 31). The restoration of these three forest types equals to 13,567.9 ha, which represents 6.99% of the total restoration potential for Azerbaijan

GEORGIA

Georgia has four out of six bioclimatic regions (Table 32). It includes fifteen comparing groups. However, five comparing groups resulted in a positive difference when comparing their AFC to PFC (Appendix K, Tables K1–K4). These inconveniences could have been caused by differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003). Therefore, alder_poplar_willow, chestnut with zelkova, poplar_willow_mountain-valleys, poplar_willow_plains, and taxus were not taken into account in this part of the analysis, as they did not any lost area to be restored.

Table 32: Forest restoration potential based on the 10% of lost hectares for each bioclimatic region existing in Georgia*

Forest Types	Bioclimatic Regions in Georgia				Total of Potentially Restorable Hectares by Types
	Colchic	East Caucasus	South Uplands	Dry Plains and Ridges	
	Restored ha.	Restored ha.	Restored ha.	Restored ha.	
Alder-Poplar-Willow (Colchic)					---
Beech		353.7			353.7
Birch_Poplar_Ash-tree	47,209.5	34,032.4	1,452.7		82,694.6
Caucasian pine	326.6	3,610.5	599.9		4,537.1

Forest Types	Bioclimatic Regions in Georgia				Total of Potentially Restorable Hectares by Types
	Colchic	East Caucasus	South Uplands	Dry Plains and Ridges	
	Restored ha.	Restored ha.	Restored ha.	Restored ha.	
Chestnut + Buxus + Zelkova	50,081.2				50,081.2
Chestnut + Zelkova					---
Dark conifers	32,787.5				32,787.5
Eldar pine				353.2	353.2
Flood plain oak + Poplar_Willow_Plains		17,638.3		6,591.6	24,229.9
Juniper_Pistachio_Hackberry		7,453.0		8,005.8	15,458.8
Oak and other broad-leaved species + Hornbeam	27,545.1	45,681.2	1,080.8		74,307.1
Pitsundian pine	150.8				150.8
Poplar_Willow_Mountain-valleys					---
Poplar_Willow_Plains					---
Taxus					---
Total of Potentially Restorable Hectares by Bioclimatic Region	**158,100.8**	**108,769.2**	**3,133.3**	**14,950.7**	**284,954.0**
Size of Bioclimatic Regions in Georgia (ha.)	3,262,645.5	2,818,197.2	284,362.7	604,083.4	

Note: *The cells in blue refer to the forest type that ended up with positive value. As mentioned in this section, these forest types and/or their values were not used for this part of the analysis. For checking the amount of hectares of these positive differences, check Appendix K, Tables K1–K4. Meanwhile, the cells in gray means that a type is not distributed in Armenia.

Likewise, the positive values of Caucasian pine and oak with hornbeam in the Dry Plains and Ridges region, as well as dark conifers in the East Caucasus region were excluded in order to have an accurate figure on how many hectares for each forest type can be restored in Georgia based on their bioclimatic distribution. Nevertheless, these intentional exclusions do not mean that any of these forest types do not need restoration efforts. It just means that due to the constraints mentioned above we were not able to estimate how many hectares could be restored.

In Georgia, the amount of hectares that need to be restored equals to 284,954.0 ha (Table 32). The restoration potential of this Caucasian country are concentrated in the Colchic and the East Caucasus regions, which respectively represents 55.48% and 38.17% of the total restored hectares needed in Georgia. Meanwhile, restoration efforts needed in the South Uplands and the Dry Plains and Ridges regions will respectively help overcoming 1.10% and 5.25% of Georgia total restoration potential, which together equal to 18,084.1 ha.

The total plantation of restorable hectares of birch_poplar_ash-tree and chestnut with buxus and zelkova in the Colchic region, as well as for birch_poplar_ash-tree and oak with hornbeam in the East Caucasus and the South Uplands (Table 32) will contribute with more than 50% of the total restoration potential in each of these climatic regions (61.54%, 73.30% and 80.85%, respectively).

Meanwhile, the restoration of juniper_pistachio_hackberry will help decreasing the amount of hectares that will need to be restored in the Dry Plains and Ridges (53.55%), followed by flood plain oak with poplar_willow_plains (44.09%).

Birch_poplar_ash-tree, and oak with hornbeam forest types need to be restored in around 75,000 ha each. They together represent 55.10% of the total forest cover restoration potential in Georgia. For both forest types, 57.09% and 61.48% of restorable hectares are respectively located in the Colchic and the East Caucasus regions. From the remaining eight types, beech, chestnut with buxus and zelkova, eldar pine, and pitsundian pine forest types are highly important, although their restoration potential are not as dramatic when comparing to Georgia forest cover needs (chestnut with buxus and zelkova is the highest of these four types with 17.58%). For these types, their importance relies on their distribution, which is confined within one bioclimatic region (Table 32).

Caucasian pine can be found in three bioclimatic regions, whereas flood plain oak with poplar_willow_plains and juniper_pistachio_hackberry comparing groups in the same two regions (Table 32). For the first two forest types, their biggest amounts of restorable hectares are concentrated in the East Caucasus region (3,610.5 ha and 17,638.3 ha, respectively), which respectively represents 79.58% and 72.80% of the total reforestation needs for Georgia. Meanwhile, the restorable hectares for juniper_pistachio_hackberry are equally distributed between its two regions (Table 32). These three types together equal to 44,225.8 ha, which represent 24.39% of Georgia total restoration efforts.

4. Strategies for Responding to the Impacts of Climate Change on Forests

In the preceding chapter of this report, we presented the results of modeling the impact of climate change on the suitability of future environmental conditions for the forest formations that exist in the region today. In this chapter, we discuss the implications of those results for the future of the region's forests and the goods and services they provide, and how we can respond to the threat posed by climate change by taking measures to mitigate and adapt to its impacts.

4.1. What the Models Tell Us

The potential effects of climate change on forest ecosystems are complex and poorly understood. Changes in site variables such as temperature, rainfall, wind and humidity are likely to affect many processes, including growth, reproduction, pollination, seed dispersal, phenology, pest and disease resistance and competitive ability (Broadhead, Durst and Brown, 2009; Maroschek et al., 2009). The present study uses assumptions about the relationship between forest health and a range of site variables and about changes in the site variables as a result of long-term climate change, to model the suitability of conditions in the southern Caucasus for the forest classes that occur in the region today. The models predict that conditions in the southern Caucasus will become less suitable for most forest classes that occur in the region (Table 33). According to the ecological more favorable climate model B2A, conditions will become more suitable over a larger part of the region for dry woodlands, buxus, castanea, parrotia, and zelkova; under the ecological less favorable climate model A2A, conditions will become more suitable over a larger part of the region only for dry woodlands and zelkova. Overall, changes in environmental conditions will result in a reduction in the area of the southern Caucasus suited to the forest classes that occur in the region today: by about 8% compared with actual forest cover in 2011 under the ecologically more favorable climate scenario and by about 33% under the ecologically less favorable climate scenario.

Table 33: Impact of climate change on forest classes at the study area level based on Modeled Present and B2a and A2A Model outputs

Forest Classes	B2A	A2A
	%	%
Dry woodlands	46.38	70.89
Betula_etc	-73.29	-85.89
Buxus	5.54	-25.43
Carpinus	-13.29	-56.13
Castanea	0.20	-24.26
Fagus	-17.49	-45.35
Parrotia	0.08	-43.84
Picea_Abies	-24.16	-47.09
Pinus_pts	-55.56	-94.70
Quercus_Pinus	-17.51	-33.29
Quer_casta	-5.92	-46.57
Quer_pedun	-26.78	-69.11
Taxus	-9.38	-35.37
Zelkova	47.83	33.12
TOTAL	**-7.85**	**-33.25**

Minus		Plus	
<20		<60	
20-40		60-120	
40-60		120-180	
60-80		180-240	
80-100		240-300	

The impacts will be different in the three countries. Under the ecological more favorable climate scenario, in Georgia conditions become more favorable overall for the forest classes that occur in the country, while in Armenia conditions become slightly less favorable and in Azerbaijan conditions become a lot less favorable (Table 34).

Table 34: Impact of climate change on forest classes in each country based on Modeled Present and B2a and A2A Model outputs

Forest Classes	Armenia		Azerbaijan		Georgia	
	B2A	A2A	B2A	A2A	B2A	A2A
	%	%	%	%	%	%
Dry woodlands	162.18	286.90	25.27	33.91	162.17	258.36
Betula_etc	-96.87	-99.27	-81.10	-95.34	-61.16	-77.87
Buxus			-100.00	-100.00	5.66	-25.35
Carpinus	-11.39	-100.00	-46.35	-96.15	9.10	-16.75
Castanea	-92.30	-100.00	-92.03	-98.86	13.87	-13.18
Fagus	-41.95	-100.00	-65.69	-96.66	10.16	-8.51
Parrotia	126.25	-100.00	-48.71	-95.10	23.39	-3.30
Picea_Abies	-3.29	-100.00	-57.39	-100.00	-23.72	-43.99
Pinus_pts					-55.56	-94.70
Quercus_Pinus	-15.84	-49.04	-50.09	-74.70	0.44	-3.80
Quer_casta	38.93	-100.00	-52.50	-94.77	15.36	-10.49
Quer_pedun	104.99	-100.00	-62.30	-98.45	40.62	-5.18
Taxus	-58.60	-100.00	-75.87	-98.54	8.72	-15.93
Zelkova			-79.78	-100.00	63.48	49.44
TOTAL	**-2.37**	**-52.08**	**-36.59**	**-62.08**	**9.81**	**-11.05**

Minus		Plus	
<20		<60	
20-40		60-120	
40-60		120-180	
60-80		180-240	
80-100		240-300	

Meanwhile, under the ecologically less favorable climate scenario the area suitable for existing forest formations in Armenia and Azerbaijan will fall substantially (by 52% and 62% respectively) and several forest classes 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 classes.

The impact of long-term climate change on forests 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 vigor and may die prematurely; seed production and the formation's capacity for natural regeneration will be reduced. Over time forest density will decline and the forest will disappear unless species that are better adapted to the changing conditions are able to colonize the site. Since the models only predict the area that will be suited to different forest classes, if species that are better adapted to the changing conditions do not move into their modified range of suitability, the reduction in forest area will be higher than that predicted by the models.

4.2. Other Impacts on Forests

Apart from the gradual changes to environmental parameters, which will have negative consequences for some forest classes in some parts of the region and positive consequences for some forest classes in some parts of the region, climate change will have other impacts:

More frequent extreme weather events: Global warming is likely to result in more frequent and more intense storms (IPCC, 2007). 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 prolonged droughts: Parts of the region are likely to experience increased drought, leading to reduce plant growth, primary productivity and altered plant recruitment. The drought stress of trees will also make forests more vulnerable to infestation by insect herbivores and fungal diseases (Kolström, Vilén and Lindner, 2011).

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 favor many forest pathogens by enhancing sporulation, dispersal and host infection (Garrett et al., 2006 as cited in Lucier et al., 2009). Warm climate conditions have clearly contributed to some recent insect epidemics: e.g. bark beetles in North America (Berg et al., 2006; Tran et al., 2007; Raffa et al., 2008 as cited in Lucier et al., 2009), defoliators in Scandinavia (Jepsen et al., 2008 as cited in Lucier et al., 2009), aphids in the United Kingdom (Lima et al., 2008 as cited in Lucier et al., 2009) and the processionary moth in continental Europe (Battisti et al., 2005, 2006 as cited in Lucier et al., 2009).

More favorable conditions for invasive species: Climate change can affect forests by altering environmental conditions and increasing niche availability for invaders (McNeely, 1999; McNeely et al., 2001; Hunt et al., 2006; Ward and Masters, 2007; Dukes et al., 2009; Logan and Powell, 2009 as cited in Lucier et al., 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 (McNeely, 1999; Tilman and Lehman, 2001 as cited in Lucier et al., 2009).

4.3. Consequences of the Impacts of Climate Change on Forests

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 immediately after the end of the last ice age. Shugart et al. (2003) notes that forests have responded to past climate change with alterations in the ranges of important tree species but a critical issue is the rate at which tree species migrate (as cited in Sedjo, 2010). After the last glacial period, tree species migrated at rates of a few kilometers per decade or less, but the projected rate of shift in climate zones of 50 kilometers per decade could lead to massive loss of natural forests.

Writing about the impacts of climate change at a global level, Broadhead, Durst and Brown (2009) remark that without appropriate human interventions, it is possible that the effects of climate change – compounded by more direct sources of anthropogenic stress – will prove devastating to the world's forests. At the level of the southern Caucasus, the changes in forest health, vitality and productivity caused by long-term changes in environmental parameters and increased risks of damaging events will have significant consequences for people living in the region. If we take no action to mitigate the impact of climate change on forests we can expect:

- an overall reduction in the quantity of timber and non-wood forest products such as mushrooms, berries and nuts from the forest classes 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.

4.4. Adaptation of Forests to Climate Change

There are three possible approaches to adapting forests to climate change: no intervention, reactive adaptation and planned adaptation (Bernier and Schoene, 2009). No intervention means business as usual, with no changes in management objectives or practices in anticipation of climate change. Reactive adaptation is action taken after climate change impacts have already occurred; for example salvage harvesting after storms, and recalculation of allowable cuts in response to declining productivity. 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. However we can assume that the temperatures will rise, weather extremes will increase and the patterns of rainfall will exchange. 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).

Forestry agencies and forest managers in some countries have already started to take practical steps to mitigate the impacts of climate change on forests (Easthaugh et al., 2009). At a political level, Armenia, Azerbaijan and Georgia and other, European countries have committed themselves to responding to the impacts of climate change on forests: the 2011 meeting of European forestry ministers recognized “that climate change is one of the gravest threats faced by society and … that urgent action is required to minimize risks of damage from events such as storms, floods, fire, drought, pests and diseases in order to protect European forests and their functions”. The meeting adopted goals for European forests including: “Forest management in Europe is being adapted to changes in climate, forests are healthy and resilient to natural hazards and protected against human-induced threats such as forest fires, and the productive and protective functions of forests are maintained”. The targets for 2020 set by the meeting includes: “strategies for forests and climate change adaptation and mitigation in national forest programs or equivalents and all other relevant national strategies” (Forest Europe, 2011).

4.5. Planned Adaptation Responses

This section describes some of the actions which forest managers and forestry agencies can take to mitigate the impacts of climate change on forests. Responses for existing forests are described first, followed by forest restoration as a response strategy in its own right, then the special case of forest protected areas and lastly government policy responses.

4.5.1. Adapting the Management of Existing Forests

Increasing the natural adaptive capacity and resilience of forests: Adaptation theory suggests that more diverse natural systems are more resilient to short term shocks and long-term changes in environmental parameters. For example, forest ecosystems with greater diversity with regard to age, structure, species and genotypes, usually show a greater adaptive capacity (SCBD, 2003; Fontaine et al., 2005), 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.

Planting species and provenances that are more resilient or promoting them in naturally regenerated stands by selective tending and thinning:
Regarding the selection of species for climate change adaption there is a clear priority scheme:

- Adaption of forests to climate change should focus in the utilization of native (Southern Caucasian) species, which are adapted to the respective soil, altitude and climate conditions. For example in the zone between 350 and 1800 m hornbeam and oak are the naturally dominating tree species in the Southern Caucasus.
- In the ambit of warm and dry climate some native species (e.g. Juniperus, Quercus) could extend their area of distribution, others, less drought-tolerant species, could lose distribution area.
- Introduction of (not native) drought resistant tree species should be limited to extreme site conditions and be the exceptional case. Ecosystem processes might be at risk (co evolution of insects, etc). Therefore in a first step use of interesting “exotic” species should be limited to scientifically accompanied and documented experimental plantations. (Bachmann, M., Konnert, M., Schmiedinger, A., LWF Wissen 63, 2009).

It is common sense that the tapping of the potential of the existing natural set up of species should be first priority. (Krabel, Doris „Anpassungspotentiale forstwirtschaftlich relevanter Baumarten, AFZ- Der Wald 11/2010, 8-9).

Increasing the resilience and natural adaptive capacity of forests at a landscape level: For example, by reducing fragmentation, creating ecological corridors which will facilitate the natural movement of species, and strengthening and extending 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: In the Southern Caucasus the risk of forest fires is not a major threat. However increasing temperatures and longer period of drought could change this situation. Therefore, a forest firefighting strategy should be developed and implemented. Nevertheless the best insurance against forest fires are mixed and structured forest stand composed by site adapted, native species.

Adaptation of pest and disease prevention and control practices: Pests and diseases are common in monocultural and not site adapted forest stands. The best way to reduce the vulnerability of forest stands is to promote close to nature forest management with mixed and structured forest stands. However, we should pay attention to invasive alien species (e.g. Ailanthus in the Southern Caucasus) which might become more competitive as the native species suffer from climatic stress. Again, this threat should be addressed by silvicultural measures.

Adaptation of silvicultural practices to manage declining and disturbed stands: Underplanting of native, site adapted species and enrichment planting in declining stands and artificial monocultures can reduce vulnerability of the future tree generation. Advance plantings offer an excellent way for establishing new, robust stands in good time and silvicultural freedom. They demand competent planning and completion. The term defines the planting of the future main tree species under protection of the mature forest. Exclusion of livestock grazing reduces costs and minimize risks (Schoelch, M., 2009).

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 (Borrini-Feyerabend, 2000 as cited in Robledo and Forno, 2005). It is a formal process for continually improving management policies and practices by learning from their outcomes (Taylor et al., 1997 as cited in Robledo and Forno, 2005). The key characteristics of adaptive management include (Sit and Taylor, 1998 as cited in Robledo and Forno, 2005):

- 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;
- Development of risk assessment maps to generate criteria for decision;
- 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 (Nyberg, 1999 as cited in Robledo and Forno, 2005). 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 proper mid term forest management planning therefore should reflect the results of the previous time and the deductions made.

4.5.2. Forest Restoration and Transformation of Forest Plantations

The comparison of actual forest cover vs. potential forest cover (section 3.1.) suggests that 55% of the region's maximum post-glacial forest cover may have been lost-an area of about 5 million hectares-mostly converted to pasture and arable lands and for settlements and infrastructure. The models of suitability of future climatic conditions for present-day forest classes in the region suggest that there is a serious risk of further losses in forest cover. Climate change will reinforce the degradation of forests, which continues today in the region as a result of unsustainable and illegal logging and grazing.

Restoring degraded forest stands and reforesting former forested land will help to mitigate the impacts of further losses and could help to mitigate the risk of further losses: restoring forest cover using species and provenances that are adapted to future climatic conditions will provide alternative supplies of forest products and services which are lost as a result of reduced productivity or complete loss of existing forests. At the landscape scale, forest restoration can reduce fragmentation of forest massifs, increase connectivity between forest stands, and increase the resilience and adaptive capacity of the forest fund. Forest restoration also contributes to combating climate change by absorbing and storing carbon dioxide.

In section 3.4.3, how many hectares could be restored was estimated. Its purpose was to exemplify what areas might need to be urgently tackled. For this exercise, ten percent of the total lost area was used as threshold for calculating the amount of hectares that need to be restored. This fixed figure was chosen based on (a) our experience in managing natural resources in the Caucasus, and (b) the assumption that the remaining 90% of the lost area has been transformed either into pastures, agriculture lands or urbanized areas.

Likewise, increasing resilience of forest plantations to climate change is needed. In total, forest plantations cover around 213,600 ha, which are broken down by country as follow: Armenia (36,600 ha), Azerbaijan (98,000 ha) and Georgia (79,000 ha)[9]. From Soviet time until now, mostly non-native species (e.g. European black pine – *Pinus nigra*, black locust – *Robinia pseudoacacia*, poplar – *Populus spp.* etc.) have been used in forest plantation practices for different reasons (erosion, landslides and avalanches control, wind-shields, recreation, etc.). In case of non-native forest plantations' transformation ultimate target could be nearly 100%.

[9] A forest plantation map was not included in this document because the sizes of plantation plots are small for being reflected in the scale of attached maps.

Taking into account the restoration efforts done so far and on-going pilot forest transformation project, supported by EU Programme on Environment and Natural Resources, we recommend the following (Box1):

Box 1-Recommended approach for forest restoration and transformation of forest plantations
Carrying on forest restoration and transformation activities nowadays and in near future should use the forest landscape restoration approach (see also Box 2 below) and the climax vegetation concept, considering modeled tendencies of forest types' changes reflected in this document.

4.5.3. Adaptation of Protected Forest Areas and Networks

Protected forest areas and other protected areas have been acknowledged for many years to be important for conserving biodiversity. The location and design of individual protected areas and the design of protected areas networks have been decided on the basis of the biodiversity values at the time and probably on the assumption that those values would not change within human timescales if management was effective. Protected forest areas will be affected by climate just as other forest areas: legal designations will not stop nature responding to a changing environment. Under future climate scenarios many of the current protected areas will no longer be able to fulfill their role of protecting representative habitat for species targeted for conservation (Mansourian et al 2009). In anticipation of climate change impacts on protected areas Mansourian et al. (2009) advocate the following (Box 1):

Box 2-Responses to anticipated impacts of climate change on forest protected areas (adapted from Mansourian et al., 2009)

- **Designing protected areas in landscapes** A well-planned protected area network is necessary if species that are present in few fragmented patches of habitat, in small numbers or at the limits of their range are to adapt to climate-related changes. Size, shape and altitudinal gradients all contribute to a protected area's resilience to climate change and to species' freedom of movement. Optimally designed protected area networks should reduce barriers and obstacles between protected areas. They should incorporate buffers, connections, corridors and stepping stones for the movement of animal species across the landscape and abundant good habitat across a vast range of altitudes, so that in times of stress species can move to more favorable environments within the relative safety of a protected area.

- **Expanding the protected area network** In seeking to maintain a representative network of ecosystems, it is no longer safe to assume that all of a species' historic range remains suitable in a changing climate. The Convention on Biological Diversity's Programme of Work on Protected Areas (CBD, 2004) urged great expansion of the protected area network across the globe to secure long-term representativeness of ecosystems and help species adapt to climate change. In subsequent years the world's protected areas have expanded exponentially, but the expansion needs to continue.

- **Managing protected areas in landscapes** Effective management is essential to climate adaptation. Protected area management to ensure adaptation to climate change may include restoration, focusing on resilient habitats, managing specifically for anticipated threats such as fire and pests, and addressing other threats (which can be exacerbated by climate change). Restoration will be important both within protected areas and around them in targeted locations within the wider landscape. A forest landscape restoration approach, in which key elements of the landscape are identified for restoration to achieve multiple objectives, makes the whole landscape more functional in meeting environmental, social and economic objectives (Mansourian, Vallauri and Dudley, 2005).

4.5.4. Government Policy Responses

There are many actions that forest managers can take to mitigate the impacts of climate change on forests but they cannot deal with the challenge entirely on their own. Governments must help by providing a supportive policy environment and funding for actions aimed at helping forest managers plan for adaptation. Examples include:

Making appropriate changes to forest law and strengthening forest law enforcement mechanisms: Continuing anthropogenic pressure on forests will compound the negative impacts of climate change. National forestry authorities should review forest law and forest law enforcement mechanisms and make any changes necessary to mitigate anthropogenic pressure. Regulations regarding granting licenses and permissions for forest use could be strengthened; by requiring forest managers to include mitigation and adaptation measures in forest management plans. Regulations on the choice of species and provenances may need to be changed to allow forest managers to select species and provenances that are better adapted to future climatic conditions.
For example appropriate measures in the southern Caucasus will be:

- Obligation to reforest clear felled sites
- Forest management plan as an obligatory prerequisite in case of forest use
- Development of regulations regarding forest reproductive material especially to safeguard the provenance of seeds and planting material

Promoting and funding supportive research and monitoring: Research is needed into the tolerance of different species and provenances to climate change and their suitability to the future climate under different warming scenarios. Investment needs to be made in tree breeding programs to provide forest sector with high quality seedling material of proven identity. In this manner new forests will be established, that are more resilient to climate change. Systematic monitoring of the health of forest species, forest stands and forest landscapes needs to be implemented and systems implemented for learning about relationships between observed changes in the forest and changes in the climate.

Communicating the threat to forests and the need for action: Environment and Forestry ministries and their agencies need to do more to make people aware of the impacts that climate change will have on forests and how those impacts will affect their lives. Forestry learning institutions should include the topic in their curriculum. Education ministries should include the topic in environmental education in schools.

Becoming leaders of forest adaptation: Governments manage large areas of forest and forest land on behalf of the state and this gives governments an opportunity to be leaders of forest adaptation. Government-managed forests can become field laboratories where different responses to adaptation made, monitored and evaluated, and information and advice communicated to other forest managers.

4.6. Adapting to Changes in the Forest

The threats of climate change are not longer denied by any serious scientist or practitioner. The message for forestry in the Southern Caucasus therefore only can be: Diverse forests of site adapted native tree species will not end in a disaster also in changed living conditions. Mixed stands of different structure and age are equipped by high self-healing and adaptation capacity (Biermeyer, G., 2009).

Sustainable forestry management guided by an ecosystem based approach rather than being oriented towards maximum production should be the key approach for the forests in the Southern Caucasus.

4.7. Designing Adaptation Strategy

The governments of Armenia, Azerbaijan and Georgia are committed in the framework of the Forest Europe process to elaborating and implementing forest adaptation strategies. Their strategies need to address at least the following issues (adapted from Spittlehouse and Stewart, 2003):

- the research that must be started now to aid development of strategies for adapting to climate change;
- the educational needs of the forestry community to increase awareness of climate change, and to facilitate adaptation;
- the development and introduction of methods that reduce deforestation and forest degradation as much as possible;
- the information that is needed in order to be able to evaluate forest response to climate change;
- the forest management actions we take now without compromising future responses;
- whether any barriers exist to implementing adaptation in forest management, and how they can be overcome;
- what policies and policy instruments need to be in place to facilitate adaptation;
- the adequacy of current monitoring systems adequate to spot problems induced by climate change soon enough to allow implementation of an acceptable response;
- in which situations can we intervene to assist adaptation, and which forest ecosystems and species will we have to leave to adapt autonomously.

Earlier in this chapter we described the adaptive management approach and its application in forest management and in mid term forest mangememnt planning in particular. Adaptive management is equally applicable to the planning of responses at the sector level: advisors and decision makers in government need to decide policy, set targets and design instruments in the face of uncertainty using the best available information. The impacts of policies, the effectiveness of instruments and progress towards targets must then be monitored and adjustments made if the strategy is not achieving the desired outcomes.

Different actors are very likely to have different goals of adaptation, different attitudes towards possible responses, and therefore different ideas as to what actions could, or should not, be taken in response to anticipated impacts of climate change on forests. Rural communities might put a high priority on maintaining the flow of goods and services from their local forest even if it meant introducing non-native tree and shrub species. Other groups, opposed in principle to introducing non-native species, may emphasis tree breeding. Adaptation could involve large-scale changes in land use, for example restoration of forest on land that has been used as pasture for many generations. The values that underpin adaptation decisions become more diverse and contradictory as one moves from smaller scales and single actors to larger scales and multiple actors, as in the case of landscape or ecosystem management (Louman et al., 2009). An essential part of developing an adaptation strategy is dialogue between policy makers, people who use or depend on forests, people who manage forests, and researchers.

4.8. Targets for Mitigation and Adaptation Strategies

In this part of the report we suggest some objectives and targets for the forest adaptation strategies, which Azerbaijan, Armenia and Georgia will prepare in follow-up to the decision taken by European forestry ministers in Oslo in June 2011. We set out some ideas for targets for the strategy development process first, and then some ideas for targets for incorporation into the strategies. The targets are the ideas of the authors cited in this section. We consider them to be appropriate and feasible, though challenging. The targets for incorporation into the strategies need to be subjected to the type of dialogue, which we advocate in the preceding section.

4.8.1. Targets for the Process of Developing Strategies

The Forest Europe target of having national strategies or equivalents in place by 2020 pays insufficient regard to the severity of the possible impacts and the time required for mitigation and adaptation actions to have an effect relative to the speed of climate change. Therefore we propose:

> *By the end of 2015 the southern Caucasus countries will have adopted and will be implementing national strategies for mitigating, and adapting to, the impacts of climate change on forests. The national strategies will address the issues listed in chapter 4.7 of this report and other issues that may be identified in the process of developing the strategies. The strategies will include actions, which the governments will take to mitigate and adapt to climate change impacts on forests, and promote and facilitate actions by forest managers and other actors. Public sector and private sector forest managers will have started to apply the adaptive management approach in forest management planning and will already be implementing mitigation and adaptation measures. Principal concept of national forest policy will be Sustainable Forest Management (SFM) put into operation by midterm management plans. As a result of the national dialogue on climate change impacts on forests and mitigation and adaptation options, people who will be affected by the impacts and by the mitigation and adaptation options will be aware of the challenges they will face.*

We propose the following intermediate targets:

> *By the end of 2012 the ministries responsible for forestry policy will have commissioned and received national reports on the impacts of expected climate change on forests and forest goods and services and on potential mitigation and adaptation strategies, using the best available information from national and international sources.*

> *By June 2013 the ministries responsible for forestry policy will have: (a) started national dialogues on the impacts of expected climate change on forests and possible mitigation and adaptation strategies; (ib) started a regional dialogue to identify ways in which the three countries could collaborate in the development and implementation of mitigation and adaptation strategies.*

> *By the end of 2014 draft national strategies will have been endorsed by the governments and published for public consultation by the ministries responsible for forestry policy.*

4.8.2. Targets for Incorporation into the Strategies

A. Mitigation and adaptation measures in forest stands

Purposes:
1. To increase the resilience of forest stands to stresses caused by climate change.
2. To mitigate the increased risk of disturbance by fires and storms.

Targets:
1. *By 2015 all forest stands will have been categorized according to forest type and vulnerability to climate change; national forestry authorities will have published sustainable management guidelines, including guidance on mitigation and adaptation measures, for each forest type.*
2. *By 2020 mitigation and adaptation plans will have been prepared for the 50% of forest stands, which are most vulnerable to climate change and the plans will be being implemented in half of those stands.*
3. *By 2025 mitigation and adaptation plans will have been prepared for all forest stands and the plans will be being implemented in 75% of the stands.*

B. Restoration of degraded forest and reforestation of non-forest and former forest land

Purposes:
1. To compensate for the expected loss of forest and of the goods and services that they currently provide.
2. To halt and reverse fragmentation of forest massifs and to create ecological corridors, thereby increasing the resilience and adaptive capacity of existing forests.
3. To facilitate the migration of species between protected areas, thereby helping to conserve biodiversity.

Targets:
1. *By 2015 assessments will have been prepared of the condition of degraded forests and the feasibility of restoring them, and of areas of non-forest land, their suitability for forests, the feasibility of establishing forests on them, and the social and environmental impacts. The assessments will propose targets for restoration and reforestation in terms of location, forest formation and size (i.e. hectares). The results of the assessments will be incorporated into the draft strategies, which the governments will publish for consultation by the end of 2015 (see section 4.8.1. above).*
2. *By 2017 site level plans will have been prepared for the restoration of at least 30,000 hectares of degraded forest and reforestation of at least 15,000 hectares of non-forest and former forest land.*
3. *By 2020 restoration and reforestation will be underway on at least 25% of the area specified in the site level plans.*

C. Measures related to forest protected areas

Purposes:
1. To manage the risks from climate change to the ability of existing protected areas networks to fulfill their functions.
2. To manage the risks from climate change to the biodiversity and other special values of individual protected areas.

Targets:
1. *By 2013 assessments will have been carried out of the vulnerability of all protected areas in the region and of the "fitness for purpose" of the existing*

protected areas networks in the face of expected climate change. The assessments will include recommendations for changes to the boundaries of existing protected areas and for new protected areas. The results of the assessments will be incorporated into the draft strategies, which the governments will publish for consultation by the end of 2014 (see section 4.8.1. above).

2. *By 2015 mitigation and adaptation plans will have been prepared for all of the protected area in the region; national protected areas development strategies and action plans will have been revised to take account of the expected impacts of climate change.*
3. *By 2020 mitigation and adaptation plans will be being implemented in all the protected areas in the region.*

D. Research and development

Purposes:
1. To provide forest managers with a better basis for vulnerability assessments.
2. To provide forest managers with information about the environmental characteristics of species and provenances.

Targets:
1. *By 2015 comprehensive research programmes will be being implemented in the three countries to provide policy makers and managers with better knowledge about the impacts of expected climate change on forests and the goods and services provided by forests, and ways of mitigating and adapting to the impacts of climate change. The programmes will include research into the vulnerability of species and formations, tree breeding to produce high quality seedling material that are more resistant to drought and other stresses caused by climate change. There will be coordination at a regional or super-regional level on the programmes' objectives and activities.*

5. Conclusions

The world is becoming warmer, and warming is causing the climate to change. The evidence points to anthropogenic emissions of so-called greenhouse gases as the main factor behind warming (IPCC, 2007). Climate change is already having observable harmful impacts on ecosystems, including forests. Negative impacts of climate change on forests and forests goods and services will become more widespread and more severe. At the same time deforestation and degradation of forest ecosystems contribute more than 15 % to worldwide CO 2 emission. Even if we were able to return greenhouse gas emissions to pre-industrial levels tomorrow, we would continue to see and feel the impacts of climate change for decades to come.

We cannot predict with a high degree of precision the scale of climate change or the impact of climate change on forests. However, it is highly likely that the forests of the southern Caucasus will be severely affected; therefore it is wise to factor climate change into national forestry strategies and action plans. Doing nothing, or reacting to events as they occur, would put large areas of the region's forests at risk of catastrophic degradation and a large reduction in the quantity and quality of the goods and services, which forests provide and on which many people in the region depend.

Forest managers need to start now to mitigate and adapt to the impacts of anticipated climate change. At the stand level managers can increase species or provenance diversity, and plant trees bred for resistance to expected stressors. Modifying silvicultural practices may help stabilize stands against drought, storms and disease. At a landscape scale, planned adaptation can include measures to minimize the potential impacts of fire, insects and diseases, increased aforestation and reforestation, creation of biodiversity corridors and rehabilitation of degraded forests. Principally forest management should be guided by close to nature methods such as promotion of natural regeneration and planting and seeding of only native species.

Forest managers must learn to incorporate uncertainty and the increased probability of extreme events into their planning; they must become adaptive managers, setting objectives, deciding strategies and scheduling actions using the best available information, continuously monitoring and comparing the evolving reality against their assumptions, and revising their targets and strategies in the light of new information. The main strategy will be sustainable forest management.

Governments also need to act: research needs to be funded to improve our knowledge of the impacts of climate change on different forest classes in different parts of the region, on the tree species and other biological components associated with those forest classes; species and provenances need to be tested for their suitability to different conditions and tree breeding programs started; protected areas and protected area networks may need to be redesigned and management policies changed; civil society needs to be informed about the possible impacts and the available mitigation and adaptation options; and governments need to facilitate the dialogue that must take place to ensure that the complete range of attitude and opinion is taken into account in the development of national forest adaptation strategies.

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Appendixes

Appendix A: Brief description of forest zonation in the Southern Caucasus

Table A1: Description of the Colchic forest type

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
IA. Humid thermophilous Colchic broad-leaved forest (= temperate rainforest)	Up to 1000 (1200)	
IA1. Mixed broad-leaved forest	Up to 500 (600)	*Castanea sativa, Carpinus caucasica, Fagus orientalis, Quercus hartwissiana* and *Zelkovacarpinifolia*, with a Colchic understorey including *Rhododendron ponticum, Laurocerasus officinalis* and *Ruscus colchicus* as well as the lianas *Hedera colchica* and *H. helix.* In relatively dry habitats thermophilous hornbeam-oak forests occur with *Quercus iberica, Carpinus caucasica* and *C. orientalis*, in the South Colchic (from 200 m up we find pine-oak forests with *Quercus dshorochensis* and *Pinus kochiana* as well as Colchic thickets with *Rhododendron ponticum, Ilex colchica, Laurocerasus officinalis* and *Ruscus colchicus*.
IA2. Chestnut forest	500-1000 (1200)	*Castanea sativa* and *Fagus orientalis* with a Colchic understorey; further by thermophilous oak forests and Colchic thickets (see IA1 with *Vaccinium arctostaphylos*).
IB. Humid beech forest	1000 (800)-1400 (1800)	*Fagus orientalis* forest often with a Colchic understorey, and dark coniferous/beech forests (see I C) partly with a Colchic understorey. Colchic thickets (see IA1 with *R. ungernii, Vaccinium arctostaphylos, Viburnum orientale*).
IC. Nemoral humid coniferous forest	1400 (1000)-1800 (2100)	*Abies nordmanniana, Picea orientalis* and *Fagus orientalis*, partly with Colchic understorey. Colchic thickets occur as in I B.
ID. Subalpine elfin wood	1800 (1600)-2400 (2700)	
ID1. Lower subalpine	1800 (1600)-2100 (2200)	*Fagus orientalis, Quercus pontica* and *Betula medwedewii* elfin woods, often with a Colchic understorey in combination with subalpine herbaceous vegetation. Other elements include dark coniferous forests; *Rhamnus imeretina, Sorbus subfusca* or *Corylus colchica* thickets; Colchic thickets (see I B).
Upper subalpine	2100–2400 (2700)	*Betula litwinowii* and *Sorbus caucasigena*; *Rhododendron caucasicum* thickets in combination with subalpine herbaceous vegetation.

Table A2: Description of the East Caucasus forest type

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
IIA. Thermophilous oak forest	Up to 1000 (1200)	
IIA1. Riverside and foothill forest	< 500–600 (1000)	*Quercus pedunculiflora, Pterocarya pterocarpa, Populus hybrida,* thermophilous hemixeric hornbeam-oak forests on the slopes (*Quercus iberica, Carpinus orientalis*); shibliak (*Paliurus spina-christi, Rhamnus pallasii*).
IIA2. Lower mountain	500-1000 (1200)	Oak/hornbeam forests (*Quercus iberica, Carpinus caucasica*); beech and hornbeam-beech forests (*Fagus orientalis, Carpinus caucasica*).
IIB. Mesic beech forest	1000-1800 (2000)	
IIB1. Middle mountain	1000-1500	*Fagus orientalis* and *Pinus kochiana* forests.

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
IIB2. Upper mountain	1500-1900 (2000)	*Fagus orientalis* forests; *Quercus macranthera* forests; *Pinus kochiana* forests.
IIC. Subalpine elfin wood	1900 (2000)-2500 (2700)	
IIC1. Lower subalpine	1900-2200	*Quercus macranthera, Pinus kochiana* and *Acer trautvetteri* woodlands; elfin woods (*Betula litwinowii, B.raddeana*); low open juniper communities (*Juniperus hemisphaerica*) on the rocks and creeds; *Rhododendron caucasicum* thickets; in combination with subalpine herbaceous vegetation.
IIC2. Upper subalpine	2200-2500 (2600)	Birch/ash-birch elfin woods (*Betula litwinowii, B. raddeana, Sorbus caucasigena*); *Rhododendron caucasicum* thickets; in combination with subalpine herbaceous vegetation.

Table A3: Description of the South Uplands forest type

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
IVA. Hemi-xeric upper mountain forest and woodland	1500 (1400)-2200 (2300)	*Quercus macranthera, partly open Juniper woodlands (Juniperus spp.) and low woodlands in the south (Pyrus* spp.*, Acer hyrcanum, Juniperus polycarpos*)*; in combination with mountain steppes.*
IVB. Subalpine woodlands	2200-2800	*Quercus macranthera in combination with herbaceous vegetation.*

Table A4: Description of the Southern Lesser Caucasus forest type

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
VA. Lower mountain oak-hornbeam forest	Up to 1200 (1400)	*Quercus iberica, Carpinus orientalis, C. caucasica; partly in combination with open juniper woodlands.*
VB. Upper mountain oak forests and woodlands	1200 (1400)-2000 (2200)	*Quercus macranthera partly in combination with open juniper and woodlands and low woodlands with Pyrus zangezura, Acer hyrcanum.*
VC. Subalpine woodlands	2000 (2200)-2600	*Quercus macranthera in combination with herbaceous vegetation.*

Table A5: Description of the Dry Plains and Ridges forest type

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
IIIA. Flood plain and riverside poplar-oak forests	Up to 400-500	*Quercus pedunculiflora, Populus spp., Mespilus germanica*
IIB. Open dry juniper-pistachio woodlands	< 500-1000 (1200)	*Juniperus polycarpos, J. foetidissima, Pistacia mutica, with Pinus eldarica;* thermophilous hemixeric hornbeam-oak forests on the wetter slopes (*Quercus iberica*, *Carpinus orientalis*); shibliak (*Paliurus spina-christi, Rhamnus pallasii*); in combination with steppes.

Table A6: Description of the Hyrcan forest type

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
VIA. Humid thermophilous Hyrcanic broad-leaved forest (=temperate rainforest)	< 1000 (1200)	
VIA1. Mixed broad-leaved forest	up to 600	*Quercus castaneifolia, Parrotia persica, Zelkova carpinifolia, Albizzia julibrissin, Diospiros lotus* and other tress and with

Zone, subzone	Mean Altitude (m above sea level)	Formation and Species composition
		shrubs/semi-shrubs such as *Ilex hyrcana*, *Ruscus hyrcanus* and *Danaë racemosa* and lianas (*Smilax excelsa, Hedera pastuchovii*). Another forest type is characterized by the thermophilous *Quercus castaneifolia*; in northern part in combination with *Q. iberica* forests.
VIA2. Oak forest	600 to 1000 (1200)	*Quercus castaneifolia* forest (see above), beech and beech/hornbeam forests (*Fagus orientalis*, *Carpinus caucasica*) and *Quercus iberica-Carpinus caucasica* forests.
VIB. Mesic beech forest	1000-1600 (1800)	*Fagus orientalis* forests.

Appendix B: Maps of AFC and PFC

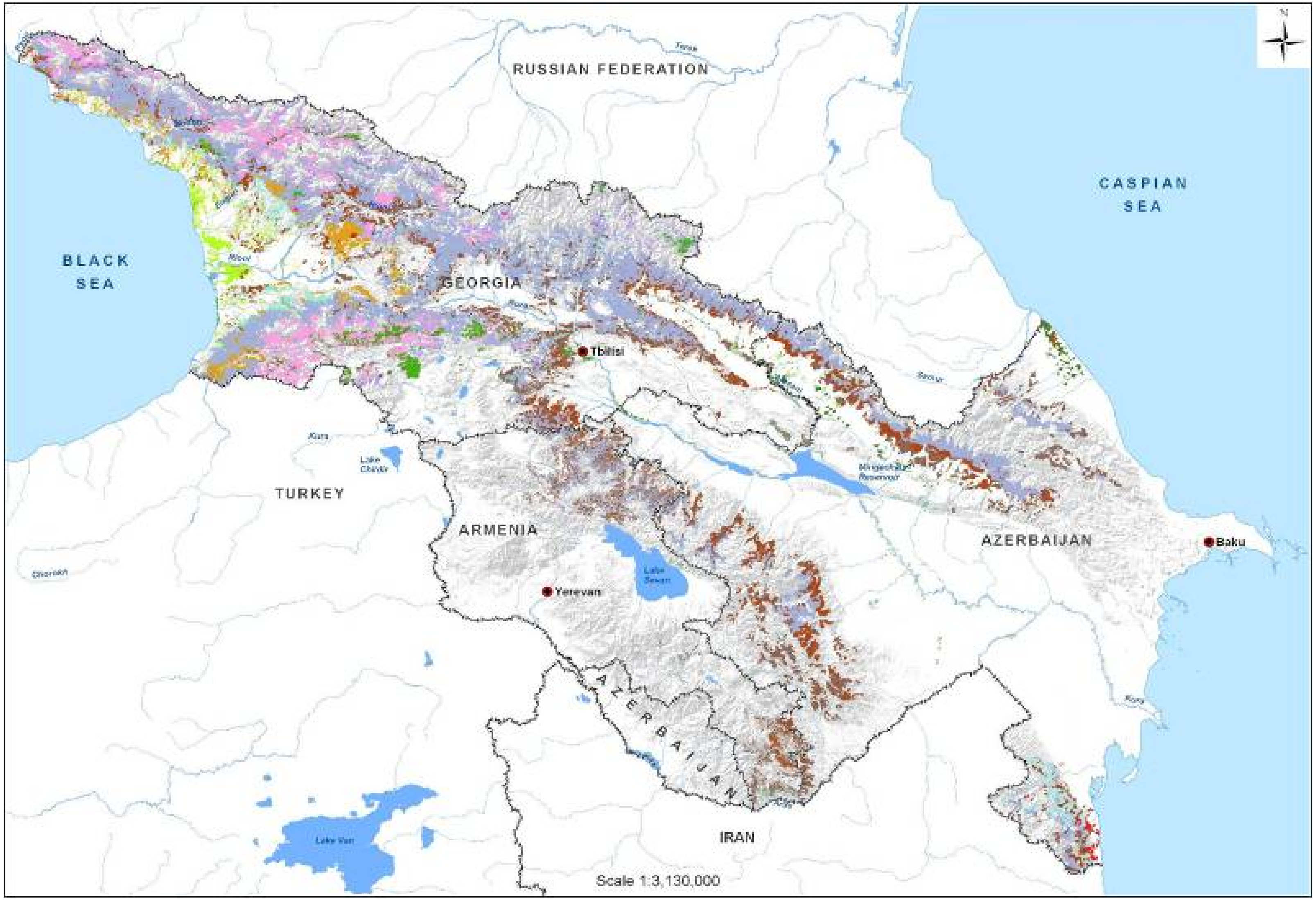

Fig. B1: Actual forest cover of the study area

Legend for Fig. B1

- Alder_Poplar_Willow
- Beech
- Birch, poplar, ash-tree
- Buxus colchica
- Caucasian pine
- Chestnut
- Chestnut-leaved oak
- Dark conifers (Picea, Abies)
- Eldar pine
- Flood-plain oak
- Hornbeam
- Iron-tree
- Juniper, Pistachio, Hackberry
- Oak and other broad-leaved species
- Pitsundian pine (Pinus pityusa)
- Poplar, willow mountain
- Poplar, willow plains
- Taxus baccata
- Zelkova carpinifolia

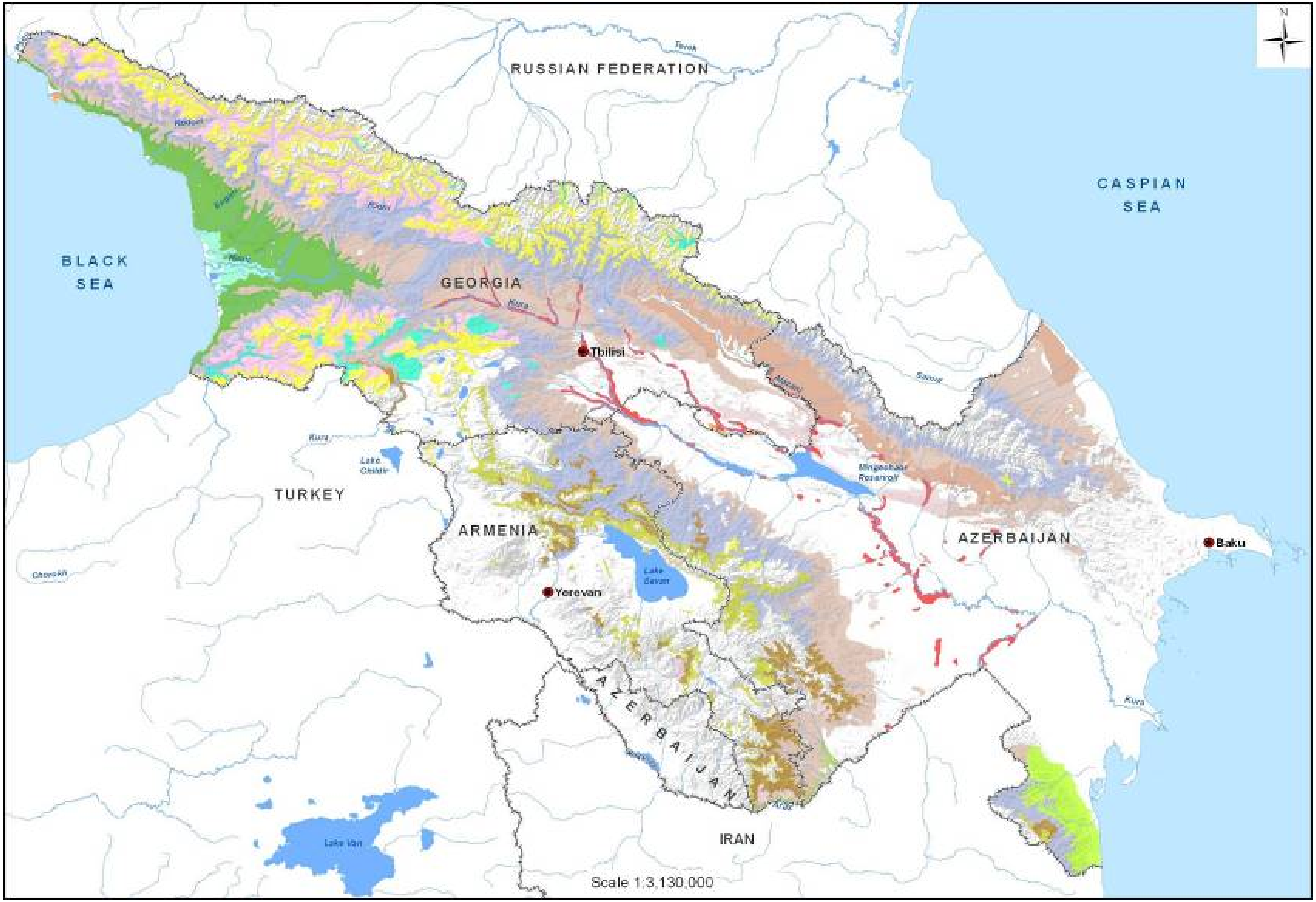

Fig. B2: Potential forest cover in the study area

Legend for Fig. B2

a1 Betula

a2 Quercus macrathera sub-alpine

b1 Picea-Abies Colchic

b2 Picea-Abies

c1 Pinus kochiana

d1 Fagus Colchic

d2 Fagus

d3 Fagus Hyrcanian

e1 Quercus iberica Cochic

e2 Quercus iberica

e3 Quercus iberica + Juniperus

e3 Quercus iberica Hyrcanian

f1 Quercus pedunculiflora

g1 Quercus macranthera

h1 Colchic polydominant

h2 Quercus castaneifolia

i1 Pinus pityusa

j1 Pinus eldarica

k1 Juniperus

k2 Dry mixed woodlands

l1 Alnus

m1 Flood plain

Appendix C: Areas of forest types and formations according to AFC and PFC maps

Table C1: Areas of forest types according to bioclimatic regions according to AFC map

Forest Types	Bioclimatic Region					
	Colchic Ha	East Caucasus Ha	South Uplands Ha	Southern Lesser Caucasus Ha	Dry Plains and Ridges Ha	Hyrcan Ha
Alder_Poplar_Willow (Colchic)	96,055.3					
Beech	799,964.7	973,807.1		859.3		30,852.3
Birch_Poplar_Ash-tree	45,077.9	62,596.1	339.1			
Buxus	6,890.8					
Caucasian pine	21,665.5	79,742.5	10,285.5		326.7	
Chestnut	156,946.4	869.2				
Chestnut-leaved oak		81.0*				63,557.0
Dark conifers	275,527.5	116,904.3				
Eldar pine					187.3	
Flood plain oak		30,764.3			3,261.9	
Hornbeam	119,026.1	365,922.2	15.4	44,857.7	4,733.3	18,404.5
Iron-tree						13,869.8
Juniper_Pistachio_Hackberry		4,956.2	4,227.4	8,478.5	15,331.9	
Oak and other broad-leaved species	66,848.2	390,425.4	6,116.2	119,599.2	9,255.5	14,270.6

Forest Types	Bioclimatic Region					
	Colchic Ha	East Caucasus Ha	South Uplands Ha	Southern Lesser Caucasus Ha	Dry Plains and Ridges Ha	Hyrcan Ha
Pitsundian pine	1,855.2					
Poplar_Willow (Mountain valleys)	58,232.6	13,220.4	347.8	55.0		
Poplar_Willow (Plains)	1,227.4	26,411.0	46.9		20,747.7	
Taxus		230.2				
Zelkova	61.9	139.5				

Note: *This figure appears here because of differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003).

Table C2: Areas of vegetation formations according to bioclimatic regions according to PFC map

Vegetation Formation	Bioclimatic Regions					
	Colchic Ha	East Caucasus Ha	South Uplands Ha	Southern Lesser Caucasus Ha	Dry Plains and Ridges Ha	Hyrcan Ha
Alnus	76,026.0					
Betula	517,173.0	414,370.1	18,436.1			
Colchic polydominant	664,711.4					

Vegetation Formation	Bioclimatic Regions					
	Colchic Ha	East Caucasus Ha	South Uplands Ha	Southern Lesser Caucasus Ha	Dry Plains and Ridges Ha	Hyrcan Ha
Dry mixed woodlands				32,499.2		
Fagus	8,505.9	1,523,205.4	15,535.6	2,105.1	5,448.3	48,787.6
Fagus Colchic	529,611.5	5,868.3				
Fagus Hyrcanian						43,986.9
Flood plain vegetation		54,144.4	921.7		179,945.0	
Juniperus		9,892.6	22,475.2	27,134.9	141,665.6	
Picea-Abies	149,391.0	110,976.2				
Picea-Abies Colchic	454,011.5	3,595.8				
Pinus eldarica					5,819.9	
Pinus kochiana	24,932.0	114,734.6	16,266.1			
Pinus pityusa	3,362.7					
Quercus castaneifolia					33.9*	198,470.8
Quercus iberica	986.2	1,245,377.6	136.1	12,251.2	46,410.6	
Quercus iberica Colchic	460,339.6					
Quercus iberica Hyrcanian						16,906.3
Quercus iberica & Juniperus		307,710.9		285,625.8	83,425.9	

Vegetation Formation	Bioclimatic Regions					
	Colchic Ha	East Caucasus Ha	South Uplands Ha	Southern Lesser Caucasus Ha	Dry Plains and Ridges Ha	Hyrcan Ha
Quercus macranthera		92,372.3	51,477.9	215,620.1		13,324.8
Quercus macranthera sub-alpina		219,739.0	93,991.4	48,978.5		8,659.2
Quercus pedunculiflora		501,549.2			12,666.2	

Note: *This figure appears here because of differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003).

Appendix D: Figures of forest lost according to bioclimatic regions

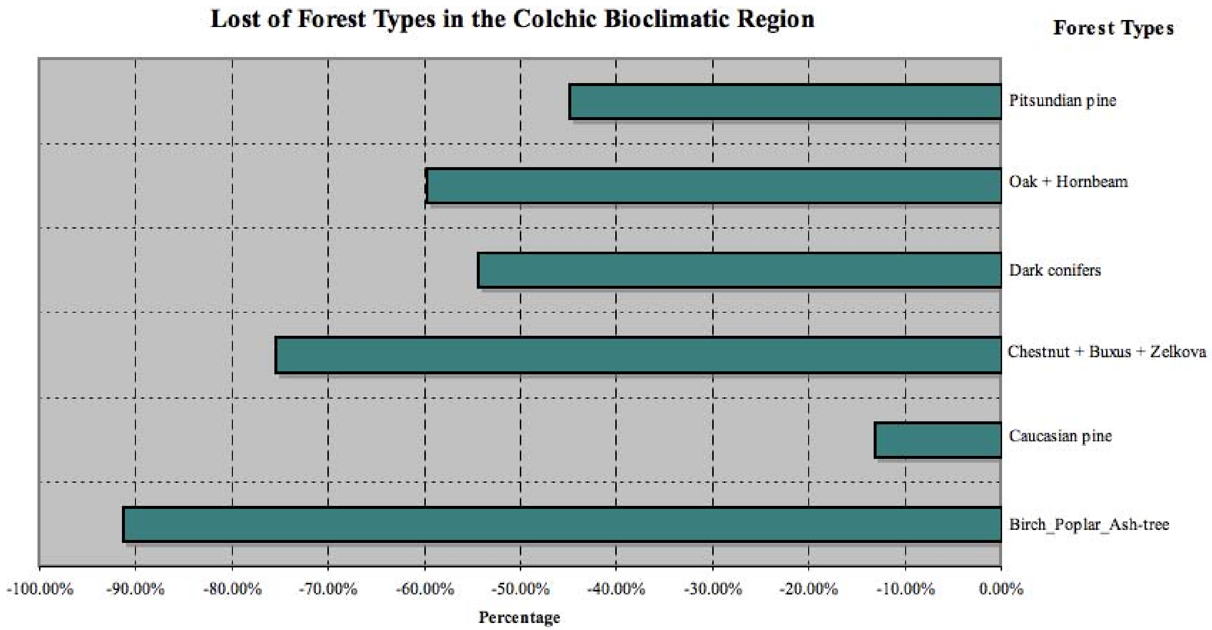

Fig. D1: Lost of forest types in the Colchic Bioclimatic Region, including only those values from table 5 that resulted in a negative difference

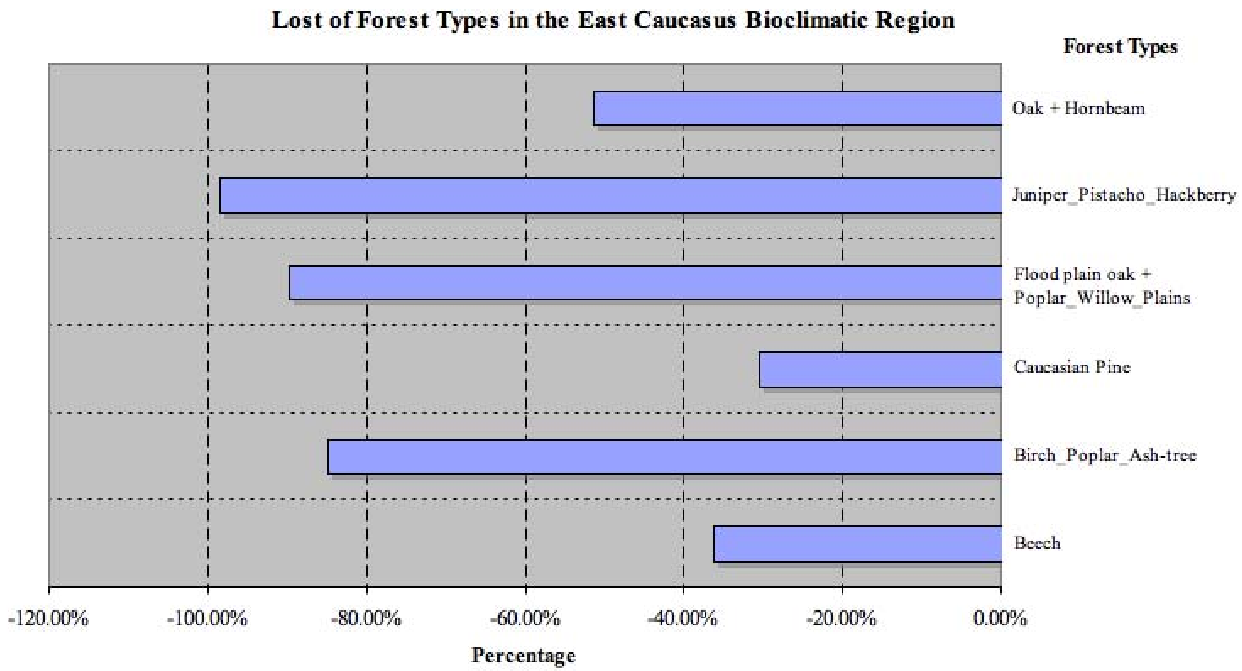

Fig. D2: Lost of forest types in the East Caucasus Bioclimatic Region, including only those values from table 6 that resulted in a negative difference

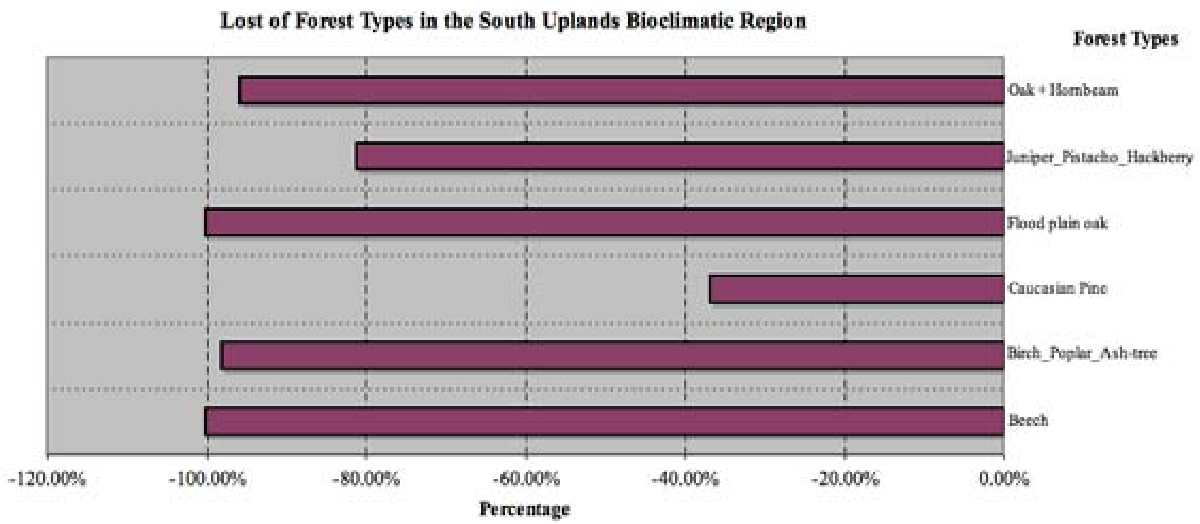

Fig. D3: Lost of forest types in the South Uplands Bioclimatic Region, including only those values from table 7 that resulted in a negative difference

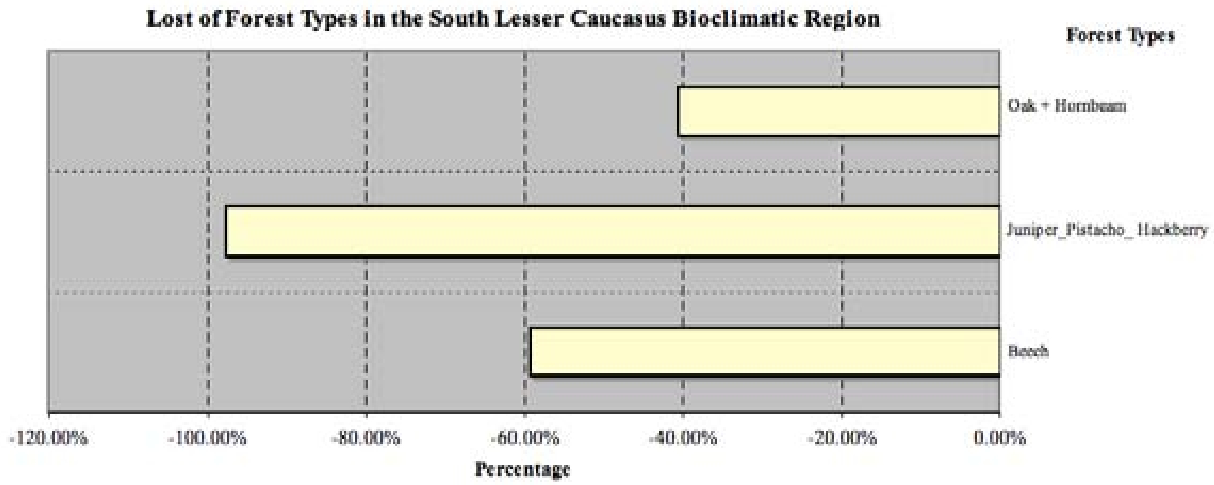

Fig. D4: Lost of forest types in the South Lesser Caucasus Bioclimatic Region, including only those values from table 8 that resulted in a negative difference

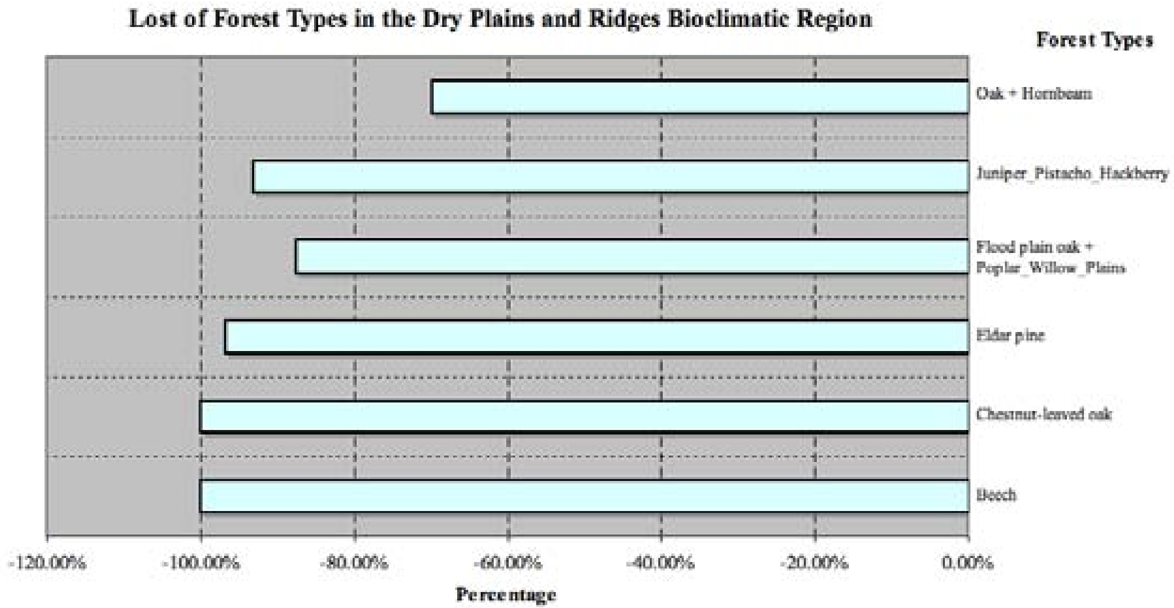

Fig. D5: Lost of forest types in the Dry Plains and Ridges Bioclimatic Region, including only those values from table 9 that resulted in a negative difference

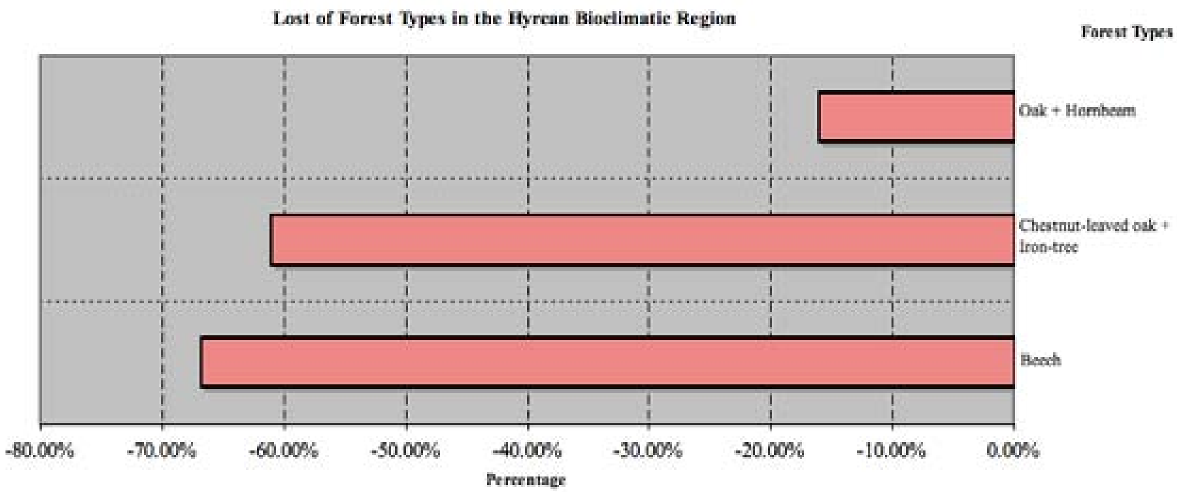

Fig. D6: Lost of forest types in the Hyrcan Bioclimatic Region, including only those values from table 10 that resulted in a negative difference

Appendix E: Figures of forest lost according to the countries

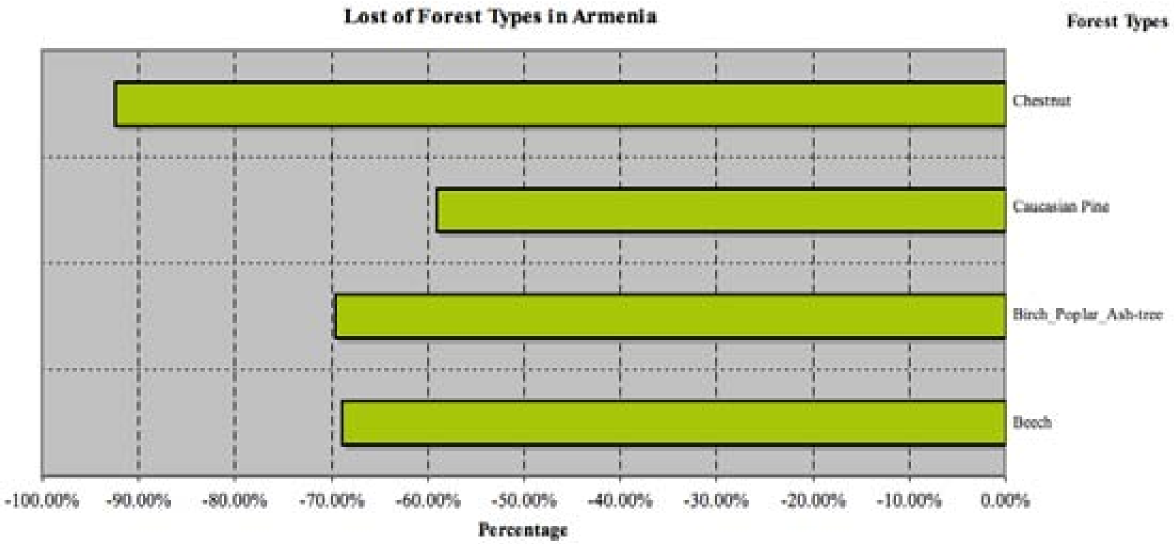

Fig. E1: Lost of forest types in Armenia, including only those values from table 12 that resulted in a negative difference

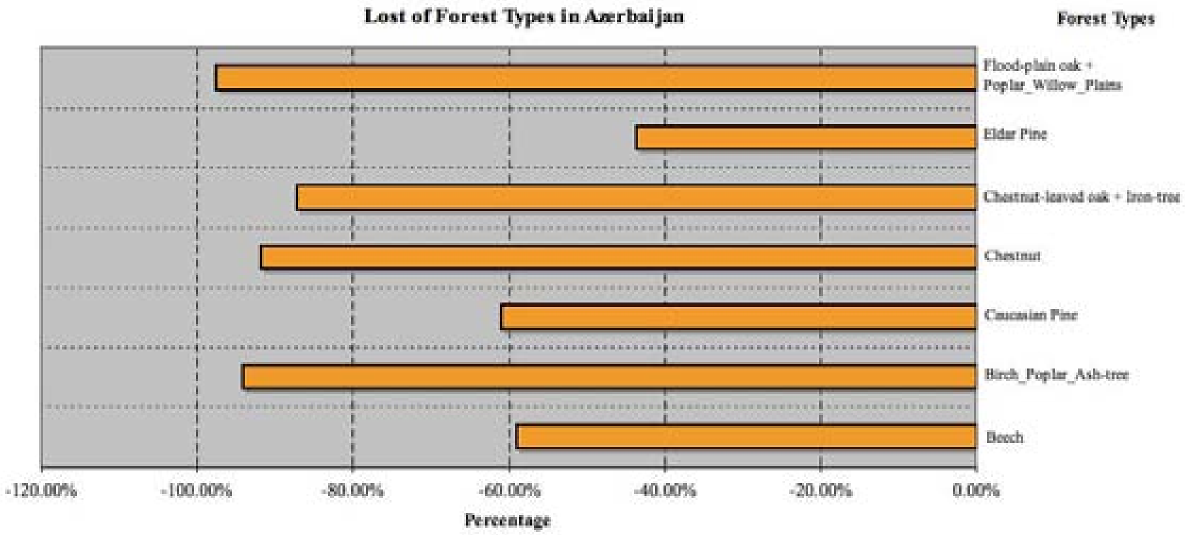

Fig. E2: Lost of forest types in Azerbaijan, including only those values from table 13 that resulted in a negative difference

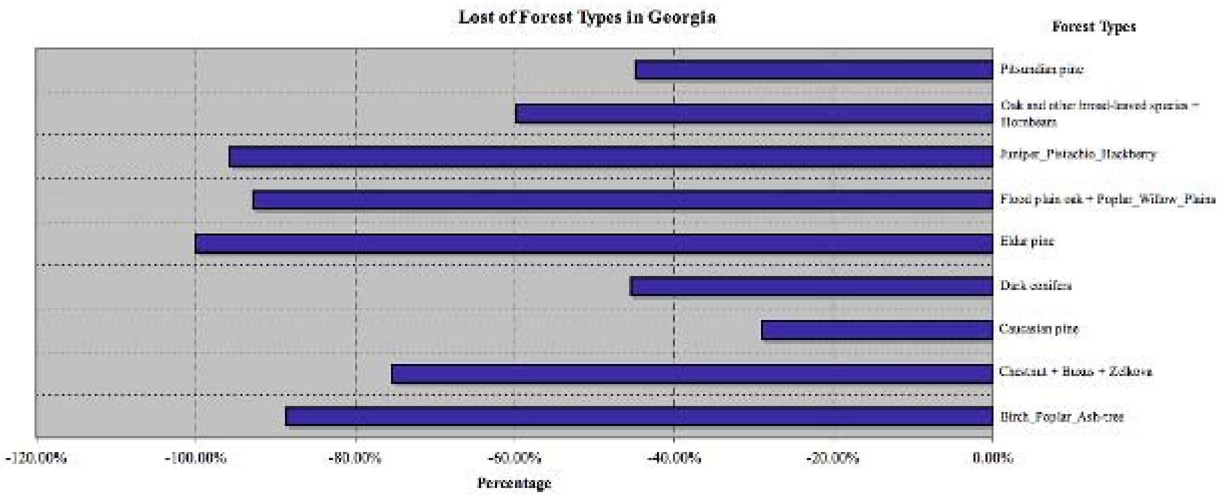

Fig. E3: Lost of forest types in Georgia, including only those values from table 14 that resulted in a negative difference

Appendix F: Habitat suitability models according to forest classes

Fig. F1a: Modeled present for Dry woodlands

Fig. F1b: A2a model for Dry woodlands

Fig. F1c: B2a model for Dry woodlands

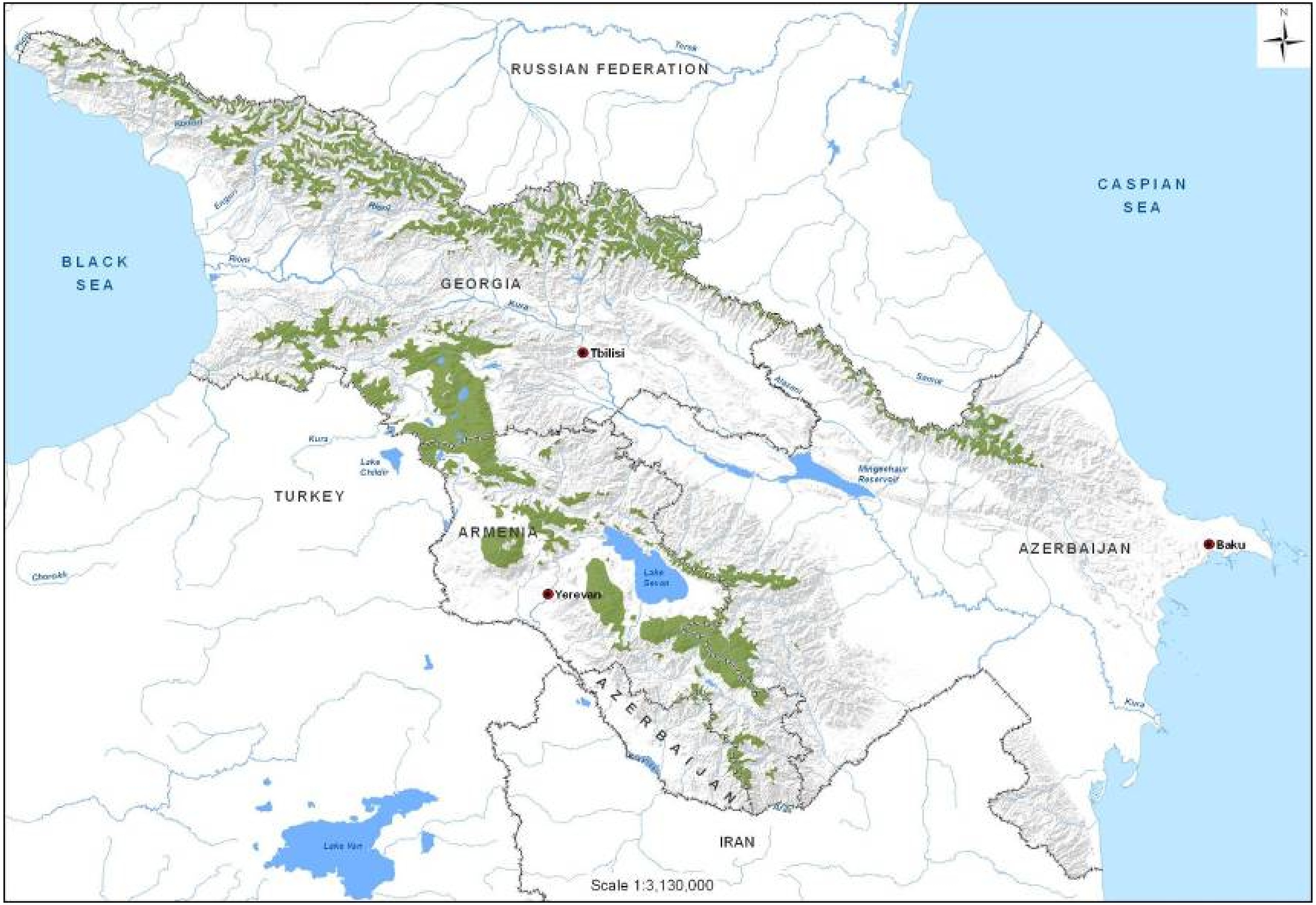

Fig. F2a: Modeled present for Betula_etc.

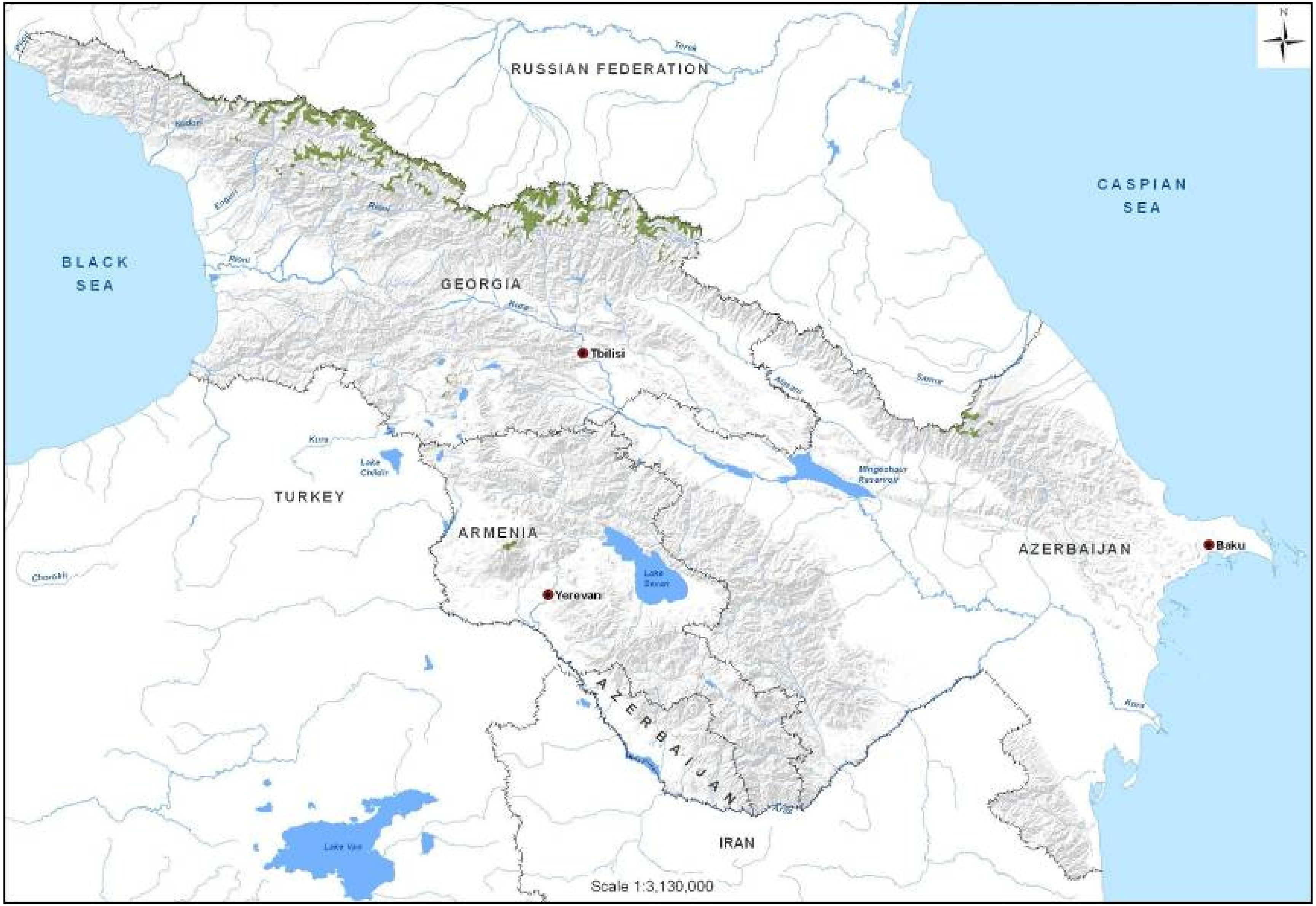

Fig. F2b: A2a model for Betula_etc.

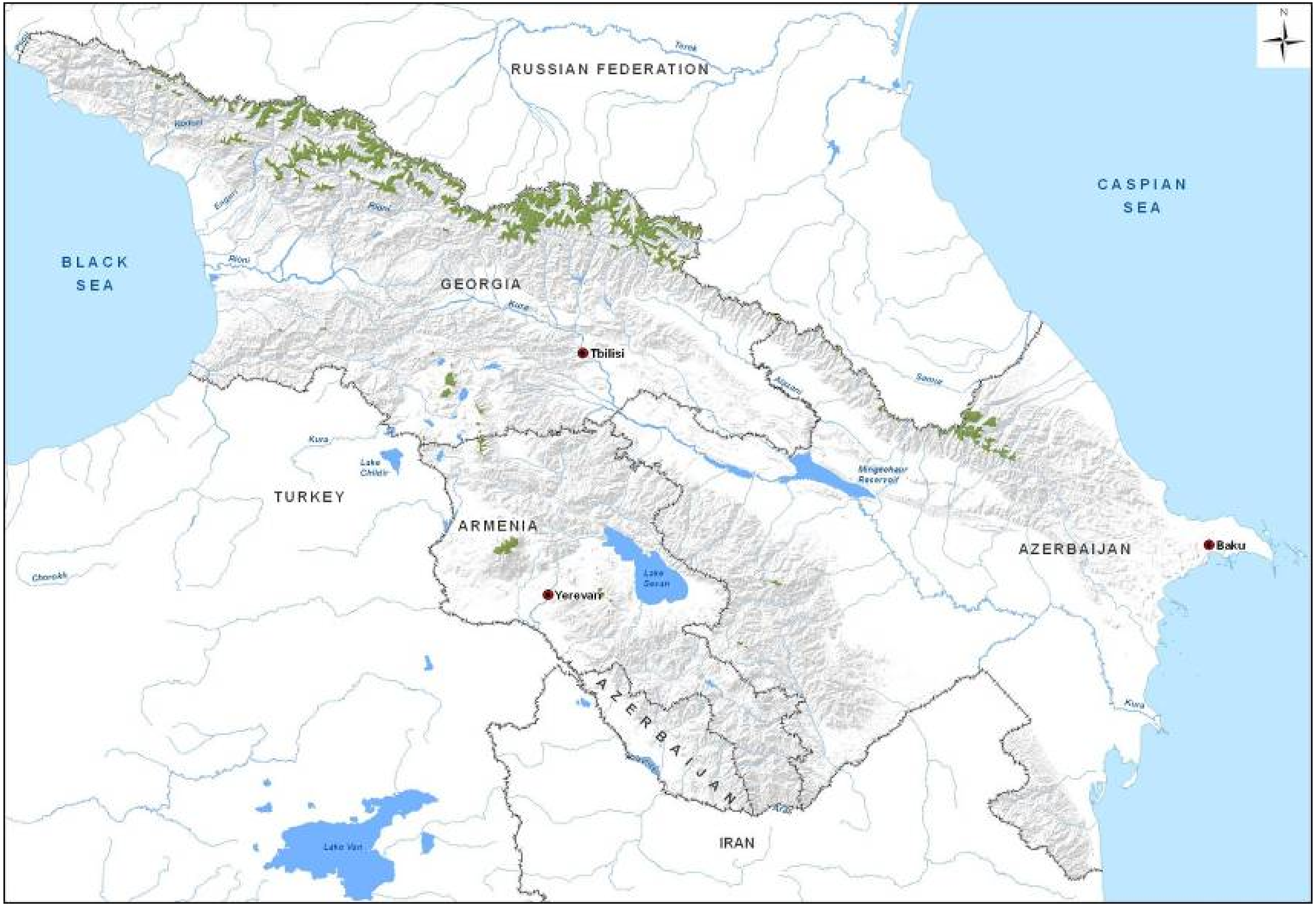

Fig. F2c: B2a model for Betula_etc.

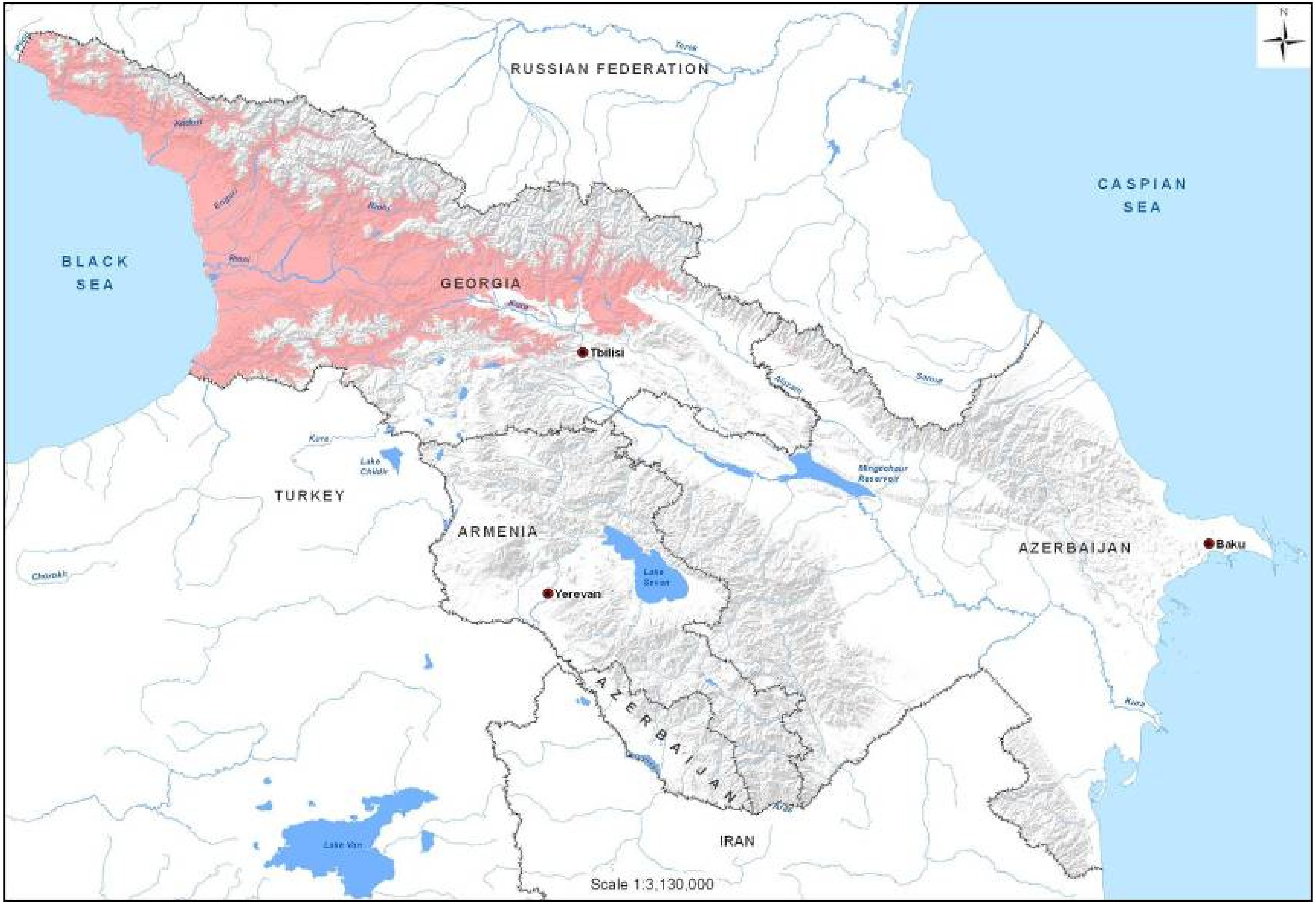

Fig. F3a: Modeled present for Buxus

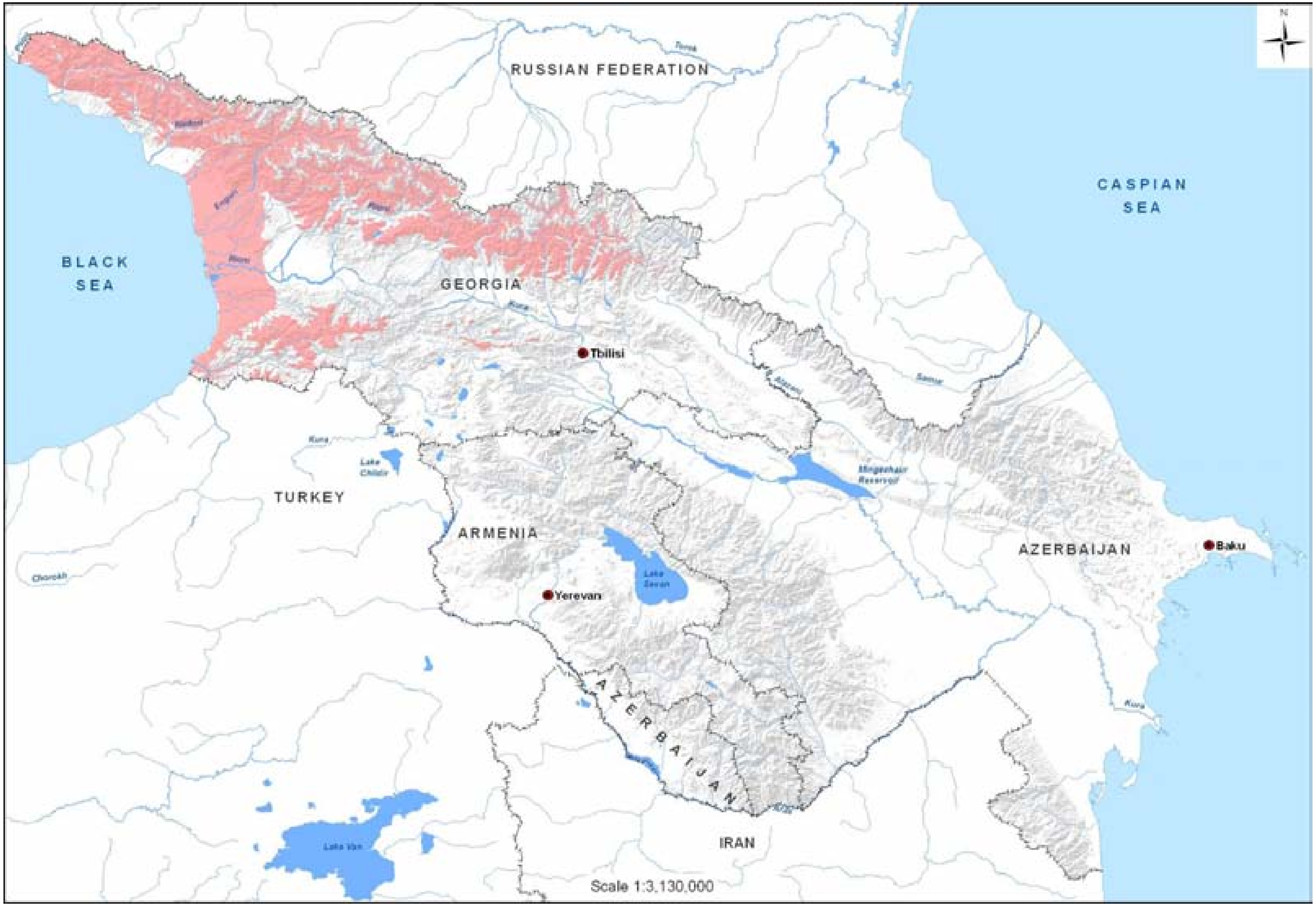

Fig. F3b: A2a model for Buxus

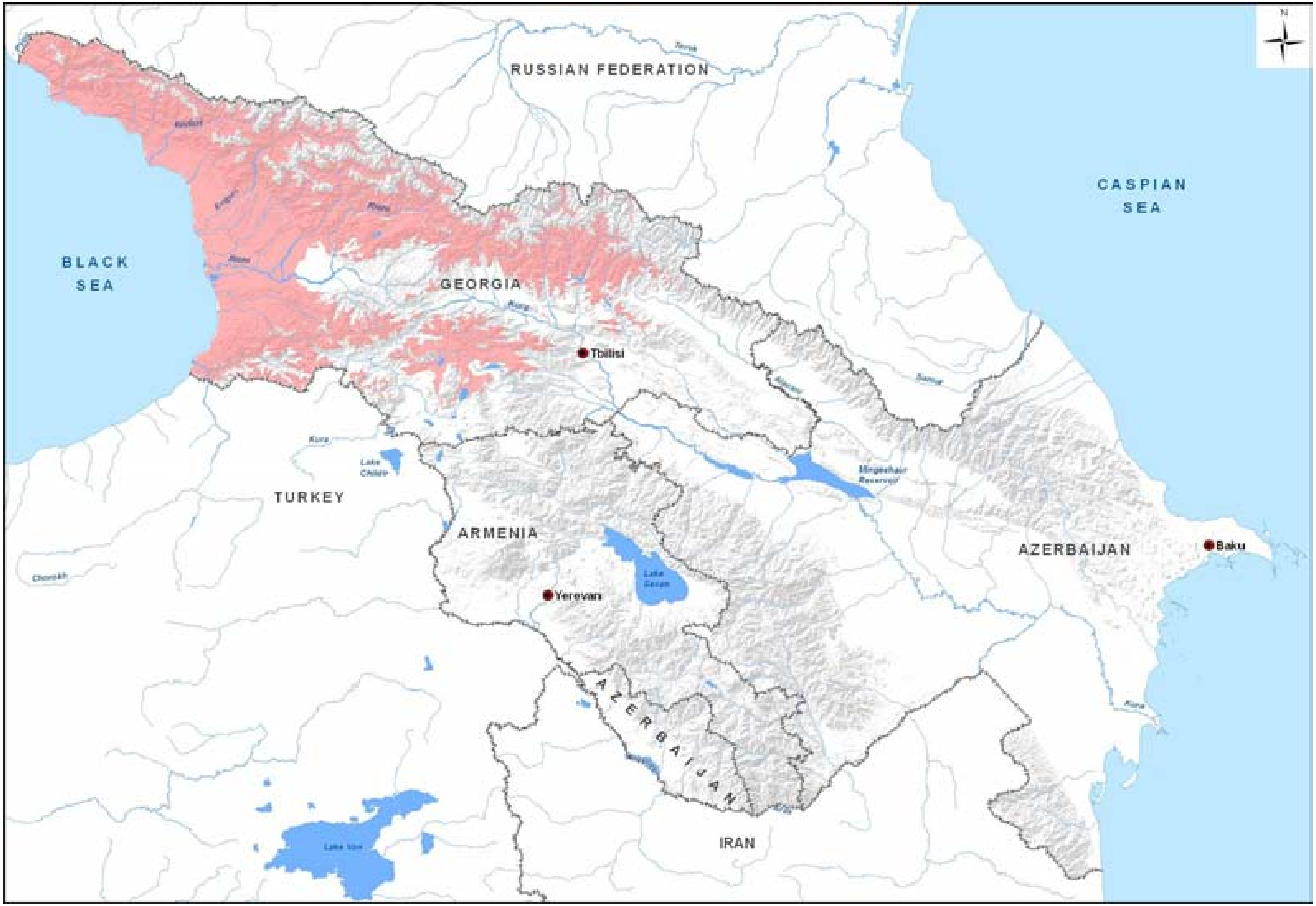

Fig. F3c: B2a model for Buxus

Fig. F4a: Modeled present for Carpinus

Fig. F4b: A2a model for Carpinus

Fig. F4c: B2a model for Carpinus

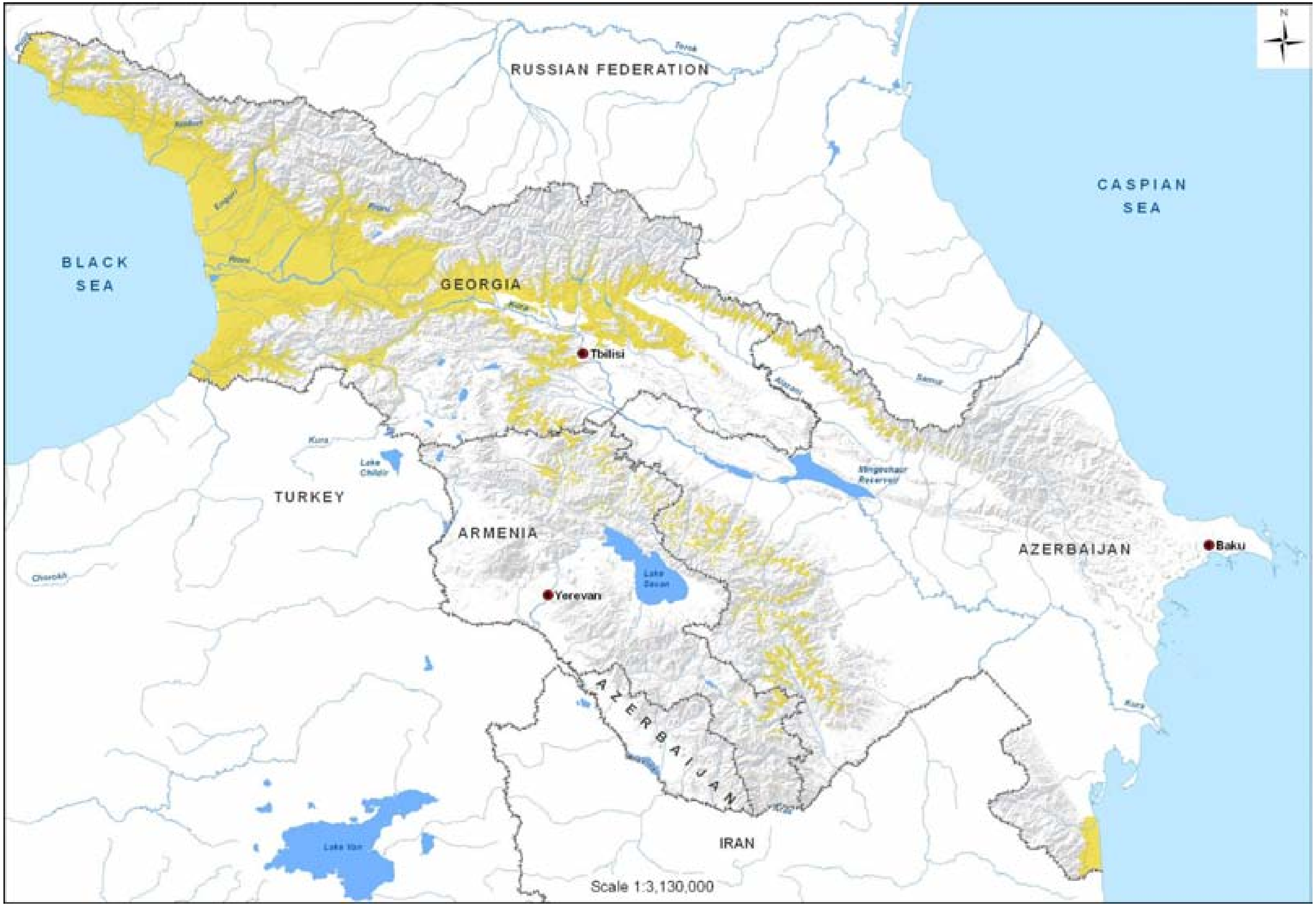

Fig. F5a: Modeled present for Castanea

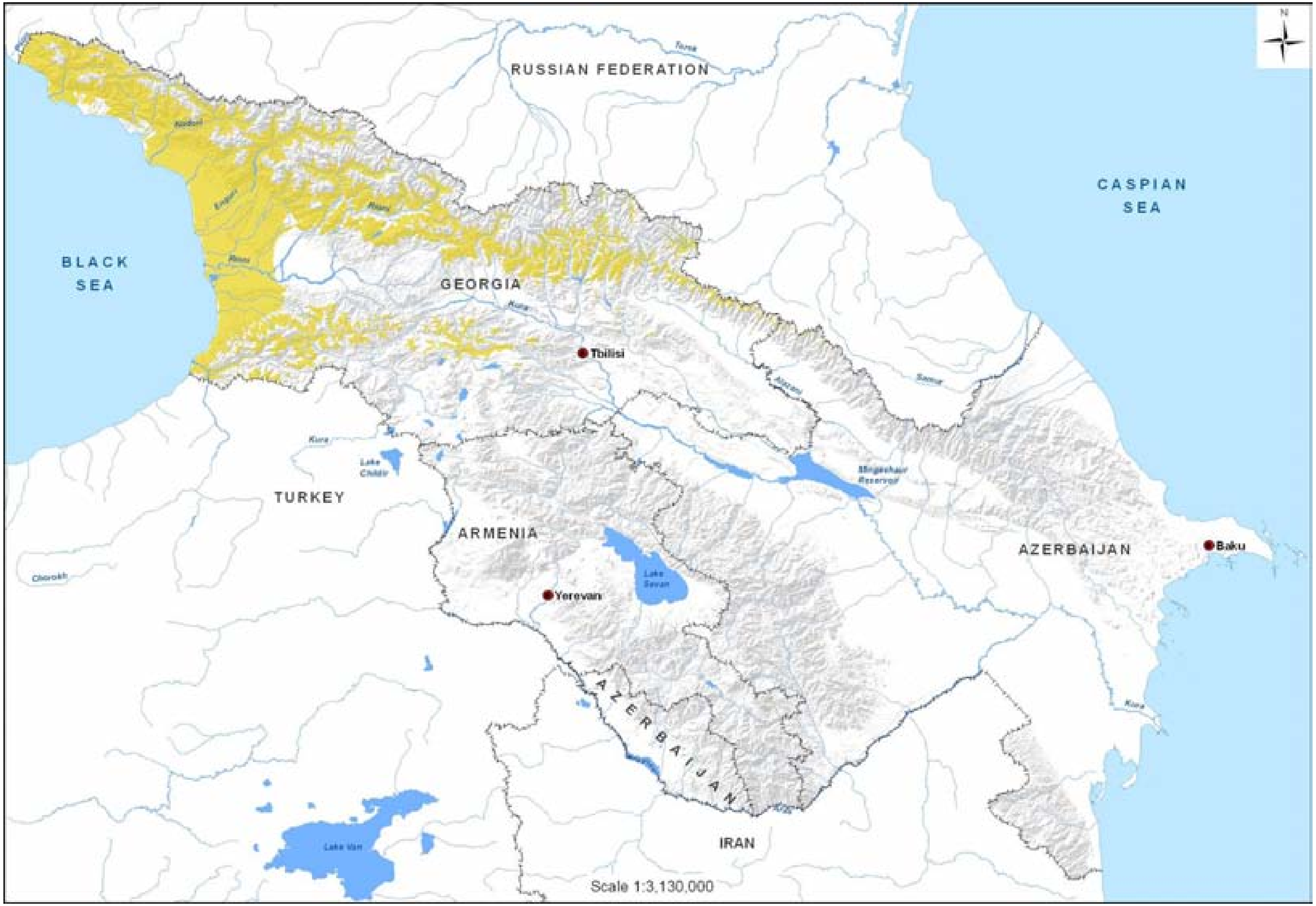

Fig. F5b: A2a model for Castanea

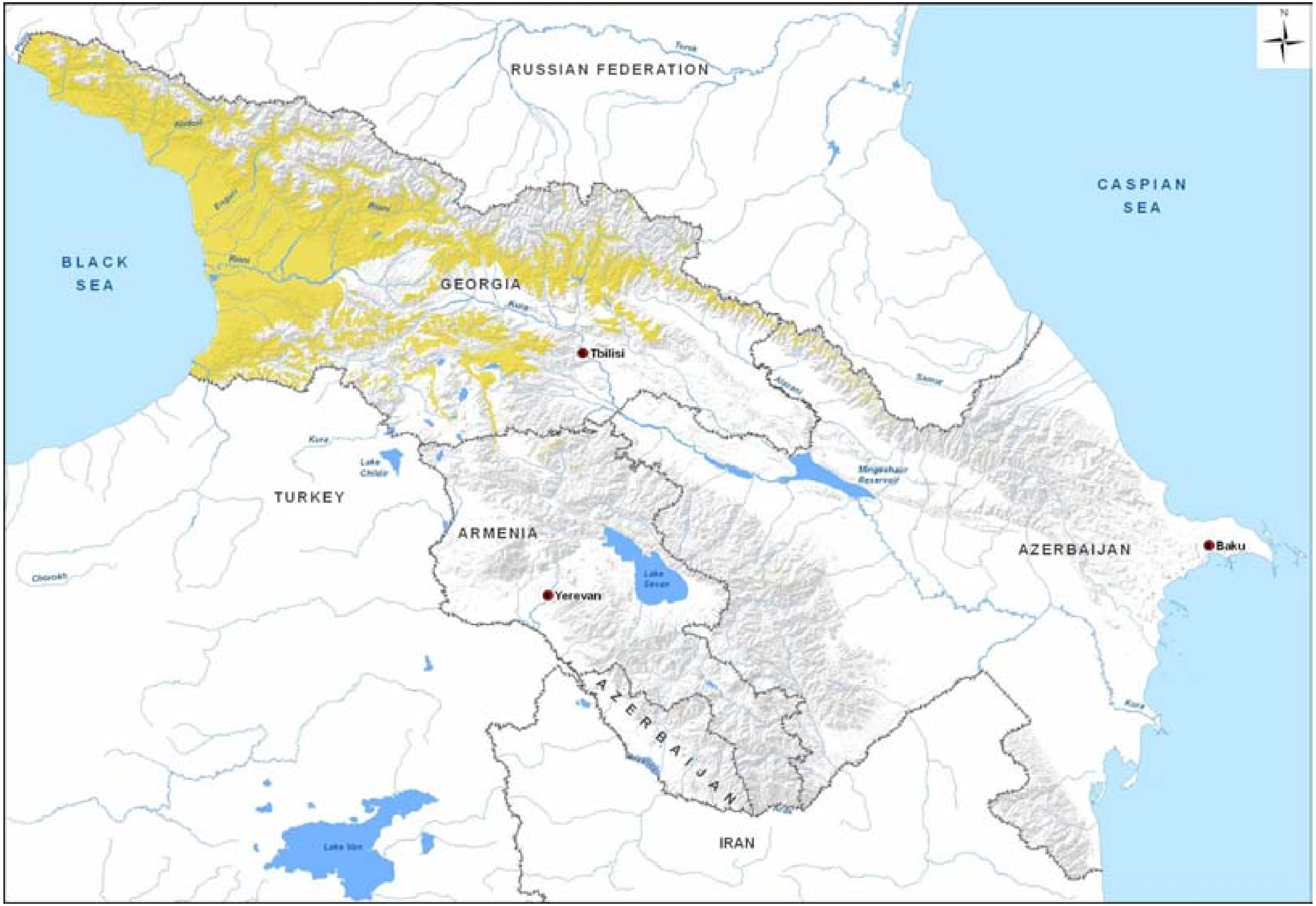

Fig. F5c: B2a model for Castanea

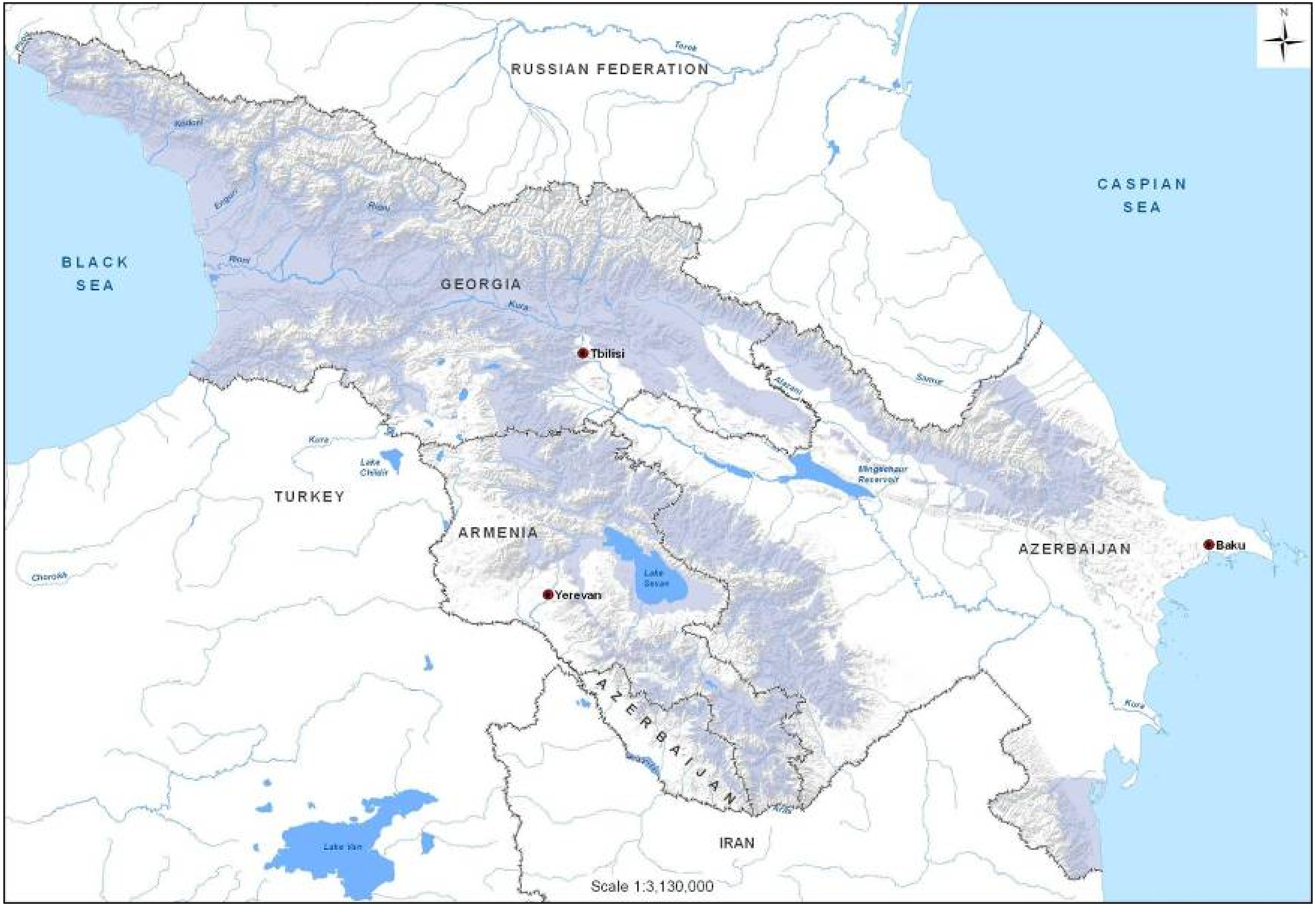

Fig. F6a: Modeled present for Fagus

Fig. F6b: A2a model for Fagus

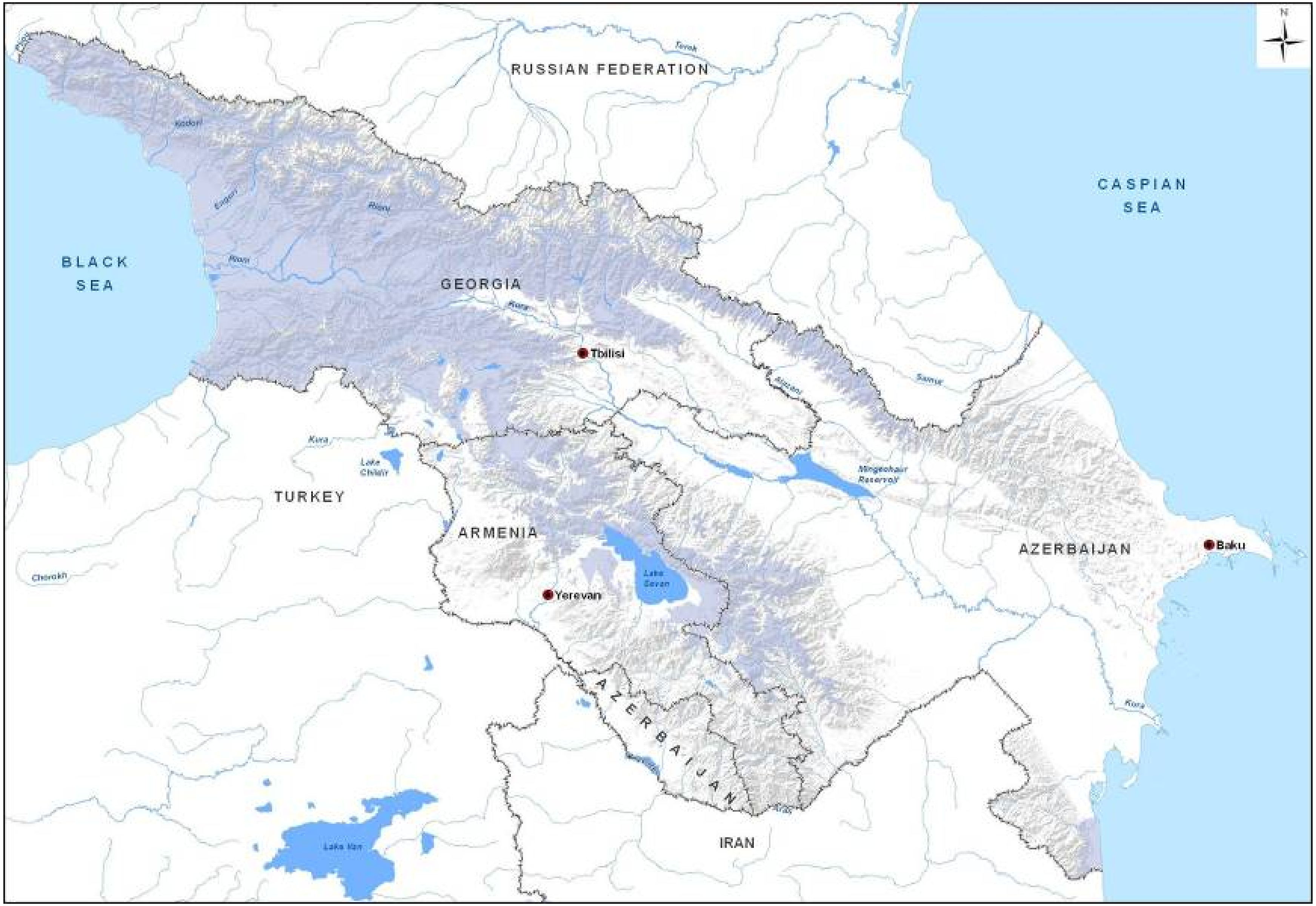

Fig. F6c: B2a model for Fagus

Fig. F7a: Modeled present for Parrotia

Fig. F7b: A2a model for Parrotia

Fig. F7c: B2a model for Parrotia

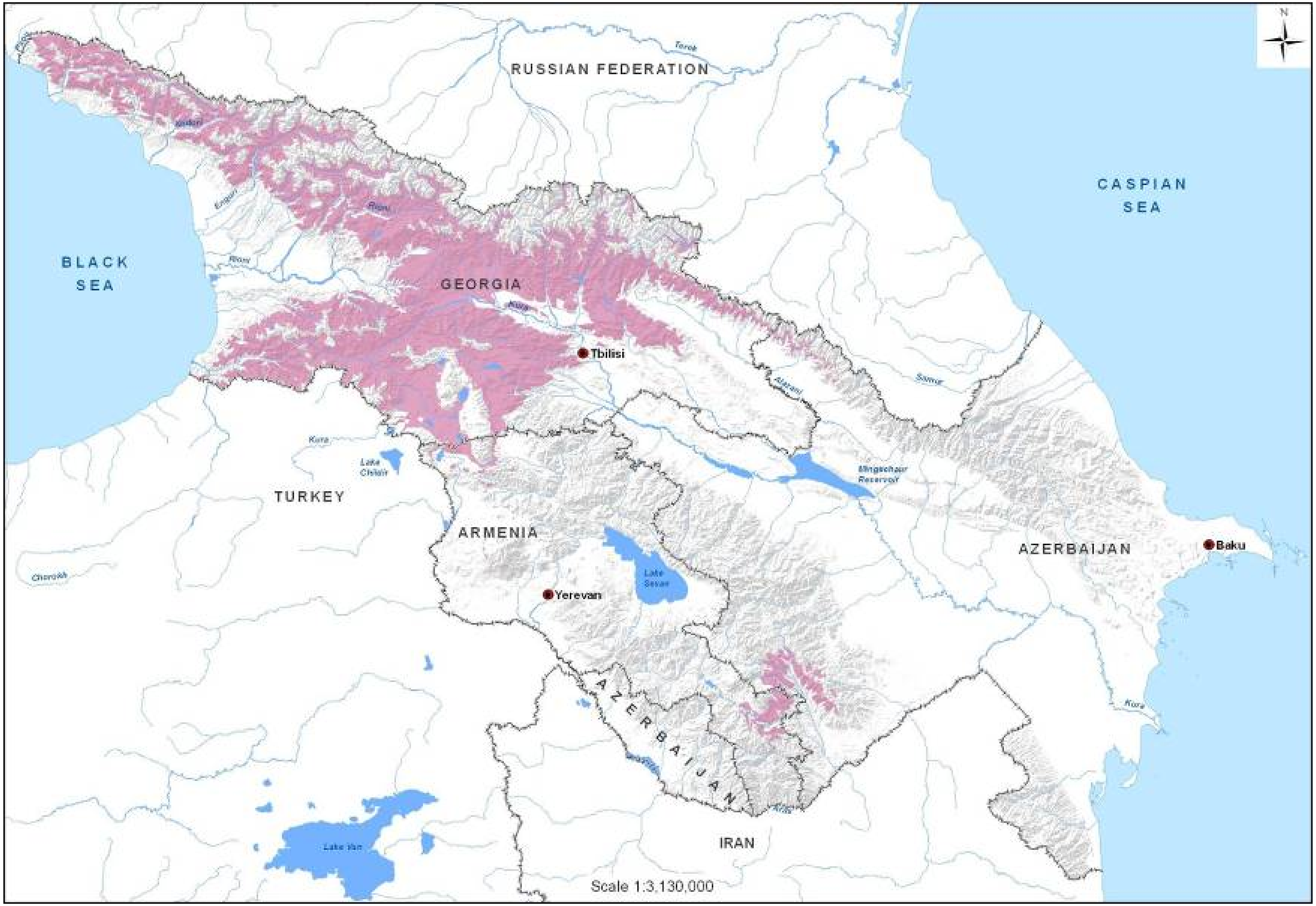

Fig. F8a: Modeled present for Picea_Abies

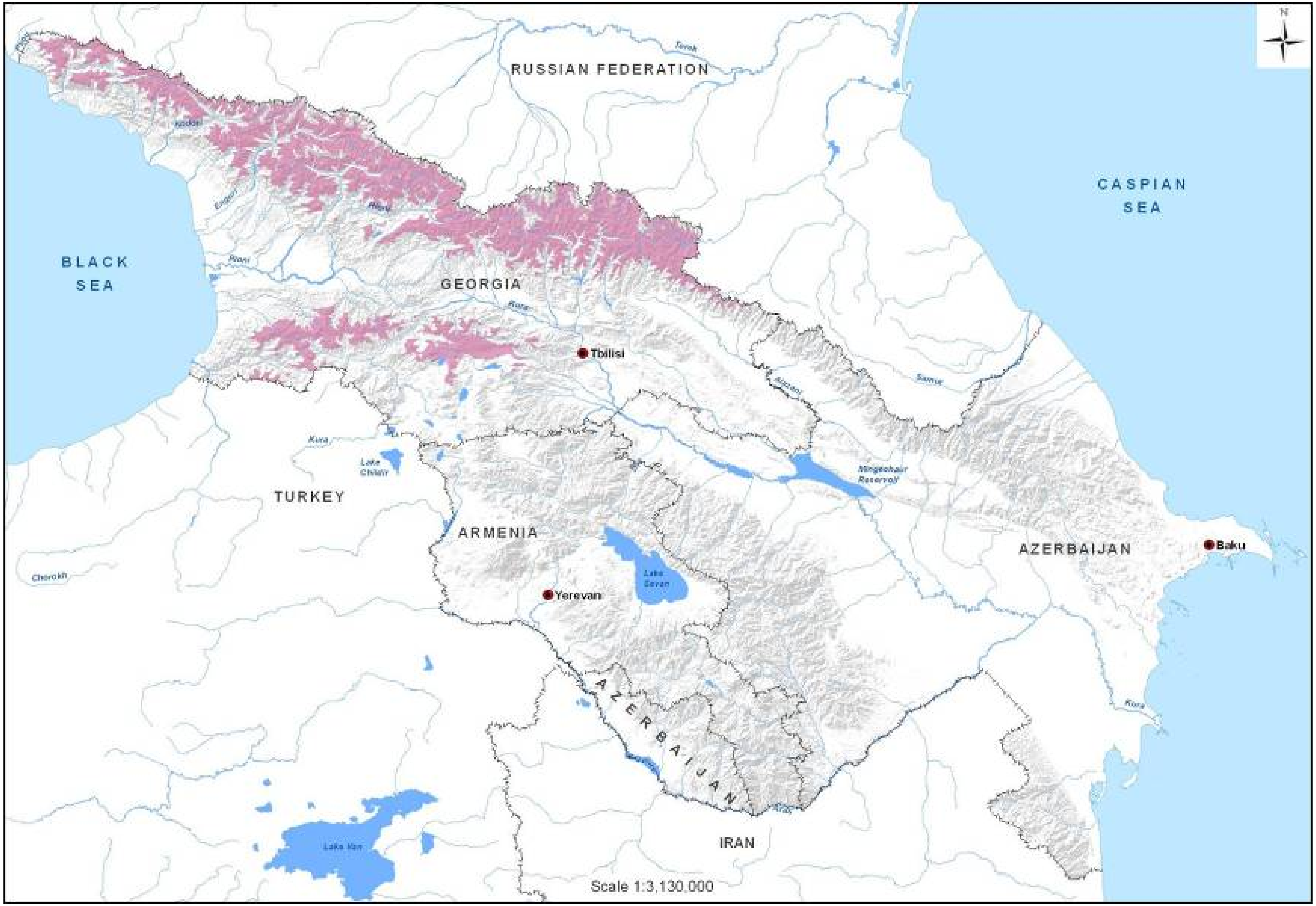

Fig. F8b: A2a model for Picea_Abies

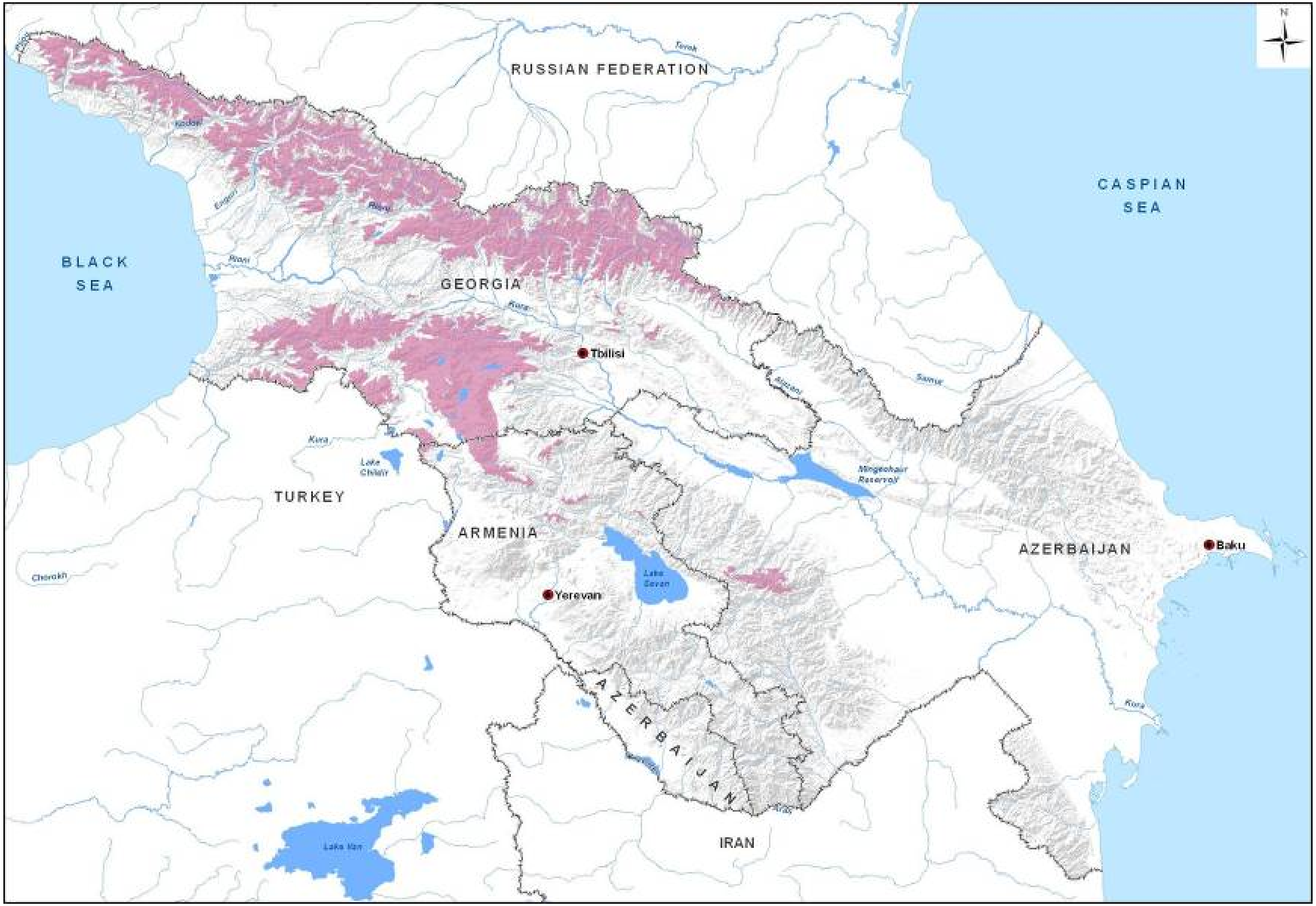

Fig. F8c: B2a model for Picea_Abies

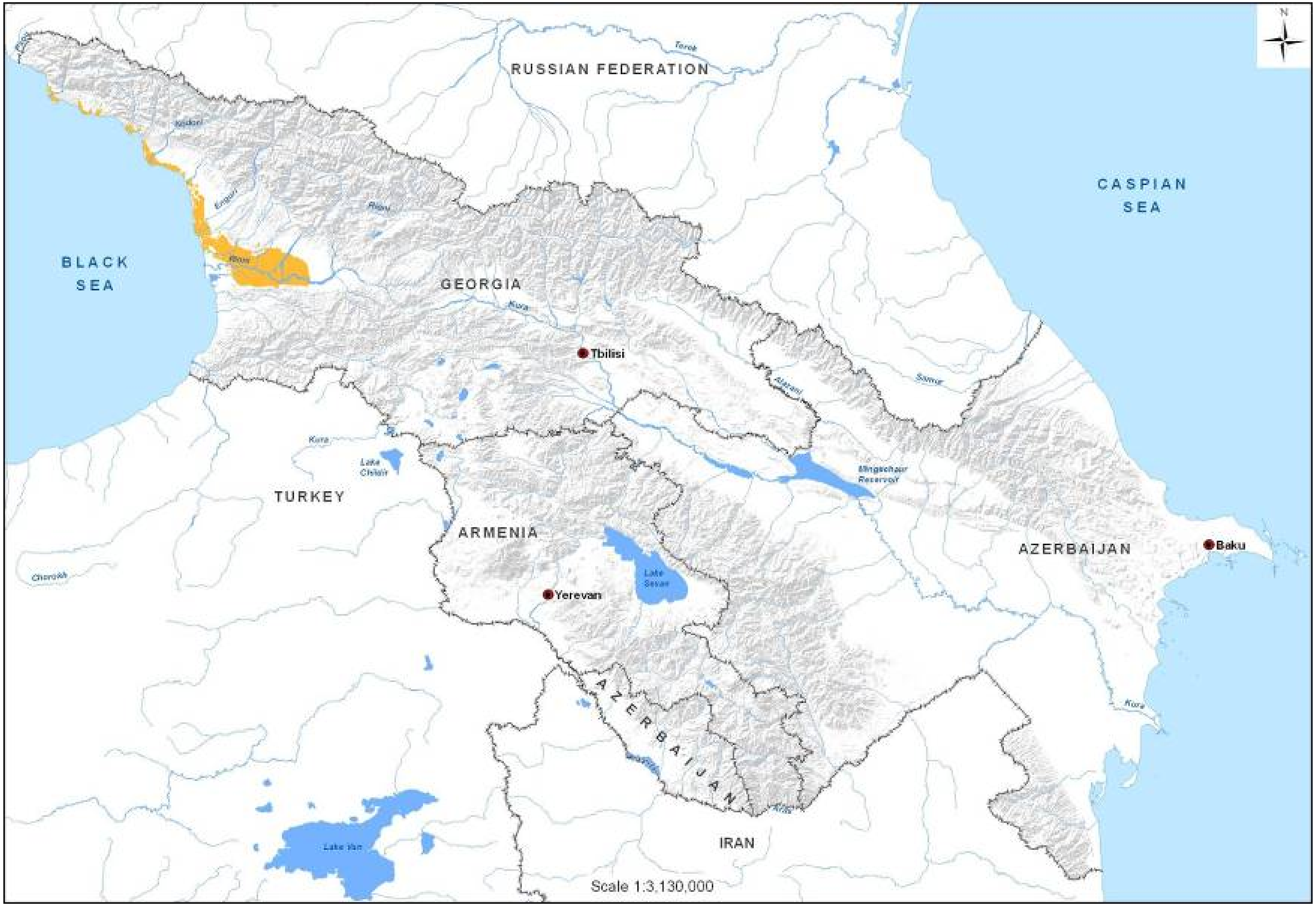

Fig. F9a: Modeled present for Pinus_pts

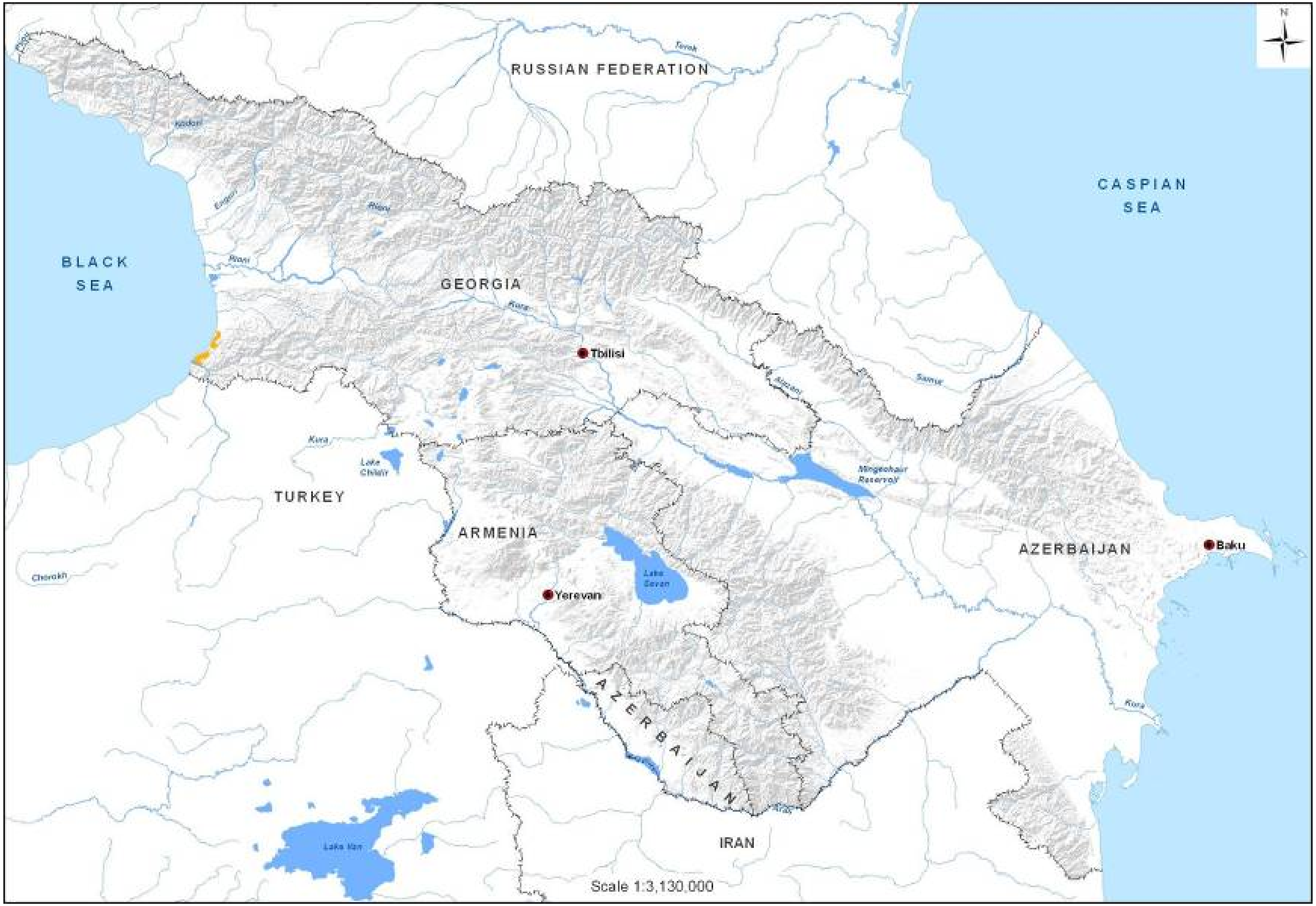

Fig. F9b: A2a model for Pinus_pts

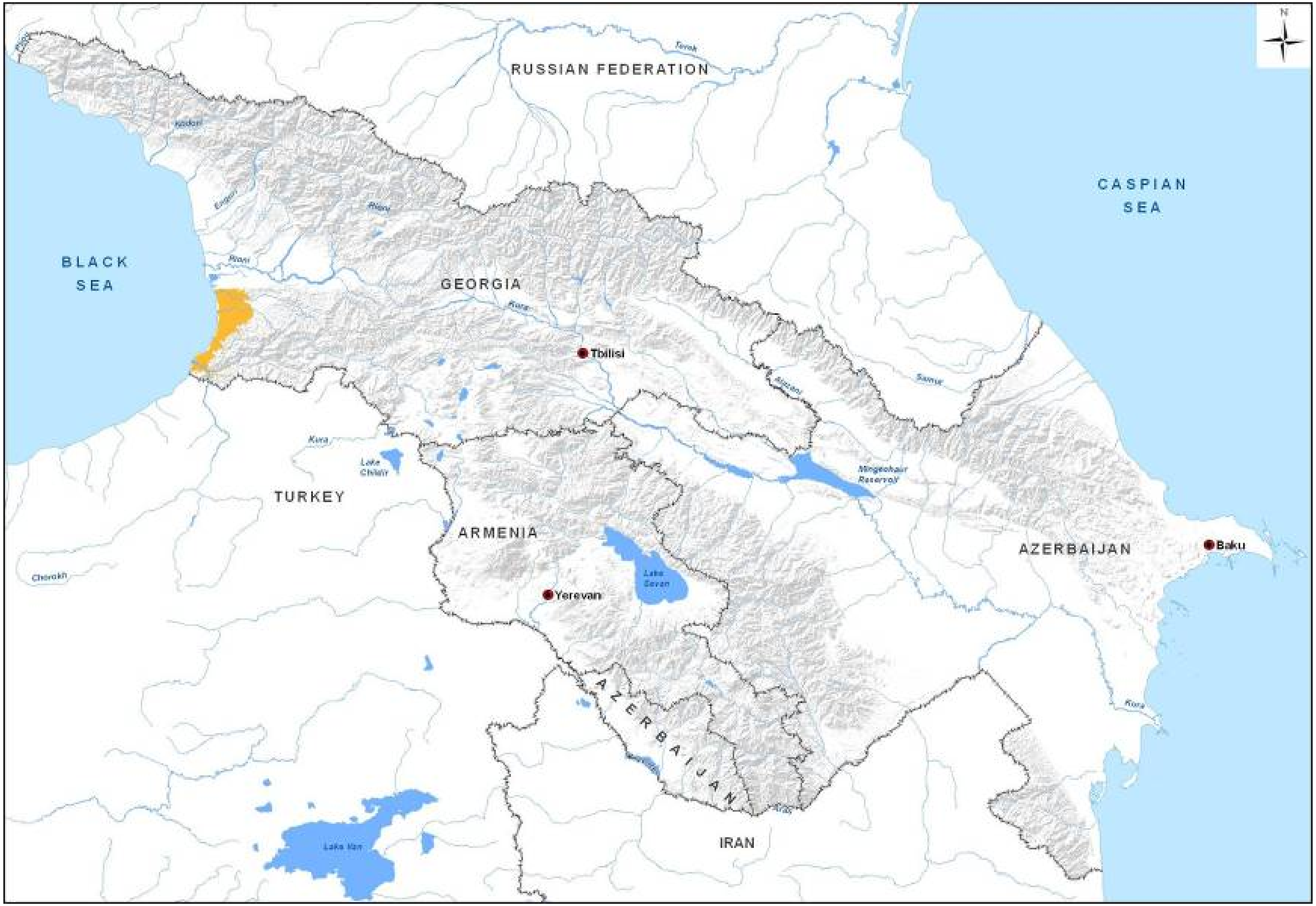

Fig. F9c: B2a model for Pinus_pts

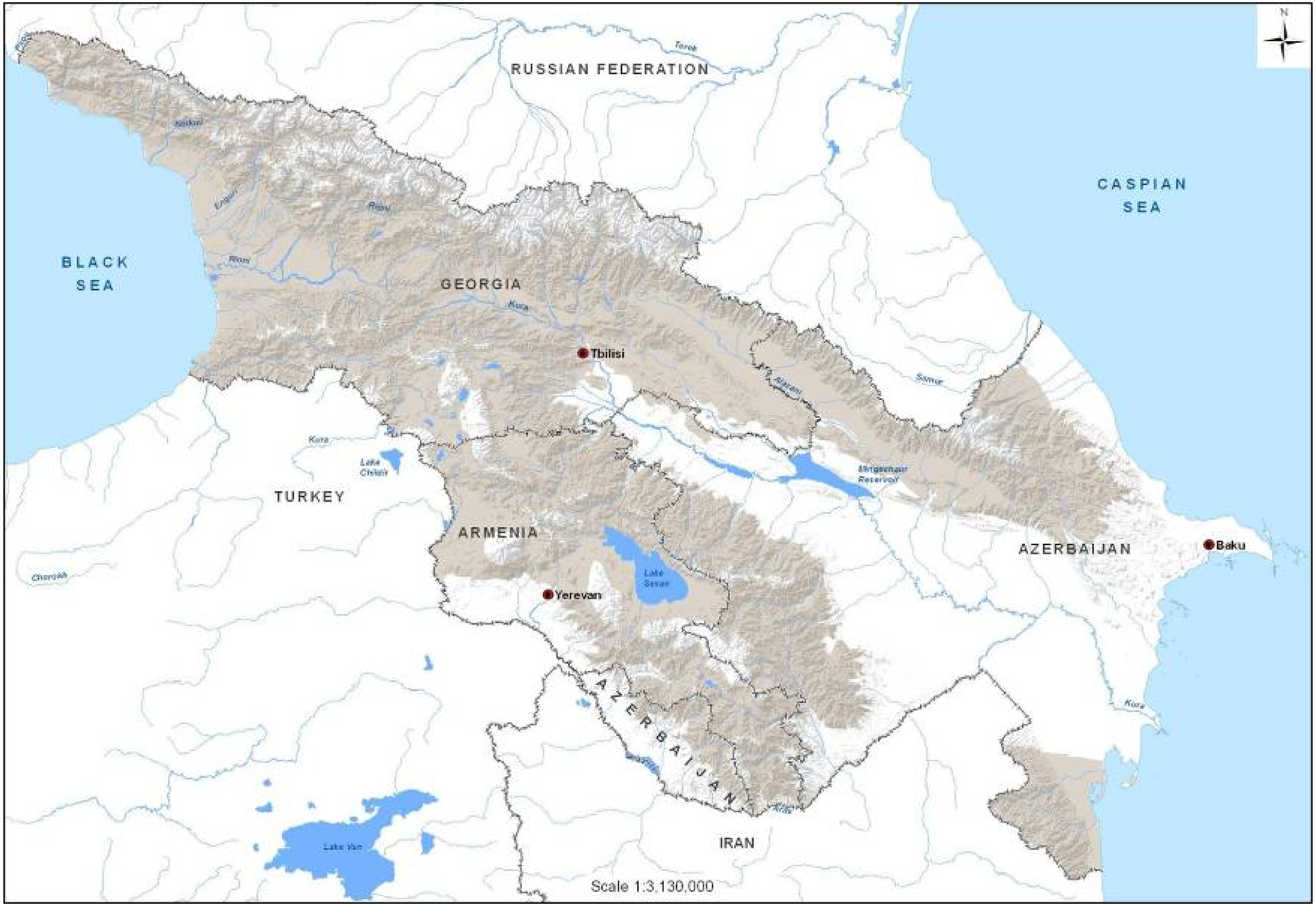

Fig. F10a: Modeled present for Quercus_pinus

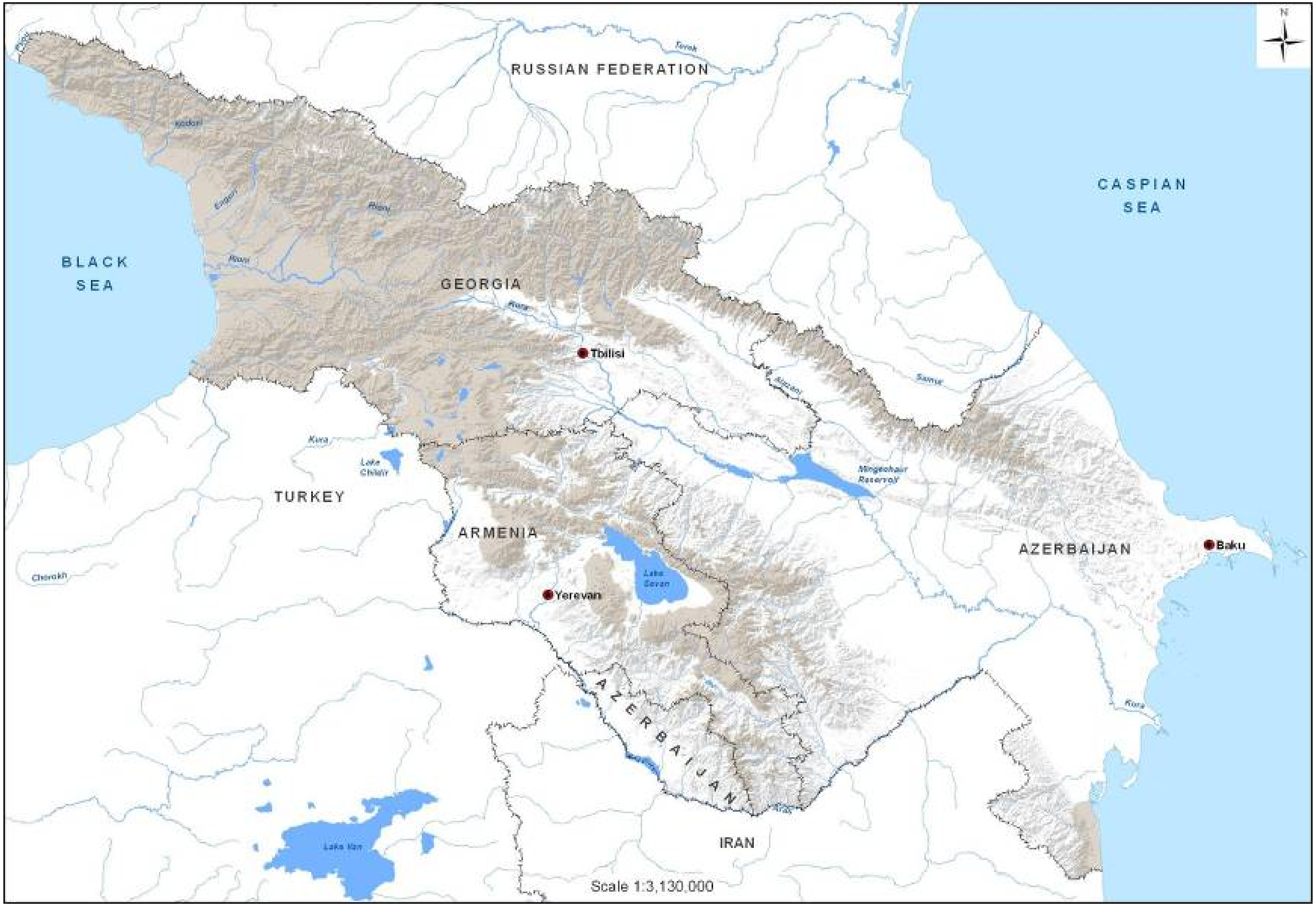

Fig. F10b: A2a model for Quercus_pinus

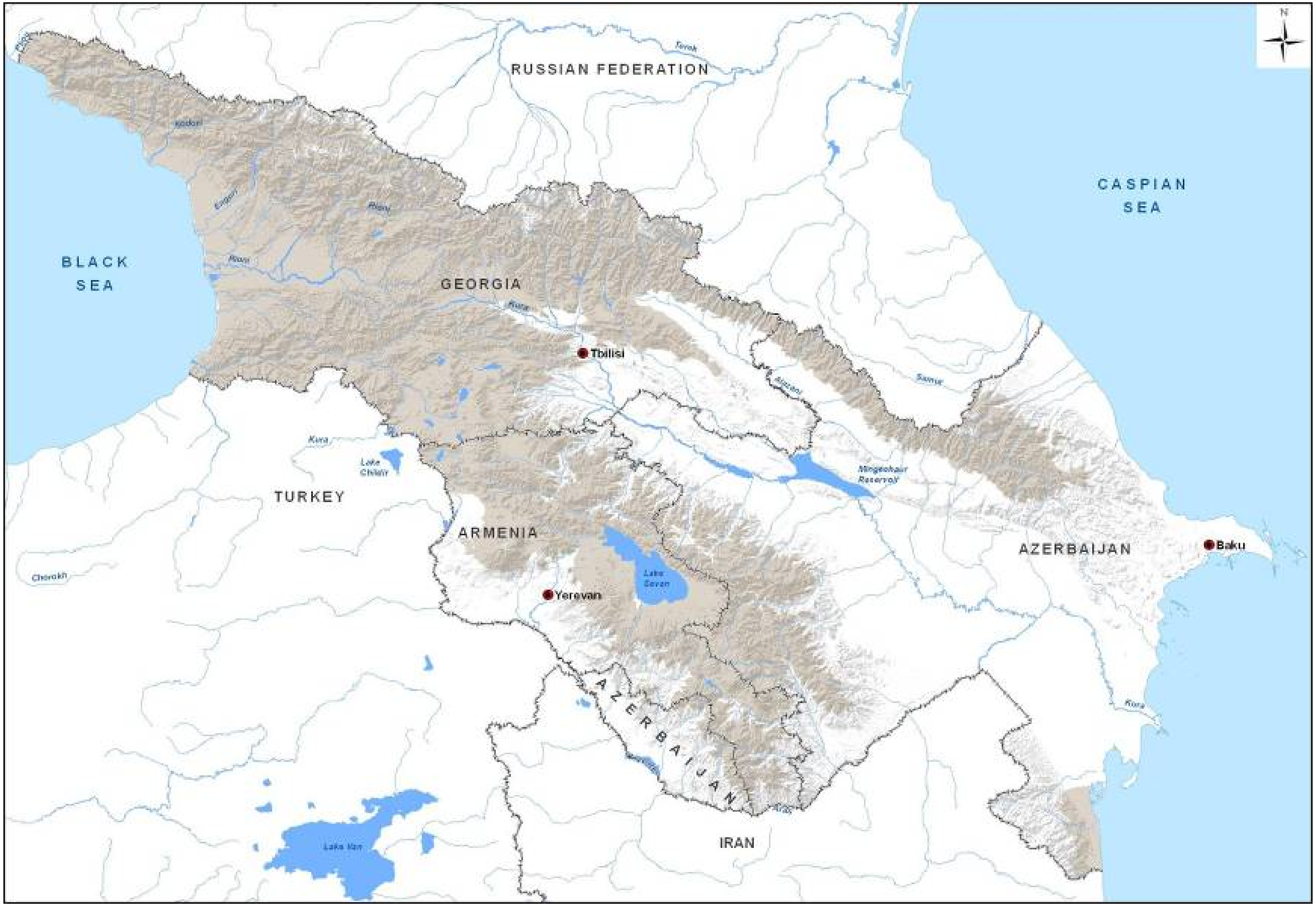

Fig. F10c: B2a model for Quercus_pinus

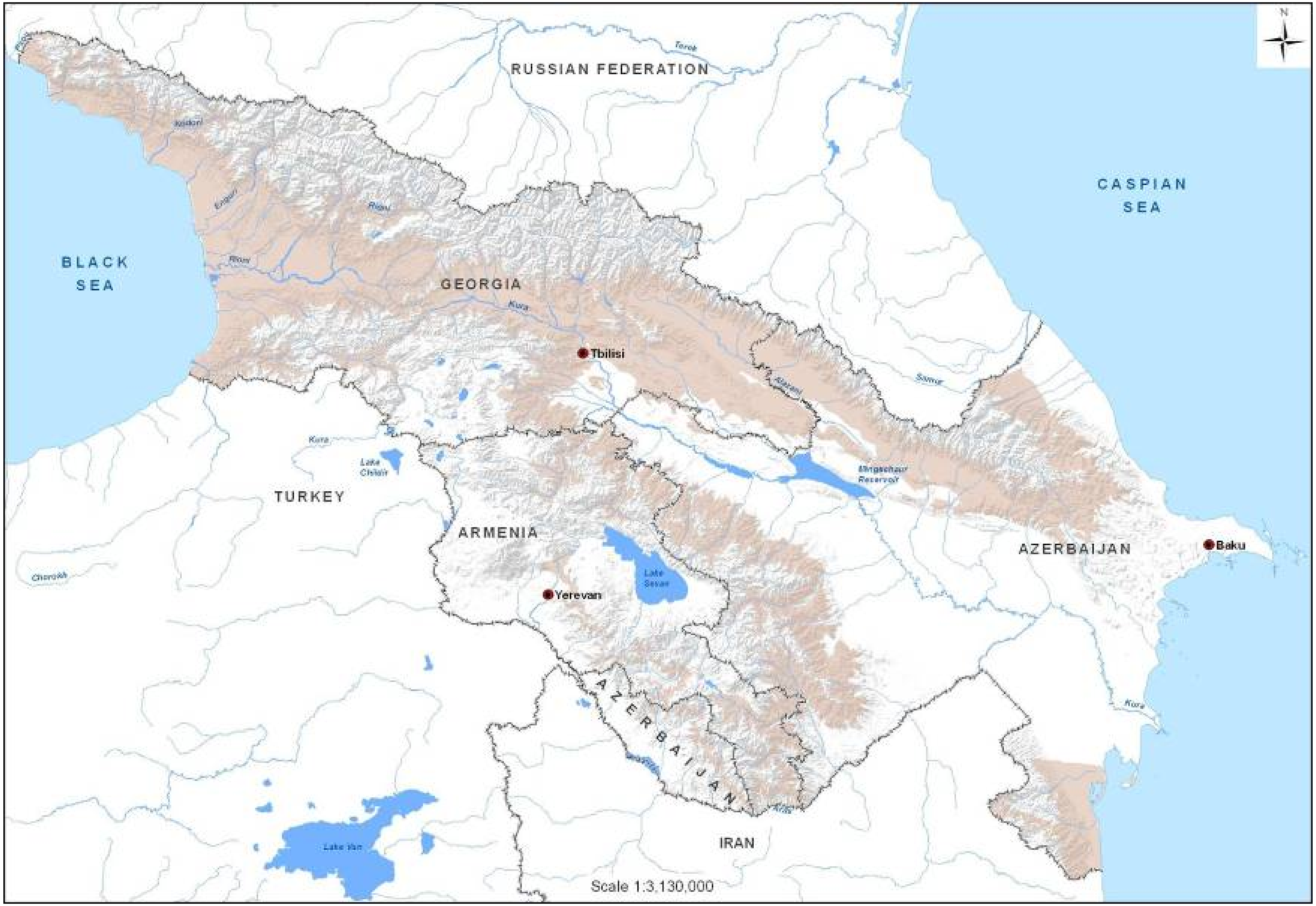

Fig. F11a: Modeled present for Quer_casta

Fig. F11b: A2a model for Quer_casta

Fig. F11c: B2a model for Quer_casta

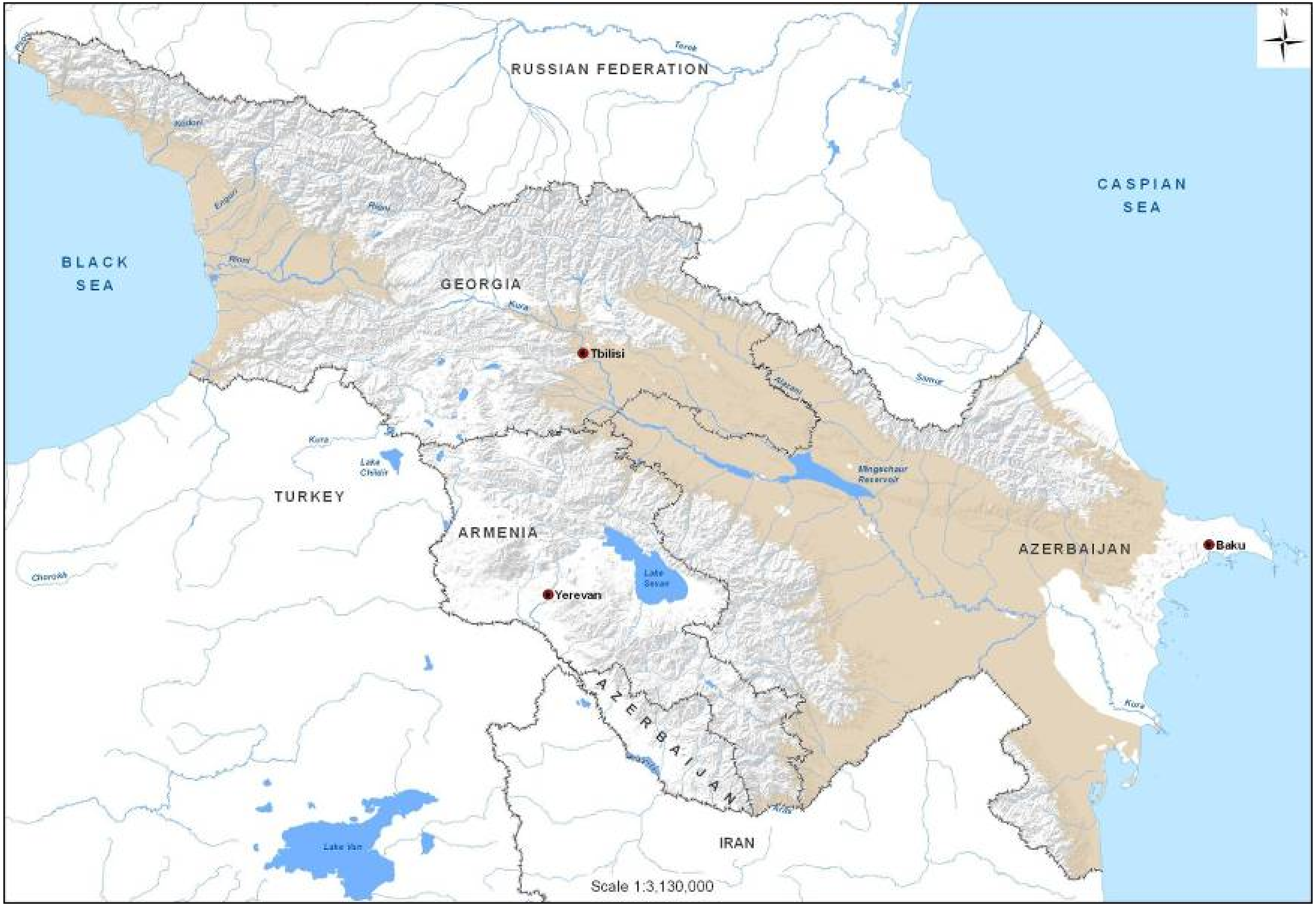

Fig. F12a: Modeled present for Quer_pedun

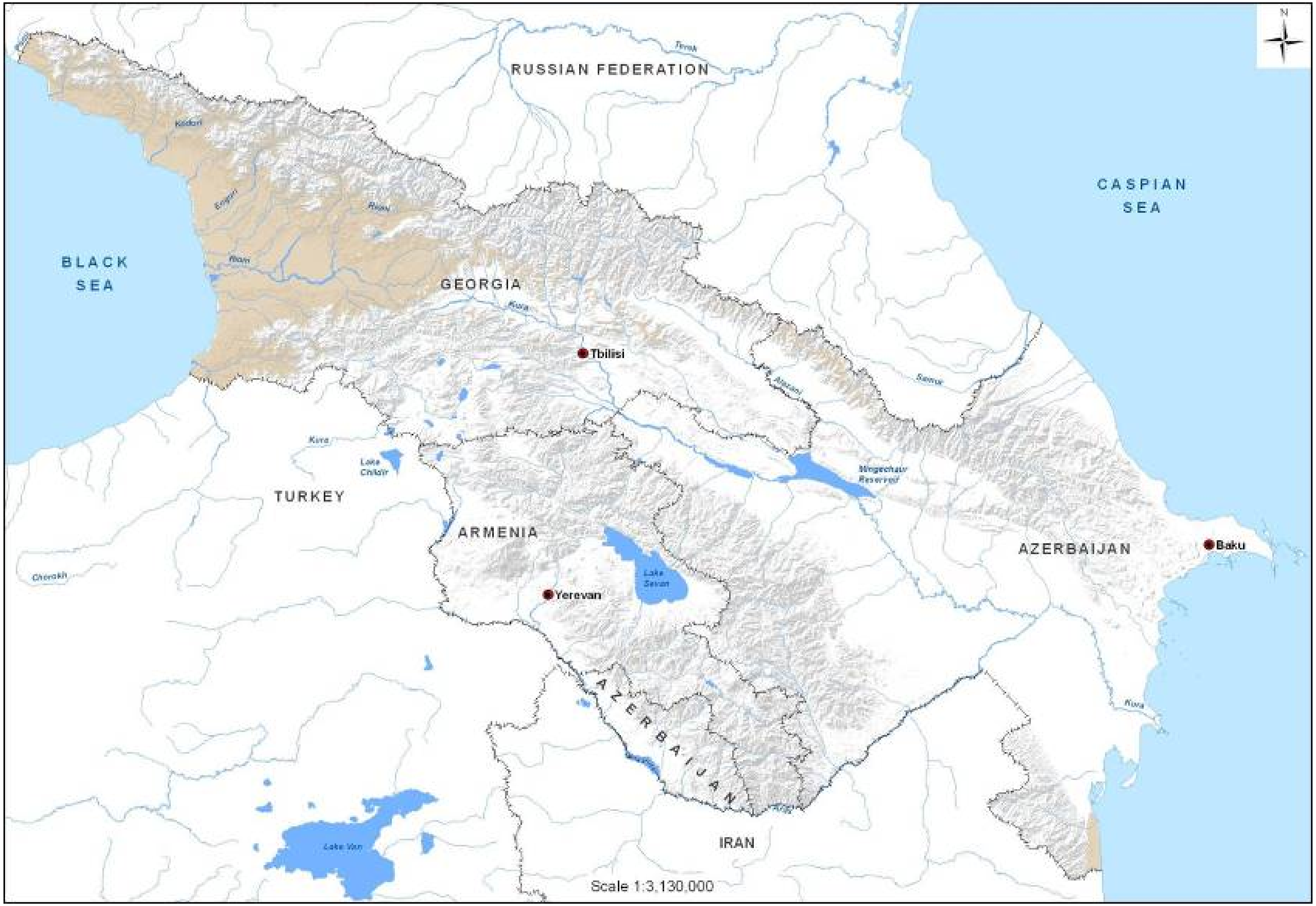

Fig. F12b: A2a model for Quer_pedun

Fig. F12c: B2a model for Quer_pedun

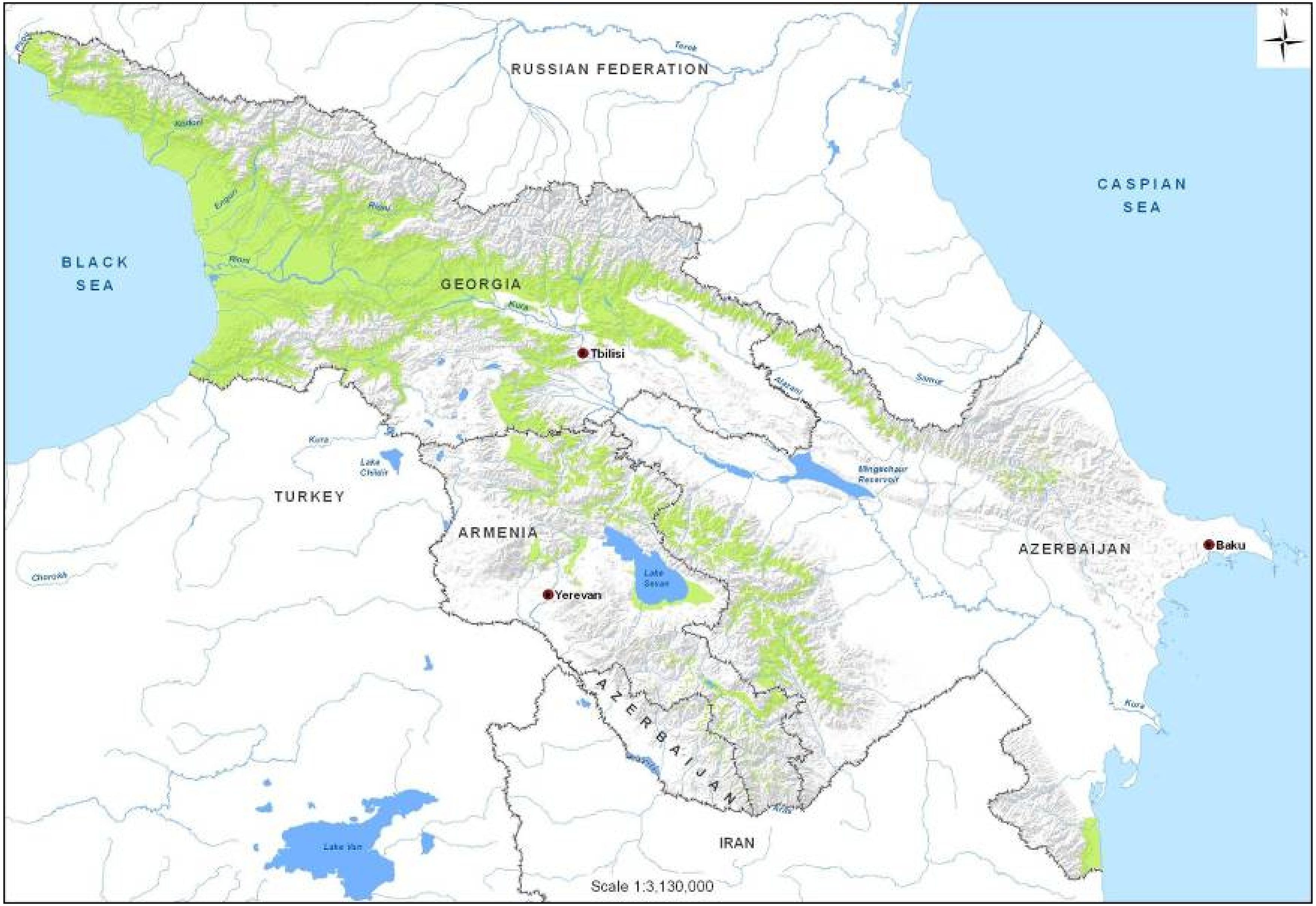

Fig. F13a: Modeled present for Taxus

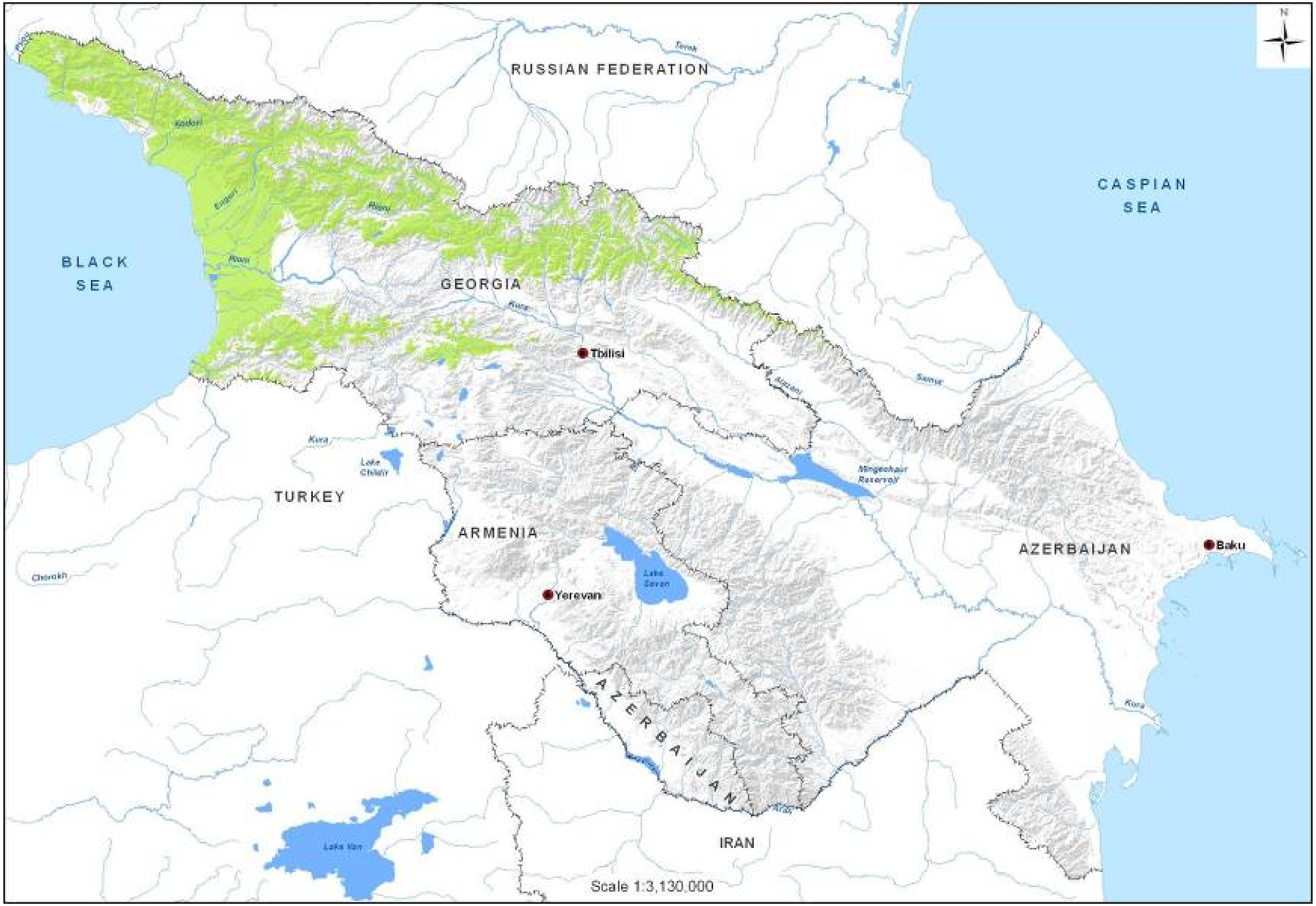

Fig. F13b: A2a model for Taxus

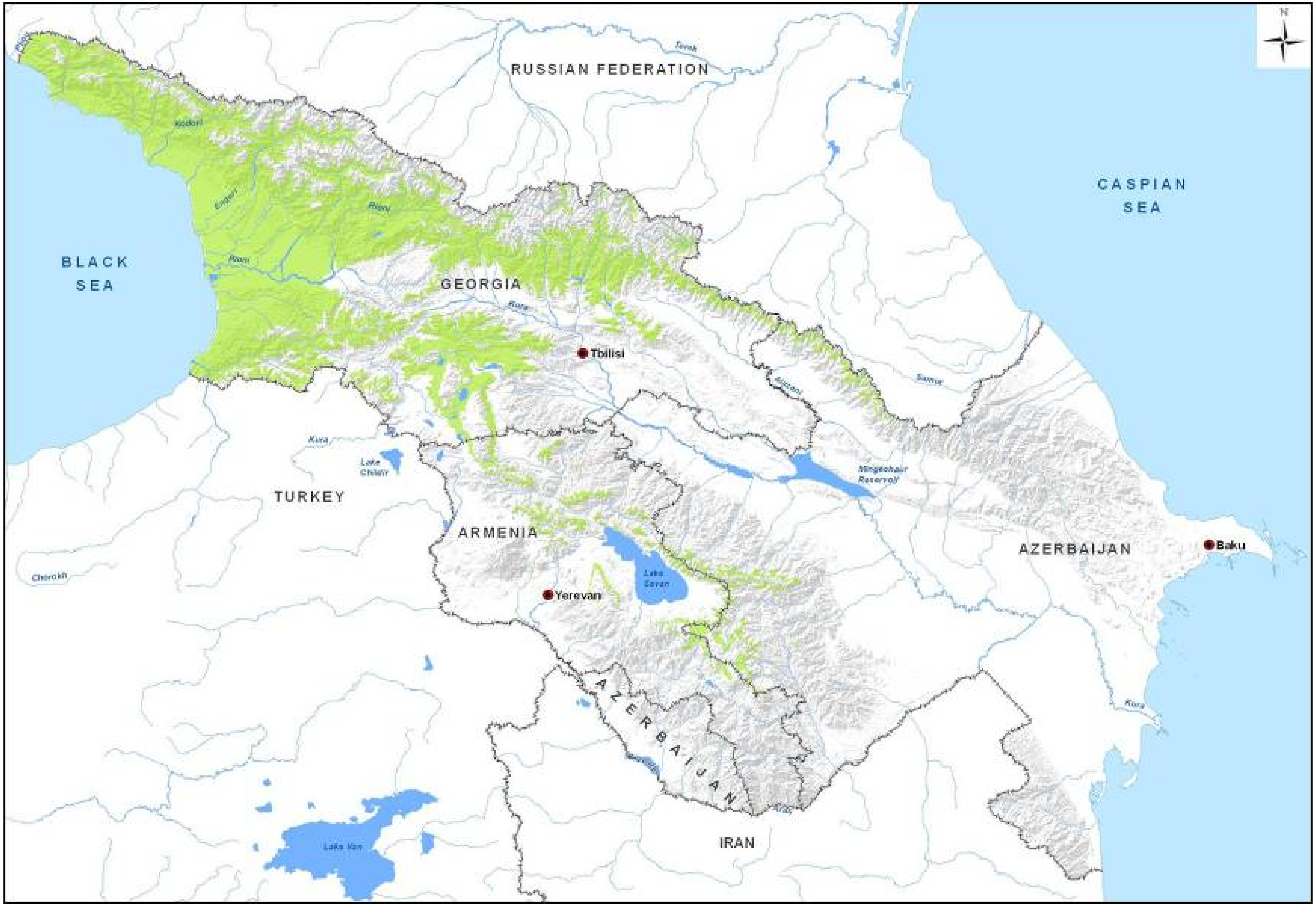

Fig. F13c: B2a model for Taxus

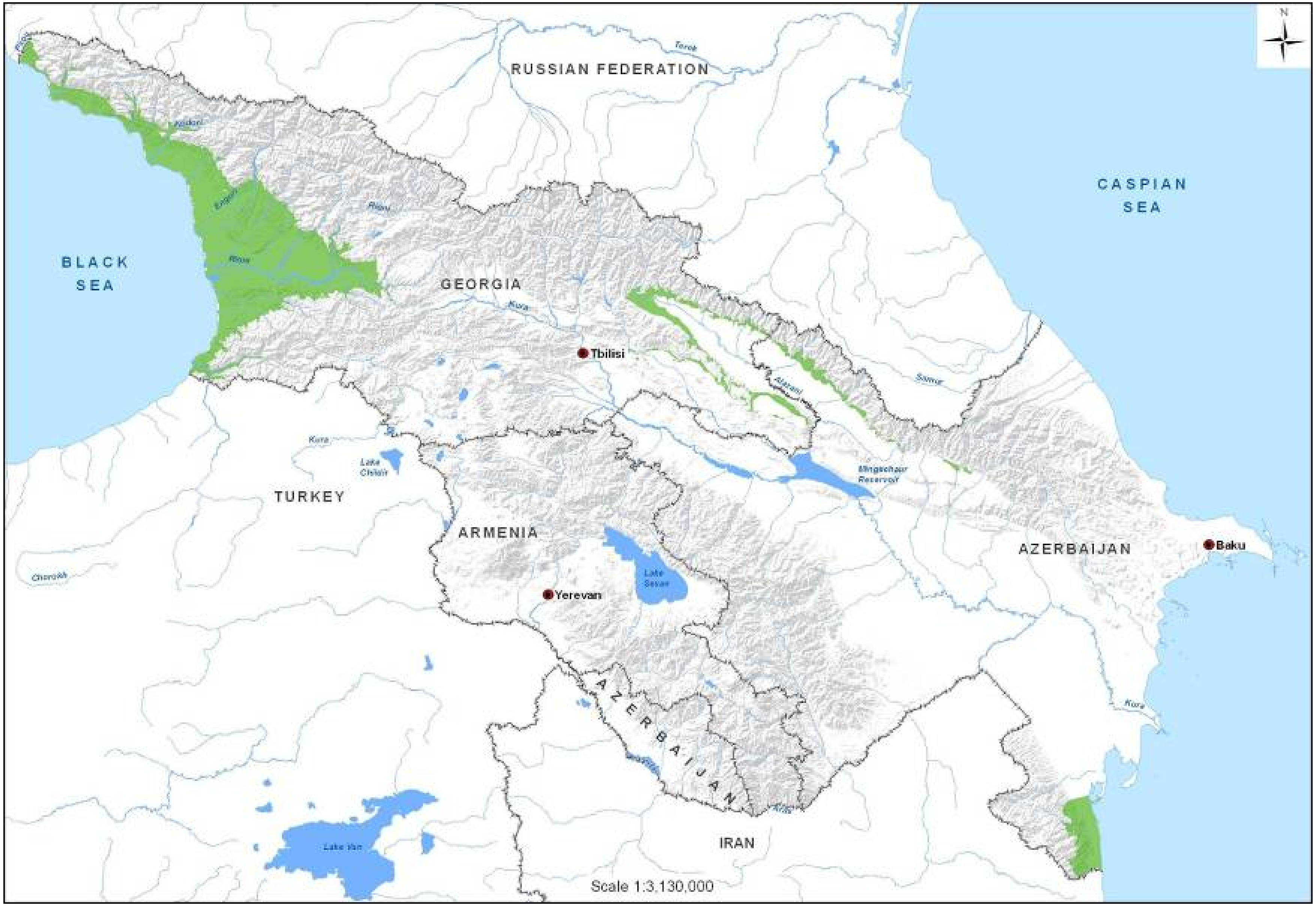

Fig. F14a: Modeled present for Zelkova

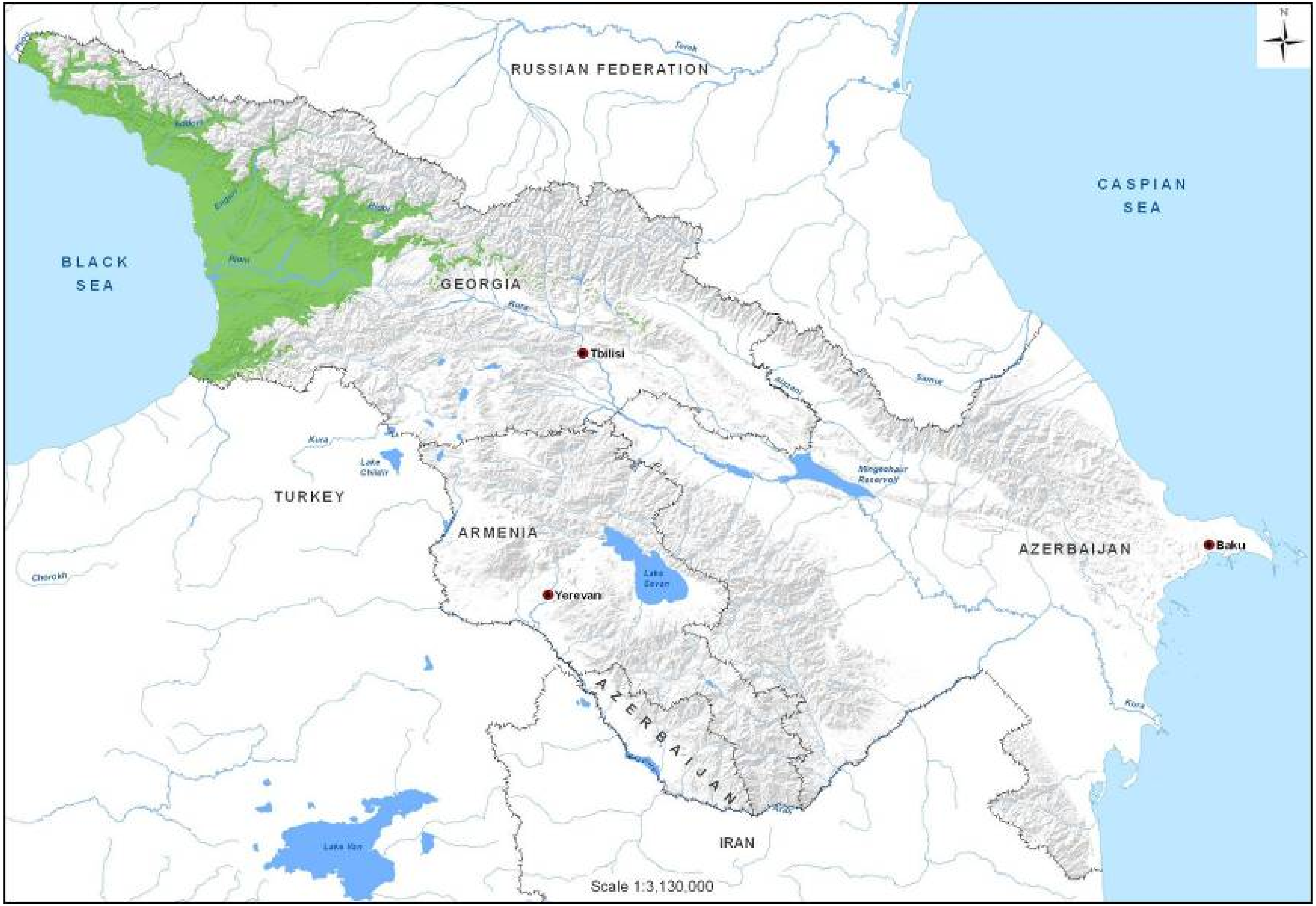

Fig. F14b: A2a model for Zelkova

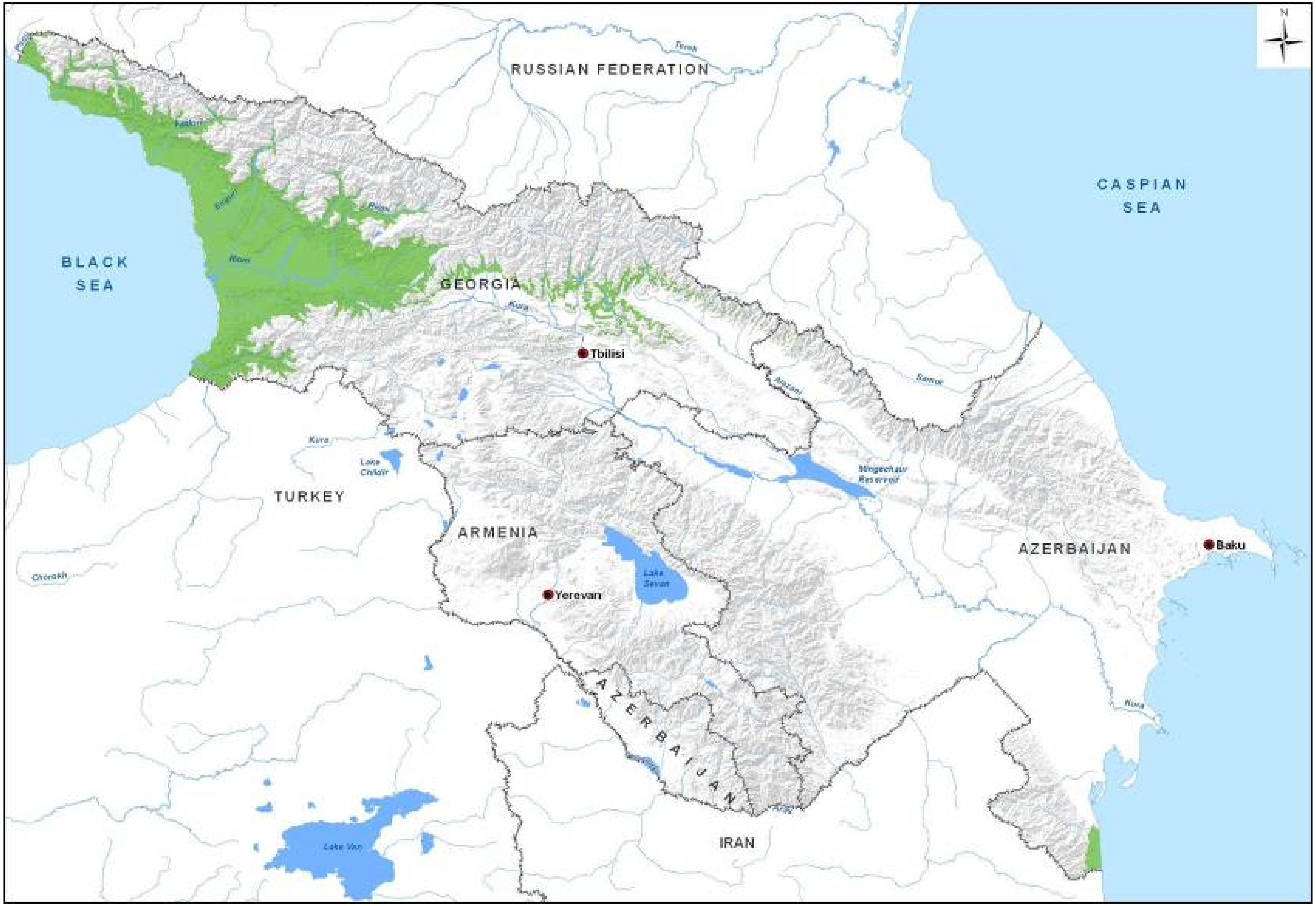

Fig. F14c: B2a model for Zelkova

Appendix G: Figures on impact of climate change based on A2a scenario

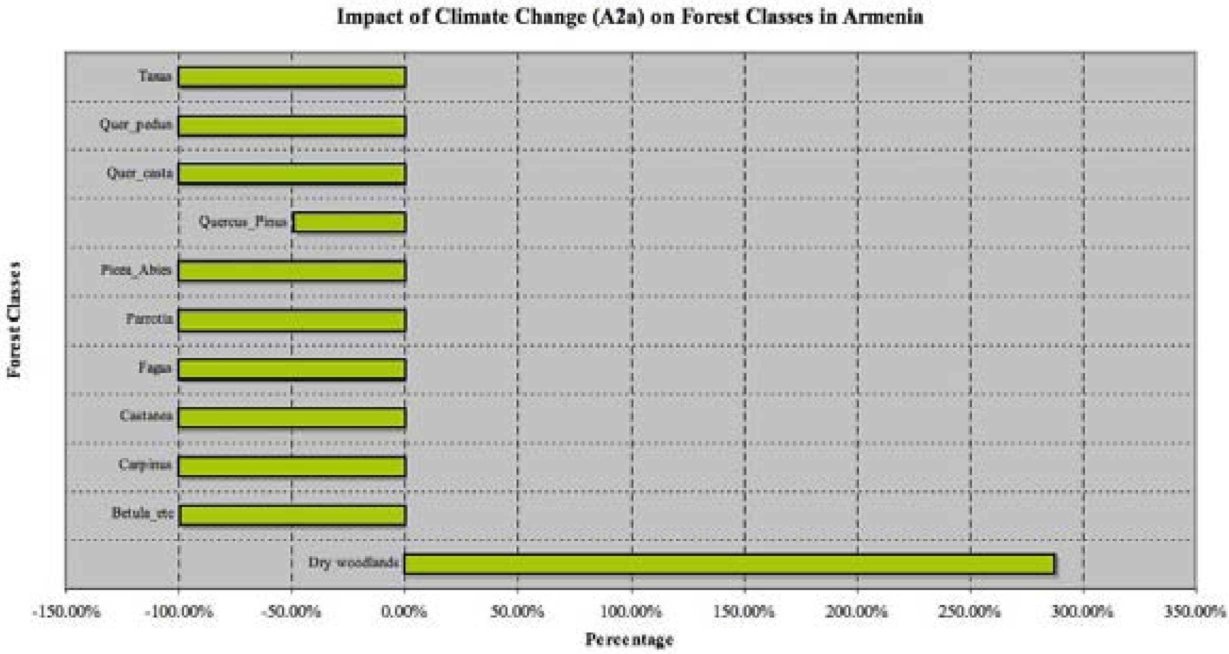

Fig. G1: Lost of forest classes in Armenia, based on values from table 17

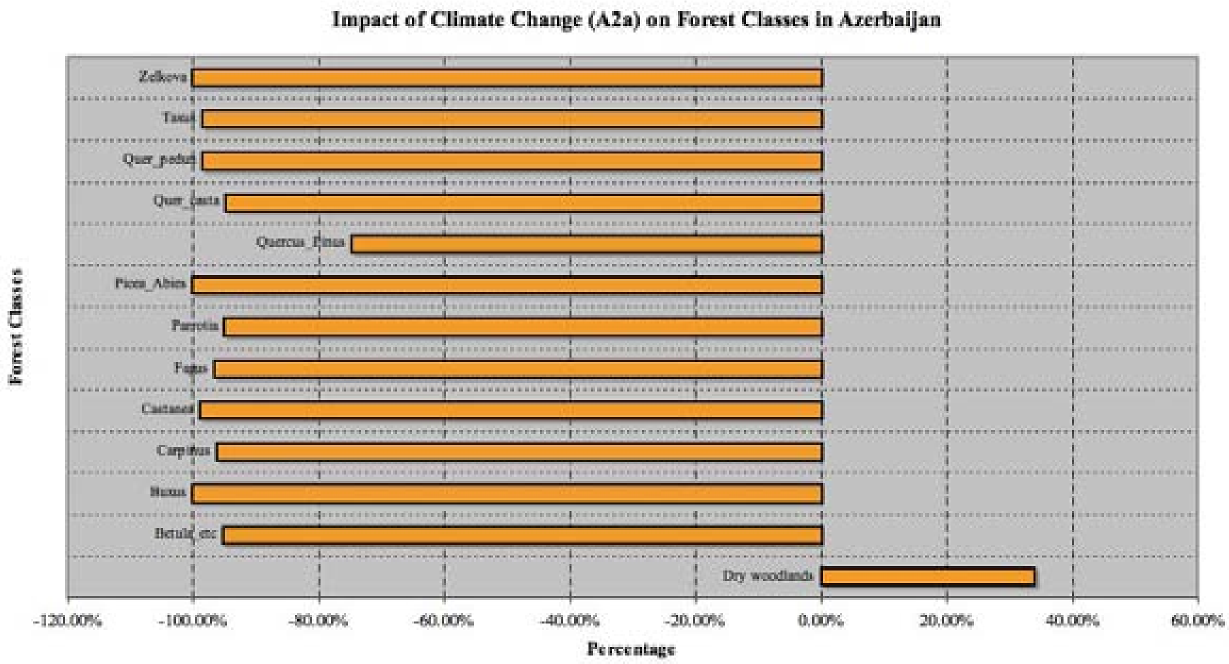

Fig. G2: Lost of forest classes in Azerbaijan, based on values from table 18

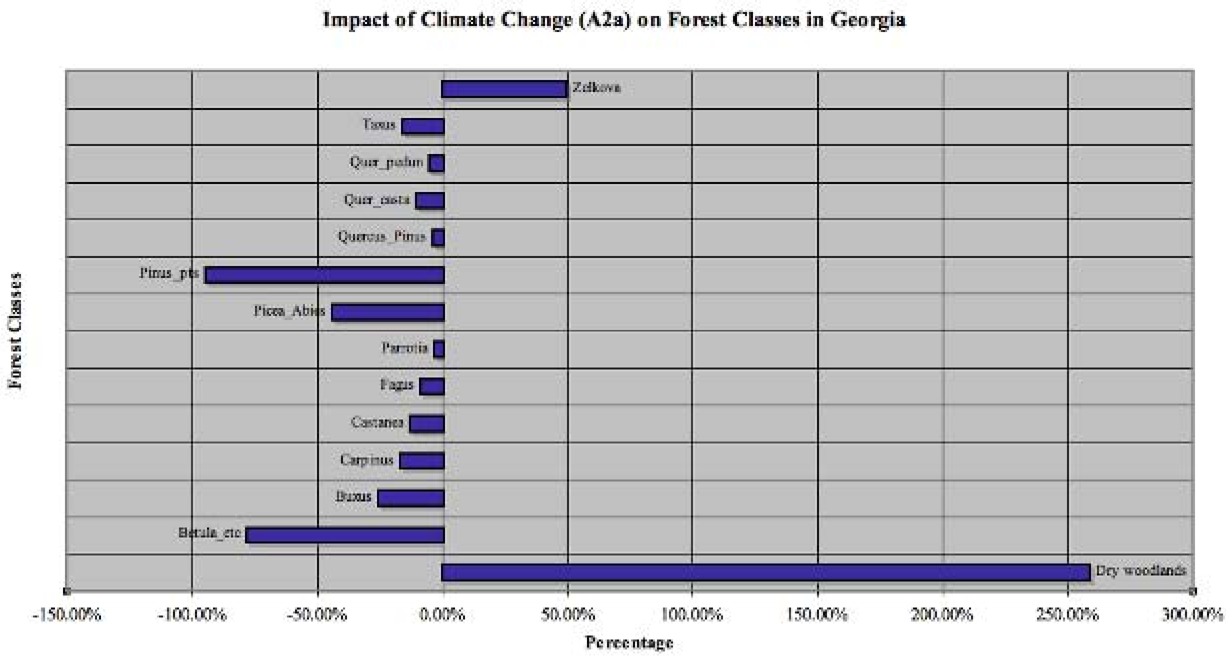

Fig. G3: Lost of forest classes in Georgia, based on values from table 19

Appendix H: Figures on impact of climate change based on B2a scenario

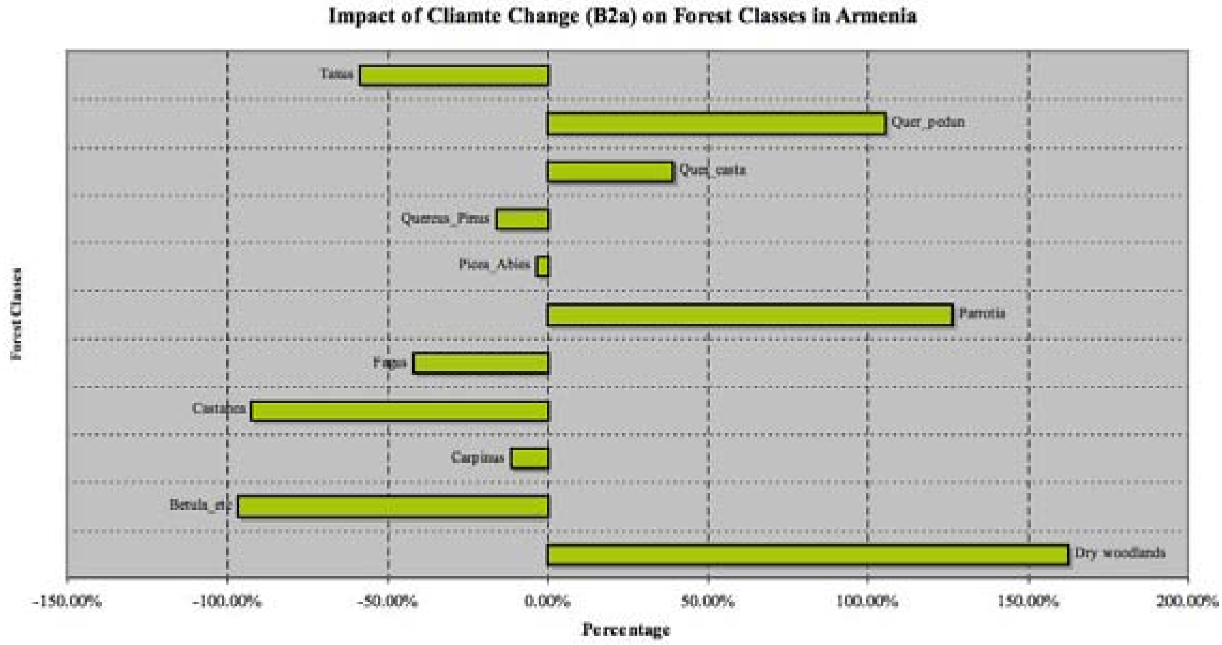

Fig. H1: Lost of forest classes in Armenia, based on values from table 21

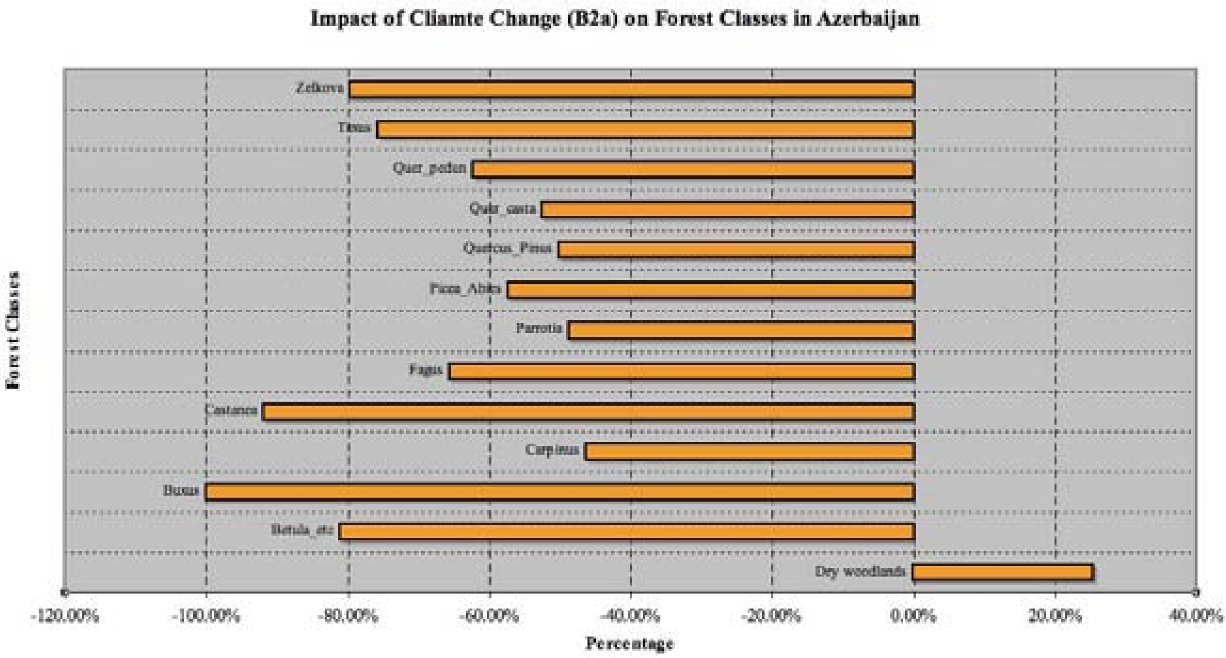

Fig. H2: Lost of forest classes in Azerbaijan, based on values from table 22

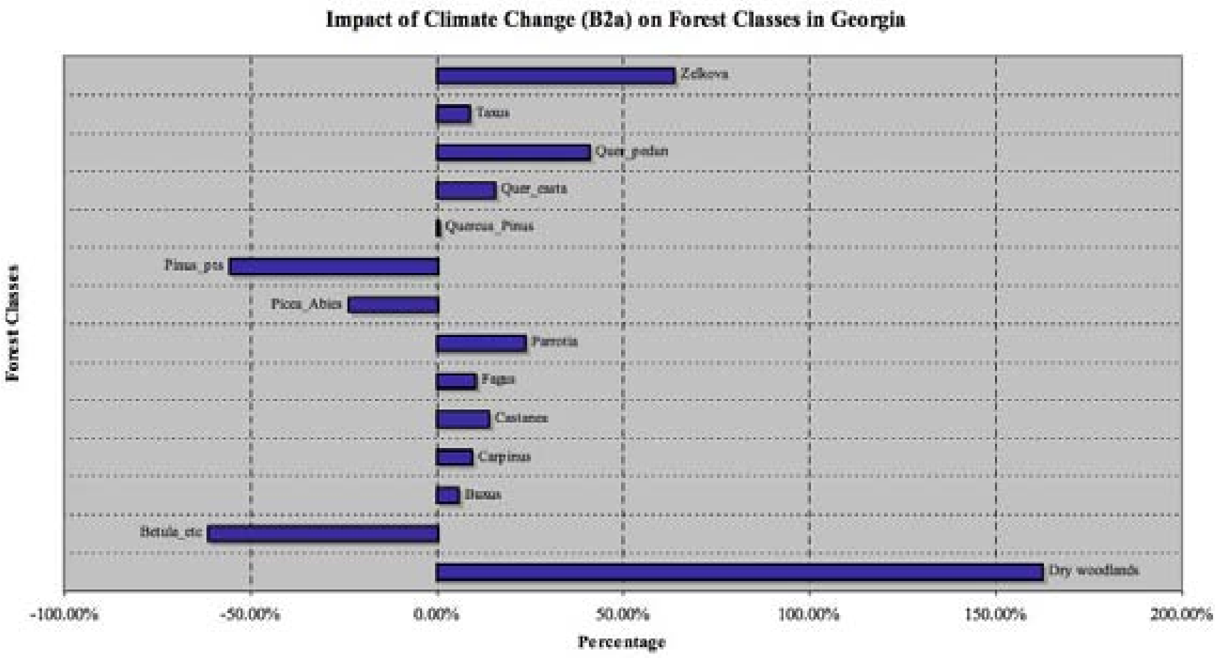

Fig. H3: Lost of forest classes in Georgia, based on values from table 23

Appendix I: Armenia-Difference between AFC and PFC according to bioclimatic regions

Table I1: Difference between forest types (AFC) and vegetation formations (PFC) for the East Caucasus bioclimatic region in Armenia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region East Caucasus			
		FT ha.	VF ha.	Lost ha.	Lost %
Beech	Fagus	94,305.7	286,702.0	-192,396.3	-67.11%
Birch_Poplar_Ash-tree	Betula	1,089.2	NDA	1,089.2	---
Caucasian pine	Pinus kochiana	739.2	NDA	739.2	---
Chestnut	Not Reflected	1.1	NDA	1.1	0.00%
Juniper_Pistachio_Hackberry	Quercus iberica & Juniperus	949.1	73,789.3	-72,840.2	-98.71%
Oak and other broad-leaved species + Hornbeam	Quercus macranthera + Q. macranthera subalpina	111,149.6	170,415.8	-59,266.1	-34.78%
Poplar_Willow_Mountain-valleys	Not Reflected	85.8	NDA	85.8	---
Poplar_Willow_Plains	Not Reflected	11.1	NDA	11.1	---
Total		**208,330.8**	**530,907.1**	**-322,576.3**	**-60.76%**

Table I2: Difference between forest types (AFC) and vegetation formations (PFC) for the South Uplands bioclimatic region in Armenia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region South Uplands			
		FT ha.	VF ha.	Lost ha.	Lost %
Beech	Fagus	0.0	15,535.6	-15,535.6	-100.00%
Birch_Poplar_Ash-tree	Betula	0.0	3,570.5	-3,570.5	-100.00%
Caucasian pine	Pinus kochiana	18.7	NDA	18.7	---
Juniper_Pistachio_Hackberry	Juniperus	4,227.4	22,475.2	-18,247.8	-81.19%
Oak and other broad-leaved species + Hornbeam	Quercus macranthera + Q. macranthera sub-alpina	4,942.6	133,717.7	-128,775.1	-96.30%
Poplar_Willow_Mountain-valleys	Not Reflected	94.8	NDA	94.8	---
Poplar_Willow_Plains	Not Reflected	46.9	NDA	46.9	---
Total		**9,330.5**	**175,298.9**	**-165,968.4**	**-94.68%**

Table I3: Difference between forest types (AFC) and vegetation formations (PFC) for the South Lesser Caucasus bioclimatic region in Armenia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		Southern Lesser Caucasus			
		FT ha.	VF ha.	Lost ha.	Lost %
Juniper_Pistachio_Hackberry	Dry mixed woodlands + Juniperus + Quercus iberica & juniperus	6,891.8	61,757.9	-54,866.1	-88.84%
Oak and other broad-leaved species + Hornbeam	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	62,028.5	130,569.8	-68,541.4	-52.49%
Poplar_Willow_Mountain-valleys	Not Reflected	55.0	NDA	55.0	---
Total		**68,975.3**	**192,327.7**	**-123,352.4**	**-64.14%**

Table I4: Difference between forest types (AFC) and vegetation formations (PFC) for the Dry Plains and Ridges bioclimatic region in Armenia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		Dry Plains and Ridges			
		FT ha.	VF ha.	Lost ha.	Lost %
Juniper_Pistachio_Hackberry	Quercus iberica & Juniperus	0.0	1,613.1	-1,613.1	-100.00%
Total		**0.0**	**1,613.1**	**-1,613.1**	**-100.00%**

Appendix J: Azerbaijan-Difference between AFC and PFC according to bioclimatic regions

Table J1: Difference between forest types (AFC) and vegetation formations (PFC) for the East Caucasus bioclimatic region in Azerbaijan

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region East Caucasus FT ha.	VF ha.	Lost ha.	Lost %
Beech	Fagus	265,984.4	625,317.1	-359,332.8	-57.46%
Birch_Poplar_Ash-tree	Betula	776.6	13,315.4	-12,538.8	-94.17%
Caucasian pine	Pinus kochiana	373.6	NDA	373.6	0.00%
Chestnut	Not Reflected	868.1	NDA	868.1	0.00%
Chestnut-leaved oak	Quercus castaneifolia	81.0*	NDA	81.0	0.00%
Flood plain oak + Poplar_willow_plains	Flood plain vegetation + Quercus pedunculiflora	43,041.0	365,187.6	-322,146.5	-88.21%
Juniper_Pistachio_Hackberry	Juniperus + Quercus iberica & Juniperus	760.9	166,038.5	-165,277.6	-99.54%
Oak and other broad-leaved species + Hornbeam	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	344,311.7	629,374.4	-285,062.7	-45.29%
Poplar_Willow (Mountain valleys)	Not Reflected	1,014.1	NDA	1,014.1	0.00%
Total		**657,211.3**	**1,799,233.0**	**-1,142,021.6**	**-63.47%**

Note: *This figure appears here because of differences in mapping scales and approaches to landscape composition between basic forestry maps and the Map of Natural Vegetation of Europe (Bohn et al., 2000/2003).

Table J2: Difference between forest types (AFC) and vegetation formations (PFC) for the South Uplands bioclimatic region in Azerbaijan

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region South Uplands FT ha.	VF ha.	Lost ha.	Lost %
Flood plain oak	Flood plain vegetation	0.0	921.7	-921.7	-100.00%
Oak and other broad-leaved species	Quercus macranthera	890.6	781.9	108.8	13.91%
Total		**890.6**	**1,703.5**	**-812.9**	**-47.72%**

Table J3: Difference between forest types (AFC) and vegetation formations (PFC) for the Southern Lesser Caucasus bioclimatic region in Azerbaijan

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		Southern Lesser Caucasus			
		FT ha.	VF ha.	Lost ha.	Lost %
Beech	Fagus	859.3	2,105.1	-1,245.8	-59.18%
Juniper_Pistachio_Hackberry	Dry mixed woodlands + Juniperus + Quercus iberica & juniperus	1,586.7	283,502.1	-281,915.4	-99.44%
Oak and other broad-leaved species + Hornbeam	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	102,428.5	146,279.9	-43,851.4	-29.98%
Total		**104,874.6**	**431,887.1**	**-327,012.5**	**-75.72%**

Table J4: Difference between forest types (AFC) and vegetation formations (PFC) for the Dry Plains and Ridges bioclimatic region in Azerbaijan

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		Dry Plains and Ridges			
		FT ha.	VF ha.	Lost ha.	Lost %
Beech	Fagus	0.0	5,448.3	-5,448.3	-100.00%
Eldar pine	Pinus eldarica	187.3	2,287.6	-2,100.3	-91.81%
Flood plain oak + Poplar_Willow_Plains	Flood plain veg. + Quercus pedunculiflora	20,630.8	126,694.8	-106,064.0	-83.72%
Juniper_Pistachio_Hackberry	Juniperus + Quercus iberica & Juniperus	11,627.2	139,715.4	-128,088.1	-91.68%
Oak and other broad-leaved species + Hornbeam	Quercus iberica	2,698.0	39,758.4	-37,060.4	-93.21%
Total		**35,143.4**	**313,904.4**	**-278,761.0**	**-88.80%**

Table J5: Difference between forest types (AFC) and vegetation formations (PFC) for the Hyrcan bioclimatic region in Azerbaijan

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		Hyrcan			
		FT ha.	VF ha.	Lost ha.	Lost %
Beech	Fagus + Fagus Hyrcanian	30,852.3	92,770.7	-61,918.4	-66.74%
Chestnut-leaved oak + Iron-tree	Quercus castaneifolia	77,426.8	198,467.0	-121,040.2	-60.99%
Oak and other broad-leaved species + Hornbeam	Quercus iberica Hyrcanian + Q. macranthera + Q. macranthera sub-alpina	32,675.1	38,882.8	-6,207.7	-15.97%
Total		**140,954.2**	**330,120.5**	**-189,166.3**	**-57.30%**

Appendix K: Georgia-Difference between AFC and PFC according to bioclimatic regions

Table K1: Difference between forest types (AFC) and vegetation formations (PFC) for the Colchic bioclimatic region in Georgia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region Colchic			
		FT ha.	VF ha.	Lost ha.	Lost %
Alder_Poplar_Willow (Colchic)	Alnus	96,055.3	76,026.0	20,029.3	26.35%
Beech	Fagus + Fagus Colchic	799,964.7	538,117.4	261,847.3	48.66%
Birch_Poplar_Ash-tree	Betula	45,077.9	517,173.0	-472,095.2	-91.28%
Caucasian pine	Pinus kochiana	21,665.5	24,932.0	-3,266.4	-13.10%
Chestnut + Buxus + Zelkova	Colchic polydominant	163,899.1	664,711.4	-500,812.2	-75.34%
Dark conifers	Picea-Abies + Picea-Abies Colchic	275,527.5	603,402.5	-327,875.1	-54.34%
Oak and other broad-leaved species + Hornbeam	Quercus iberica + Q. iberica Colchic	185,874.3	461,325.7	-275,451.5	-59.71%
Pitsundian pine	Pinus pityusa	1,855.2	3,362.7	-1,507.5	-44.83%
Poplar_Willow_Mountain-valleys	Not Reflected	58,232.6	NDA	58,232.6	---
Poplar _Willow_Plains	Not Reflected	1,227.4	NDA	1,227.4	---
Total		**1,649,379.5**	**2,889,050.7**	**-1,239,671.2**	**-42.91%**

Table K2: Difference between forest types (AFC) and vegetation formations (PFC) for the East Caucasus bioclimatic region in Georgia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region East Caucasus			
		FT ha.	VF ha.	Lost ha.	Lost %
Beech	Fagus + Fagus Colchic	613,517.1	617,054.5	-3,537.5	-0.57%
Birch_Poplar_Ash-tree	Betula	60,730.3	401,054.7	-340,324.4	-84.86%
Caucasian pine	Pinus kochiana	78,629.7	114,734.6	-36,104.9	-31.47%
Chestnut + Zelkova	Not Reflected	139.5	NDA	139.5	0.00%
Dark conifers	Picea-Abies + Picea-Abies Colchic	116,904.3	114,572.1	2,332.3	2.04%
Flood plain oak + Poplar_Willow_Plains	Flood plain vegetation + Quercus pedunculiflora	14,123.2	190,506.0	-176,382.8	-92.59%
Juniper_Pistachio_Hackberry	Juniperus + Quercus iberica & Juniperus	3,246.2	77,775.7	-74,529.6	-95.83%
Oak and other broad-leaved species + Hornbeam	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	300,886.2	757,698.6	-456,812.4	-60.29%

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		East Caucasus			
		FT ha.	VF ha.	Lost ha.	Lost %
Poplar_Willow_Mountain-valleys	Not Reflected	12,120.5	NDA	12,120.5	0.00%
Taxus	Not Reflected	230.2	NDA	230.2	0.00%
Total		1,200,297.0	2,273,396.3	-1,073,099.3	-47.20%

Table K3: Difference between forest types (AFC) and vegetation formations (PFC) for the South Uplands bioclimatic region in Georgia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		South Uplands			
		FT ha.	VF ha.	Lost ha.	Lost %
Birch_Poplar_Ash-tree	Betula	339.1	14,865.7	-14,526.5	-97.72%
Caucasian pine	Pinus kochiana	10,266.8	16,266.1	-5,999.3	-36.88%
Oak and other broad-leaved species	Quercus iberica + Q. macranthera + Q. macranthera sub-alpina	298.3	11,105.9	-10,807.6	-97.31%
Poplar_Willow (Mountain valleys)	Not Reflected	253.0	NDA	253.0	---
Total		**11,157.2**	**42,237.7**	**-31,080.5**	**-73.58%**

Table K4: Difference between forest types (AFC) and vegetation formations (PFC) for the Dry Plains and Ridges bioclimatic region in Georgia

Forest Types (FT)	Vegetation Formation (VF)	Bioclimatic Region			
		Dry Plains and Ridges			
		FT ha.	VF ha.	Lost ha.	Lost %
Caucasian pine	Pinus kochiana	326.7	NDA	326.7	---
Eldar pine	Pinus eldarica	0.0	3,532.2	-3,532.2	-100.00%
Flood plain oak + Poplar_Willow_Plains	Flood plain vegetation	0.0	65,916.4	-65,916.4	-100.00%
Juniper_Pistachio_Hackberry	Juniperus + Quercus iberica & Juniperus	3,704.7	83,763.1	-80,058.5	-95.58%
Oak and other broad-leaved species + Hornbeam	Quercus iberica	11,290.7	6,652.2	4,638.5	69.73%
Poplar_Willow_Plains	Not Reflected	3,378.7	NDA	3,378.7	---
Total		**18,700.8**	**159,864.0**	**-141,163.2**	**-88.30%**