MINISTRY OF ENVIRONMENT AND TOURISM

GOVERNMENT OF MONGOLIA

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MULTIPURPOSE NATIONAL FOREST INVENTORY MONGOLIA 2014-2017

BRIEF REPORT

Version No. 1.0
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Financed by:
Mongolian Ministry of Environment and Tourism in collaboration with the German Ministry for Economic Cooperation and Development
Printed and distributed by:
Mongolian Ministry of Environment and Tourism, Ulaanbaatar, Mongolia, 10 December 2016
Citation reference:
Mongolian Ministry of Environment and Tourism, 2018. *Brief on Multipurpose National Forest Inventory, Mongolia 2014-2017*. Ulaanbaatar. Ministry of Environment and Tourism.

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FOREWORD

The first nationwide forest inventory in Mongolia was carried out in 1956, i.e. 60 years ago. In terms of objective, scope and methodology, the recently conducted Multipurpose National Forest Inventory was a comprehensive measure, involving multiple stakeholders, as compared to the previous inventories.

As a signatory to the UN Framework Convention on Climate Change and a partner country of UN-REDD and REDD+ since 2012, Mongolia is required to report the national forest reference emission level, estimated through internationally standardised methodologies. In this context the multipurpose national forest inventory was successfully implemented over the Mongolian boreal forest, with support of Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

The reporting to UNFCCC of forest reference emission level, derived from the National Forest Inventory under the guidance of the Intergovernmental Panel on Climate Change, enables Mongolia to engage in carbon trading and may through this mechanism receive result based payments via REDD+ program for undertaking actions related to reduced emissions from deforestation and forest degradation and enhanced forest carbon stocks.

NFI facts indicate that Mongolian boreal forests are over-aged, under-stocked and under-utilized, which are the consequences of long term forest protection policy. These results provide an opportunity to ensure a transition from current demand driven forestry to sustainable forestry while conserving ecosystem equilibrium, i.e. State Policy on Forest shall be changed in Mongolia.

As a result of the GIZ project, “REDD+ National Forest Inventory in Mongolia“, which supported field inventory method development, capacity building program, inventory tools procurement, the national technical potentials and human capacities were built to maintain and develop the national forest inventory program further.

On behalf of the Mongolian Government and personally, I would like to acknowledge the strong support of the German Government, especially officers and international experts of GIZ programme “Biodiversity and Adaptation of Key Forest Ecosystems to Climate Change II“ for their provision of management and consultancy, to national experts and forest engineers for their performances under extreme natural conditions.

MONGOLIAN PARLIAMENT MEMBER, GOVERNMENT MEMBER,
MINISTER OF ENVIRONMENT AND TOURISM D. OYUNKHOROL

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ACRONYMS AND ABBREVIATIONS

AMSL	Above Mean Sea Level
BMZ	Federal Ministry of Economic Cooperation and Development, Germany
CCPIU	Climate Change Project Implementation Unit, at the Nature Conservation Fund, MET
CET	Collect Earth Tool
DB	Database
FAO	Food and Agriculture Organization of the United Nations
FRDC	Forest Research and Development Centre
FUG	Forest User Group
DFS	German Forest Service
GEF	Global Environmental Facility
GIZ	German Federal Enterprise for International Cooperation
IGEB	Institute of General and Experimental Biology
IRIMHE	Information and Research Institute of Meteorology, Hydrology and Environment
MAS	Mongolian Academy of Science
MET	Ministry of Environment and Tourism
MS Access	Microsoft Access database software
MSUA	Mongolian State University of Agriculture
MUST	Mongolian University of Science and Technology
NAMEM	National Agency for Meteorology and Environmental Monitoring
NFI	National Forest Inventory
NUM	National University of Mongolia
QGIS	Quantum Geographic Information System (open source GIS software)
RS	Remote Sensing
RSS	Remote Sensing Survey
SC	Steering Committee
SFM	Sustainable Forest Management
UN-REDD	United Nations programme for Reducing carbon Emissions from Deforestation and Degradation of forests

SUMMARY

Under the overall guidance of the Forest Policy and Coordination Department, at the Ministry of Environment and Tourism, the Multipurpose National Forest Inventory (NFI) was implemented by the Forest Research and Development Centre in collaboration with Mongolia's main forestry institutions, universities and research organisations, as well as with international experts.

The Multipurpose NFI, 2014-2017, is the first of its kind in Mongolia, building on a national-level sample-based forest inventory, applying standardised methods for field measurements on permanent field plots established for long-term monitoring of the multiple functions of Mongolia's boreal forest.

The Multipurpose NFI was established to cover the need of reliable and accurate information on the multiple functions and benefits of Mongolia's forestry resources for forest policy development, and it is compatible with the international reporting requirements for REDD+[1].

A thorough capacity development program involving more than 100 national experts has been implemented through training workshops and on-the-job training, to strengthen the institutional capacities in data collection, quality assurance and data management.

The NFI findings are the results of remote sensing surveys and a systematic field inventory of 4,367 clusters of field plots, where 255,545 trees and 12,707 tree regeneration were inventoried, and where the forest functions and environmental conditions were assessed. Among the main findings are the Total Boreal Forest Area, 11.3 million hectares, of which 9.5 million hectares are stocked with an Average Growing Stock Volume of 114 m^3 per hectare, and 1.8 million hectares of Temporarily Un-Stocked Boreal Forest Area, resulting in a total Growing Stock Volume of 1 million m^3. The NFI results indicate that Mongolia's boreal forests are under-stocked (less than 50 percent of optimal production capacity), under-utilized (small-diameter trees and a big proportion of dead-wood) and economically over-aged (about 30 percent of the harvestable growing stock tree volume is above economically viable age).

The long-term objective of multipurpose NFI is to promote sustainable management of forests and tree resources in Mongolia, founded on policies that integrate and balance relevant environmental and social aspects of forestry. Sustainable management aims at enhancing the social, economic and environmental functions of forests and trees on the basis of better knowledge and at improving the contribution of these resources to the national

[1] Reducing Emissions from Deforestation and forest Degradation

economy. The NFI findings help identify priority areas, and are of great use for the development of the forestry sector and to evaluate forestry policies/strategies, in order to ensure a coherent legislation.

The main outputs (findings and data) of the multipurpose NFI are published at the online web portal www.forest-atlas.mn, where also related documentation and interactive maps can be found.

1. INTRODUCTION TO MONGOLIA'S BOREAL FOREST

Mongolia covers an area of 1.565 million km^2 and it is situated in Central Asia between latitudes 41°N to 52°N (~1,200 km) and longitudes from 88°E to 120°E (~2,400 km), and is bordered by Russia to the north, and by to the south.

1.1. CLIMATE

The continental location of Mongolia, far from the influences of oceans, together with its rather high altitude determines its climatic conditions. Great weather contrasts occur between winter and summer as well as between day and night. Going from north to south in Mongolia the average temperature increases. July is the warmest month with annual mean temperatures up to 15˚C in the north and 20 to 30˚C in the south. In January the monthly average is –15˚C with minimum temperatures that can drop below –50˚C (HILBIG 1995). The mean annual precipitation decreases from 600 mm in the northern regions down to below 25 mm in the southern deserts.

1.2. TOPOGRAPHY AND SOIL

Mongolia is located at 1,000-2,500 m above mean sea level (amsl). Both aspect and slope tend to be very significant for the distribution of Mongolia's boreal forests. Slope influences water run-off, and aspect reflects the exposition to the sun and thereby the evapotranspiration and the temperature fluctuation between night and day. More than 80 percent of the forest is found on slopes ranging from 20 % (lower slope) to 28 % (upper slope), and almost 70 percent is located at northern expositions (NW-N-NE).

Soil texture defines drainage capacity and access to water during dry seasons. Mongolia's boreal forests are mostly found on soil with medium coarse texture (sandy loam or loam).

1.3. VEGETATION ZONES AND TREE SPECIES

Vegetation zones follow precipitation patterns and Mongolia's forests can roughly be divided into Boreal forest in the north and Saxaul forest in the south. The boreal forest "taiga" is classified into "dark taiga" and "light taiga". Dark taiga consists of shade tolerant tree species such as Siberian pine (*Pinus sibirica*), Siberian spruce (*Picea obovata*) and Siberian fir (*Abies sibirica*). Light taiga, consists of light-demanding species such as Siberian larch (*Larix sibirica*), Scots pine (*Pinus sylvestris*), Asian white birch (*Betula platyphylla*) and Aspen (*Populus tremula*). Towards the south the forests get scattered in a forest steppe zone until they disappear with an annual precipitation under 300 mm (YUNATOV 1950).

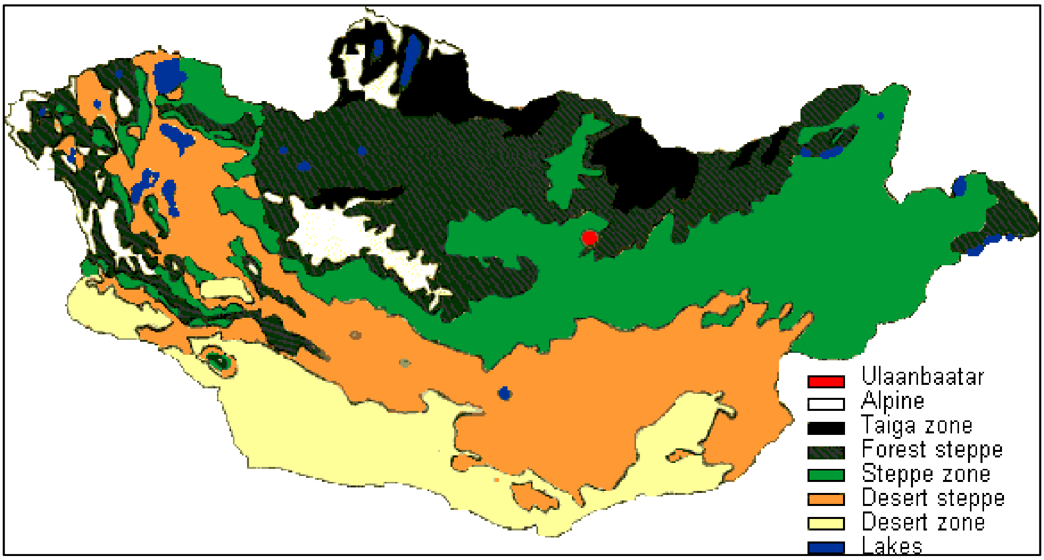

***Figure 1**: Vegetation zones in Mongolia*

2. METHODOLOGY

2.1. FOREST DEFINITION

The Multipurpose NFI embrace all boreal forest, applying a definition of forest that includes a) land covering at least 1 ha, b) with at least 10% tree canopy coverage, where trees are defined as woody perennial plants with a single main stem, or in the case of coppice with several stems, having a more or less definite crown, and which can reach a height of more than 5 meters at maturity on the site where they grow. Forest also include areas that are temporarily (<10 years) un-stocked due to natural disasters (forest fire, pest outbreak, windthrow *etc*.), or forest management practices, but excludes any land that is predominantly under agriculture or urban land use.

2.2. ASSESSMENT AND MAPPING OF BOREAL FOREST AREA

The boreal forest zone was defined by existing vegetation zones maps, which were adapted by local experts to better reflect the actual boreal forest regions of Mongolia. As a first step in defining the geographical limitation of the field survey, a rough “Forest Mask 2013” (Sonntag 2014) was created based on semi-automatic classification (QGIS plugin) of satellite data (Landsat 8 ETM from 2013) to identify growing forest biomass, i.e. stocked boreal forest, while the area of the temporarily un-stocked boreal forest (i.e. forest area non-detectable in RS data) was identified through a comparison of historical forest information from the archive of the Forest Research and Development Centre (FRDC) (i.e. forest taxation data from 2007 and onwards) and the stocked boreal forest map 2015 (Bat-ulzii, 2018).

The extent of the stocked boreal forest was carefully mapped using R-studio and QGIS software, interpreting Landsat 8 ETM data from 2015 (Schultz et al., 2016). The size of the boreal forest area was defined through a sampling-based remote sensing (RS) survey (CCPIU 2018), where on-screen interpretation of more than 123 000 RS plots were interpreted using the Collect Earth Tool (Open Foris software) and recent (2015-2016) very-high resolution RS data (Bing Map data) available in Google Earth.

2.3. SAMPLING DESIGN

The field inventory sampling design was developed to generate information on the forest characteristics and on the environmental conditions. Systematic sampling design with a total of 4367 sampling units allocated within the boreal forest (Ludwig et al. 2014 and Bat-ulzii 2018). Aligned square sampling grids were allocated throughout the boreal forest areas, with a national-wide grid of 9 km x 9 km interval, and intensified sampling grids of 4 km x 4 km, or 1.5 km x 1.5 km intervals in the major forest regions.

2.4. SAMPLING UNIT DESIGN

Each sampling unit is composed by a cluster of 3 sample plots (Ludwig et al. 2014), to cover the various forest characteristics on the measurement site (Fig.3b). The centres of sample plots are distanced by 100-112 m from each other in a triangle, where the centre of the southern plot defines the sample unit coordinates (Fig. 3c).

Each sample plot is composed by nested plots with radii of 20 m, 12 m, 6 m and 2 m (Figure 2d); on which different measurements and assessments were carried out as indicated in Table 1.

Table 1: Plot size and corresponding measurements and observations, carried out in the NFI Field Inventory

Plot radius	Measurements and observations
2 meter	Regeneration counted at 3 height classes; a) 10 – 50 cm b) 50 – 150 cm c) >150 cm with DBH < 6 cm.
6 meter	Measurement of standing trees with DBH 6 – 14.9 cm, Red-listed species and other plant species Vegetation coverage, Dead Wood Soil assessment
12 meter	Measurements of standing trees with DBH of 15 – 29.9 cm
20 meter	Measurements of standing trees with DBH ≥30 cm Assessments on Slope and Landscape Stand Structure Forest Fire, grazing, erosion Protection status

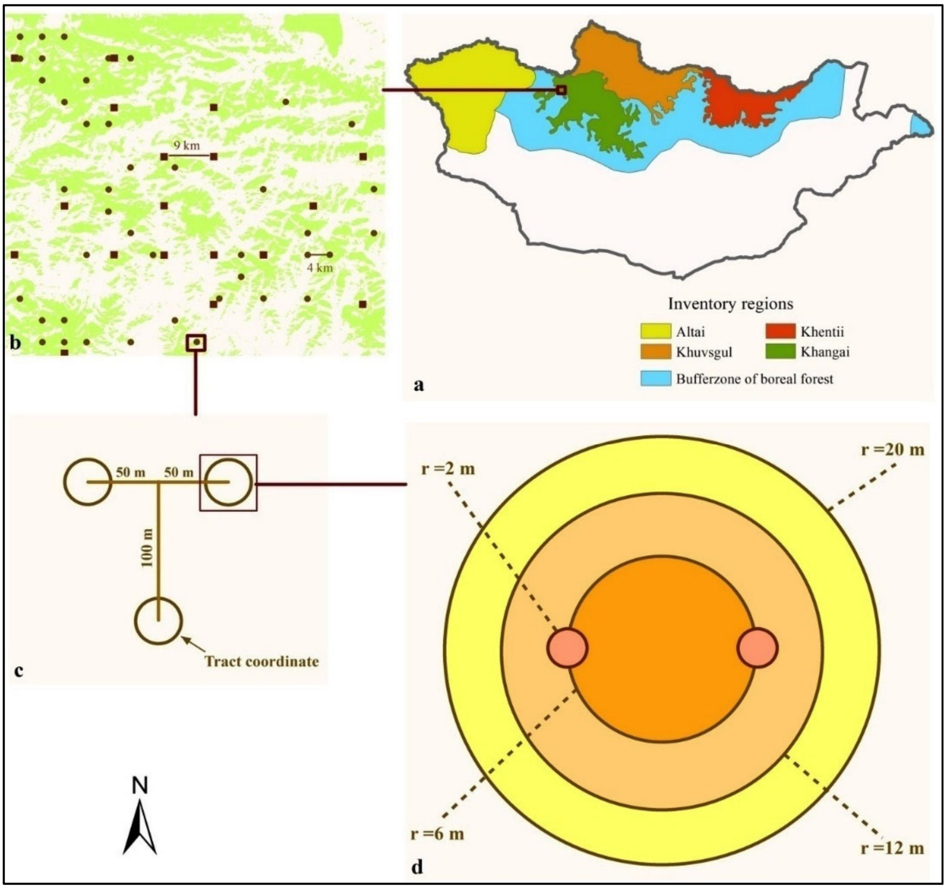

***Figure 2a-d**: Layout of sampling unit. a) NFI inventory regions over the Mongolian boreal forest. b) Spacing of sampling units in forest area. c) Sampling unit - cluster of sample plots. d) Sample plot design – nested circular plots*

2.5. PREPARATIONS AND TRAINING OF FIELD SURVEY TEAMS AND CONTROL MEASUREMENT TEAMS

National and international experts together developed the methodologies for the NFI field data collection, which are specified in a Manual for field data collection (Ludwig, R. 2012 and 2013), and 22 field survey teams, five control measurement teams, and key staff at FRDC and MET were trained in the NFI methodologies (Ludwig, R. 2014a and 2014b).

2.6. FIELD INVENTORY AND CONTROL MEASUREMENTS

The main part of the field data collection was carried out during 2014. A few field plots were inventoried in 2015, and in 2017 field plots were inventoried in temporarily un-stocked boreal forest. Totally 30 field survey teams from 9 forest inventory companies were employed in the field data collection.

Figure 3: Field measurement of tree breast-height diameter (left) Photo x: Field measurement of fallen dead wood (right)

The field survey teams established the permanent field plots and collected field data through measurements and observation, which were recorded on paper forms, and later encoded into an MS Access based database application (Ludwig, R. 2014b).

Control measurements were carried out on ten percent of the field plots by qualified staff from universities and research organisations (NUM, MUST, MSUA, IGEB and IGGE). On 350 of the control measured clusters the control teams also collected 770 soil and litter samples for forest carbon pool assessment, and on 210 of the clusters 6300 tree bore cores were collected for tree growth assessment.

2.7. METHODOLOGIES APPLIED TO RESEARCH STUDIES

The Multipurpose National Forest Inventory provided good opportunities for further scientific research and several studies have been conducted. Results from some of these studies are presented in Chapter 4 and detailed information on methods used in the research can be found in their respective publications.

3. MAIN NFI FINDINGS

3.1. NATIONAL-LEVEL FINDINGS

The total boreal forest area in 2017 is estimated at 11.3 million hectares, of which 9.5 million hectares are stocked forest (i.e. ≥40% tree canopy cover) with an average growing stock (GS) volume of 114 m^3/ha, which is equivalent to a total GS volume of more than 1 billion m^3. 1.8 million hectares are temporarily un-stocked (i.e. <40% tree canopy cover and not detectable in Landsat 8 ETM data) due to natural hazards like wild fire, pest outbreaks and drought, or due to forest management practices like logging.

Siberian Larch is the most dominant tree species in Mongolia’s boreal forest, and it represents 92 m^3/ha, or 81 % of the growing stock volume. Second dominant tree species is the Siberian Pine with 7.6 m^3/ha (6.7 %), followed by Asian White Birch, 7.3 m^3/ha (6.4 %), and Scots Pine, 5.6 m^3/ha (4.9 %). The other tree species all together represent less than 1.5 percent of the growing stock volume. Average stem density for small-sized trees (DBH 6-15 cm) is 339 stems/ha, for medium-sized trees (DBH 15-30 cm), 168 stems/ha, and for big-sized trees (DBH >30 cm) 53 stems/ha. Tree basal area (BA) is dominated by Siberian Larch with an average BA of 12.5 m^2/ha. Asian White Birch comes second with a BA of 1.4 m^2/ha, followed by Siberian Pine and Scots Pine, 1.1 m^2/ha and 0.7 m^2/ha, respectively.

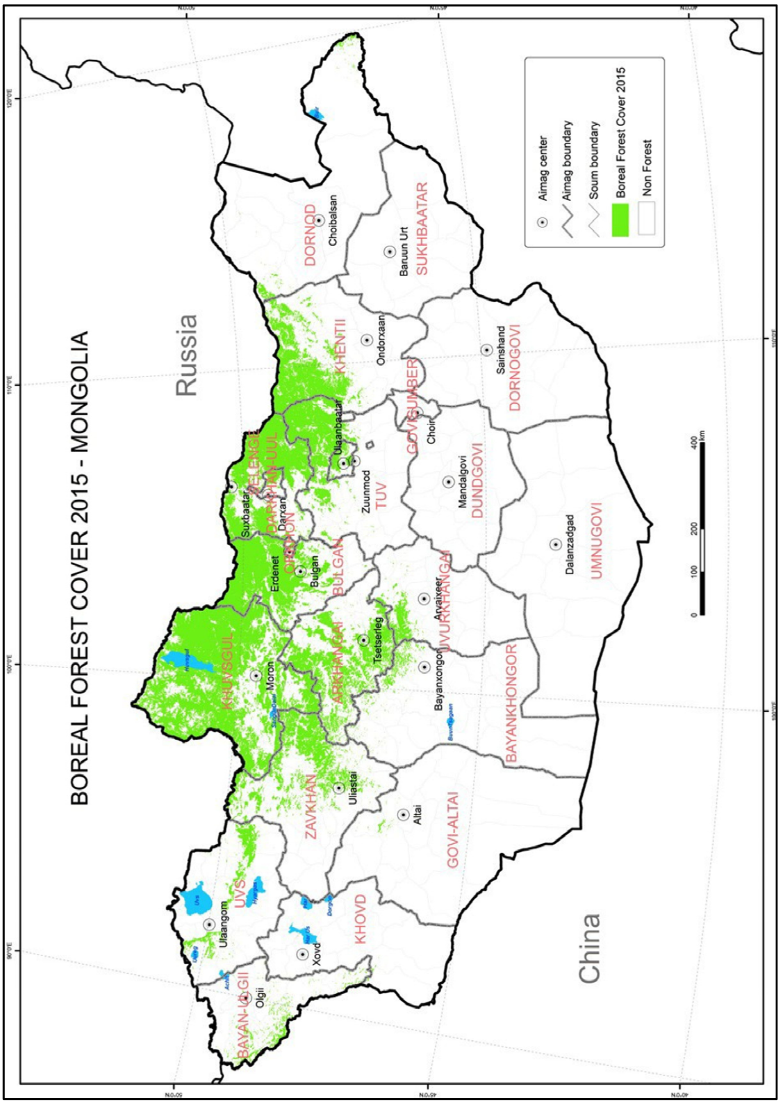

Figure 4: ***Forest Cover Map 2015 - Geographic distribution of Mongolian Boreal Forest***

3.2. BOREAL FOREST BY INVENTORY REGION

3.2.1. BOREAL FOREST IN THE ALTAI REGION

The Altai region is located western Mongolia, and it is the smallest of the four boreal forest regions, ??? million hectares (0.2 Mha stocked). The region has a wide altitudinal variation (1000 - 4000m) with a variety of environmental conditions, and the forests in this region are relatively open and have a comparatively low growing stock density, 74.1 m³/ha, very dominated by Siberian Larch (95.1%) and with some presence of Siberian Spruce. Shrubby vegetation, represented by species like the Net-leaved Willow (*Salix reticulata*) and the Shrubby Birch (*Betula humilis*), is more present in this region than in others.

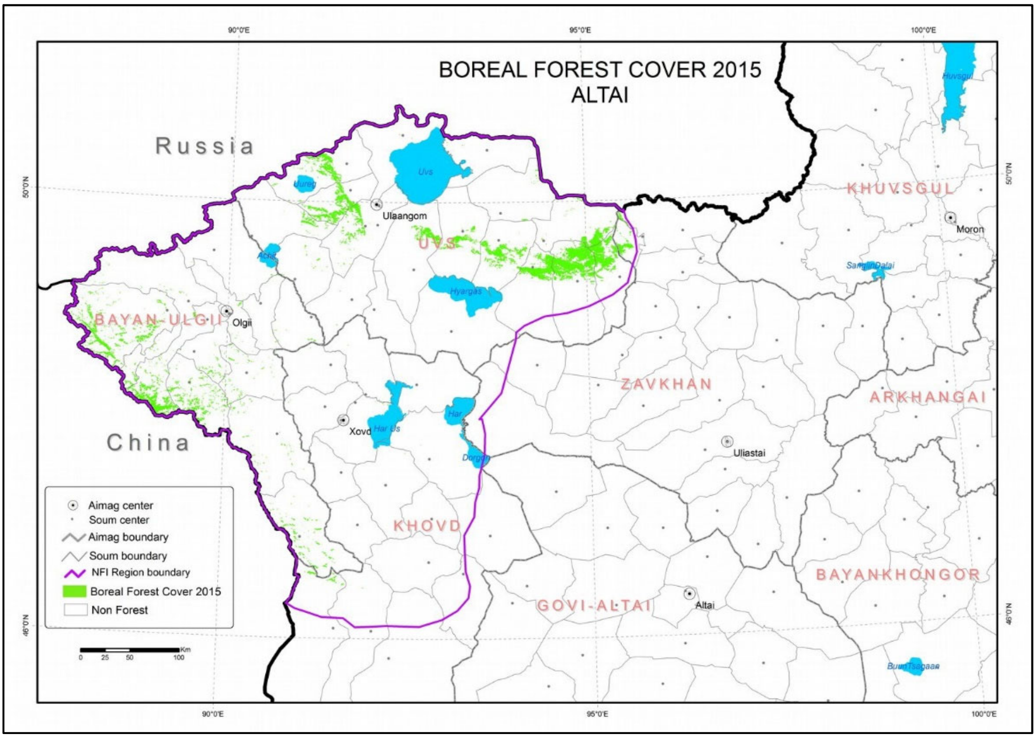

Figure 5: Boreal forest cover 2015 in the Altai region

3.2.2. BOREAL FOREST IN THE KHANGAI REGION

The Khangai region, located in the central part of the country, is dominated by Forest steppe. Its forest area covers ??? million hectares (1.8 Mha stocked) and has the country's highest average growing stock density, 130 m³/ha. The major part of this volume is represented by big and medium sized Siberian Larch (96.8%). Siberian Pine is present at low frequencies.

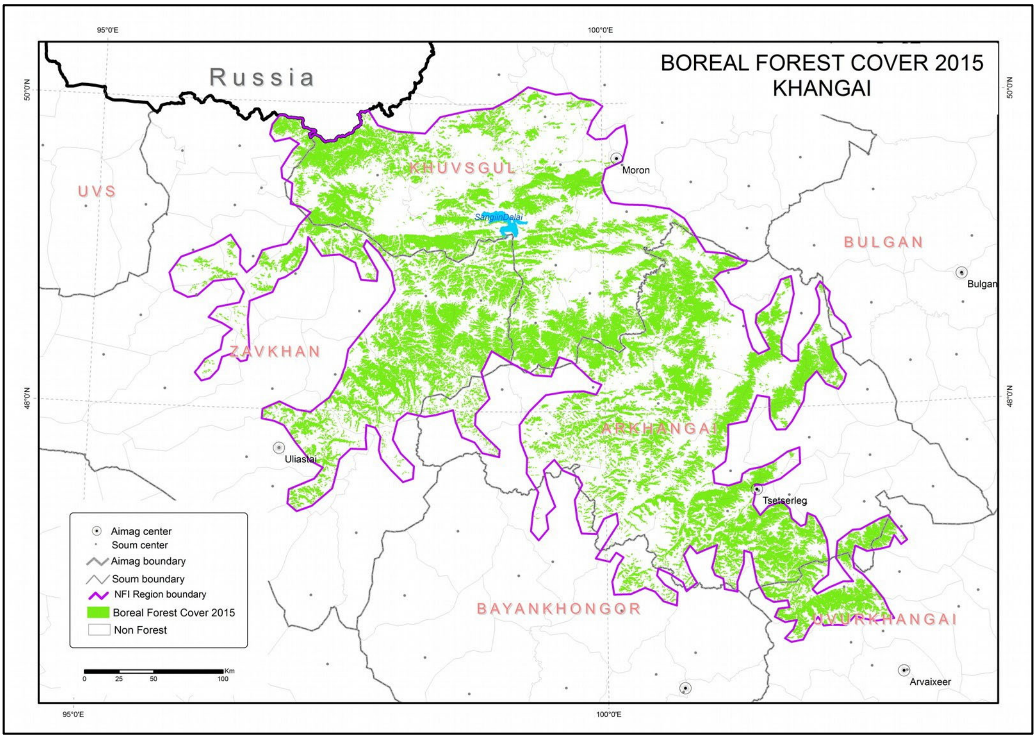

Figure 6: Boreal forest cover 2015 in the Khangai region

3.2.3. BOREAL FOREST IN THE KHUVSGUL REGION

The Khuvsgul region can be found in the very north of Mongolia and is represented by the Alpine and the Taiga vegetation zones. The forest area is the largest of the four forest regions with ??? million hectares (4.5 Mha stocked), which corresponds to nearly half of Mongolia's boreal forest area. The growing stock density is among the higher, 121 m^3/ha, and it is dominated by the Siberian Larch, 86.6 %. Asian White Birch, Siberian Pine and Scots Pine can be found at low frequencies.

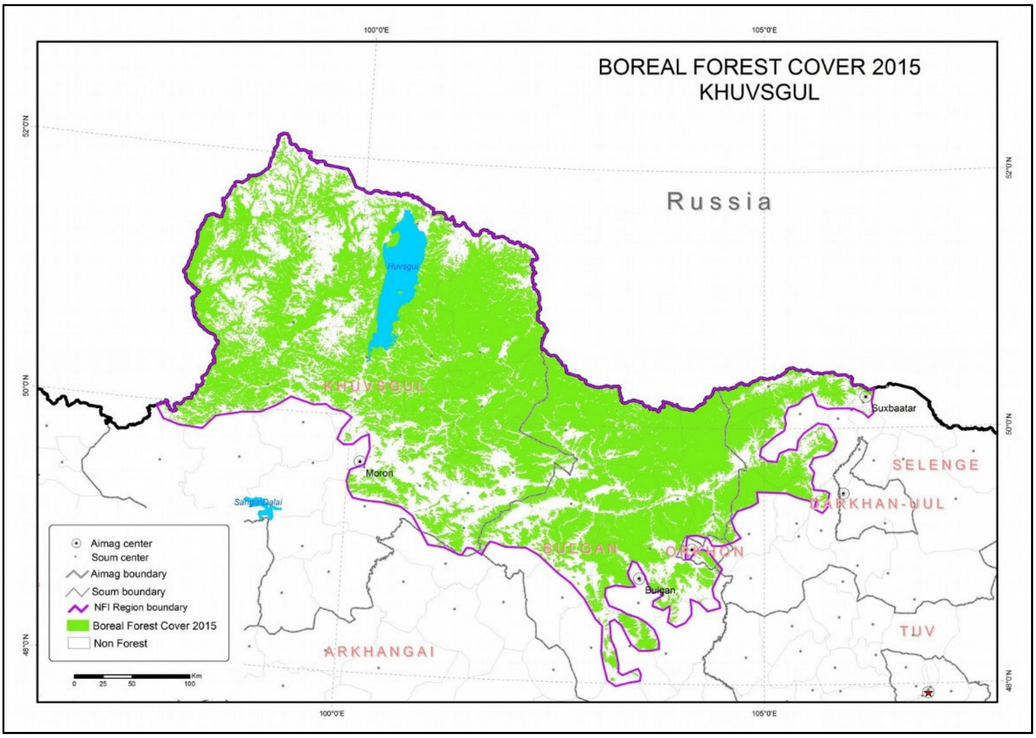

Figure 7: Boreal forest cover 2015 in the Khuvsgul region

3.2.4. BOREAL FOREST IN THE KHENTII REGION

The Khentii region is located east of the Khuvsgul region, and is represented by the taiga and forest steppe zones. The region's boreal forest cover is ??? million hectares (2.5 Mha stocked), which is composed by the greatest variety of tree species. The total growing stock density is 95.5 m³/ha, and the Siberian Larch is dominating with 50.0 %. However, co-dominating tree species are Siberian Pine, 16.9 %, Scots Pine, 16.0 %, and the Asian White Birch, 14.0 %.

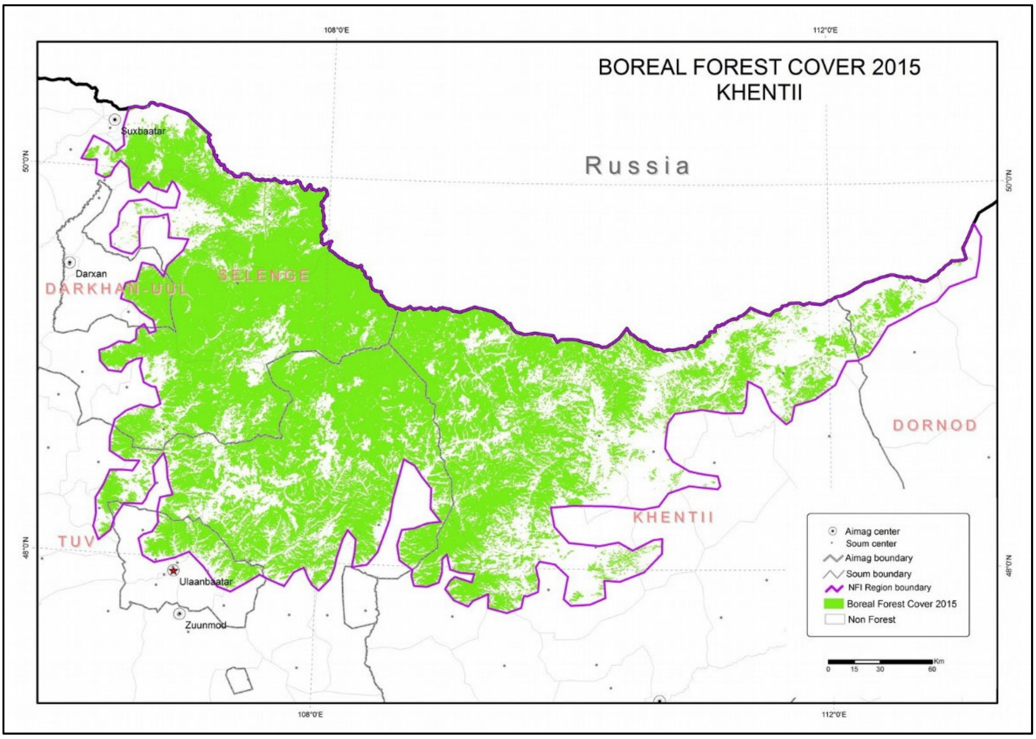

Figure 8: Boreal forest cover 2015 in the Khentii region

3.2.5. SUMMARY OF MAIN FINDINGS BY INVENTORY REGION

Table 2 below presents a summary of the main NFI findings by inventory region.

***Table 2**: Summary of Main Findings by Inventory Region*

Further details on the boreal forest in the four inventory regions						
Parameter	**Forest Inventory Region**					**Mean for Mongolia**
	Altai	**Khangai**	**Khuvsgul**	**Khentii**	**BBZ**	
Total Forest Area *(Mha)*	**174 700**	**1 704 900**	**4 311 700**	**2 403 000**	**501 600**	**9 095 900**
Stocked Forest Area *(Mha)*	13	221	523	229	50	1 036
Growing stock volume *($m^3/ha_{stocked}$)*	74	130	121	96	99	114
Stand density *(stems/ha)*	470	684	586	445	500	546
Shrub density *(stems/ha)*	15,0	1,2	4,9	2,6	1,7	5,9

3.3. ACTUAL AND OPTIMAL GROWING STOCK VOLUME

In Figure 9 the actual volume density in stocked forest area, measured by the NFI field inventory, is compared with the "optimal" volume density for a given tree species composition and a given average height (as defined by Dorjsuren et al 2012).

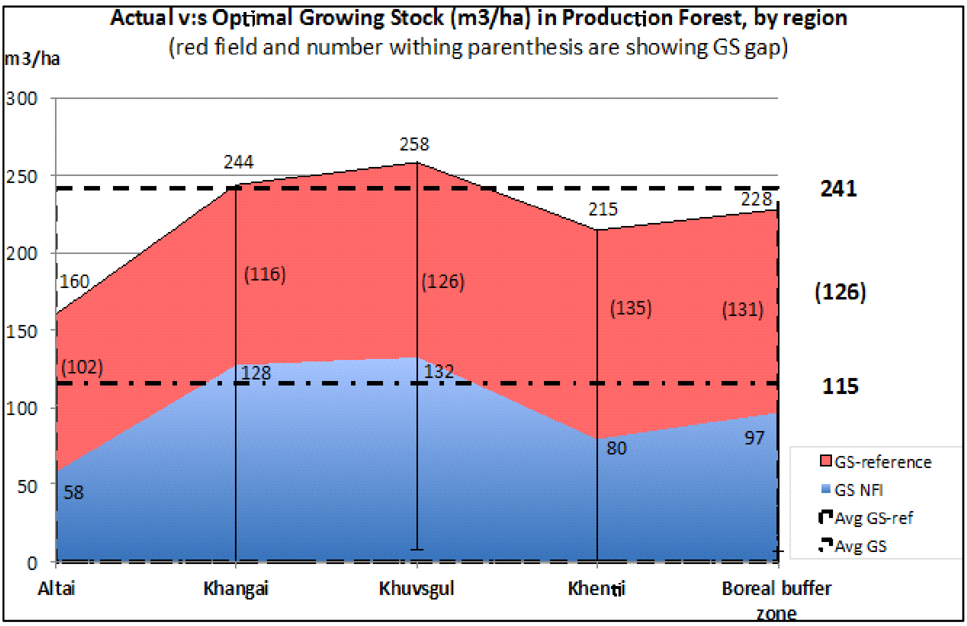

***Figure 9**: Actual vs Optimal Growing Stock Volume in Stocked Production Forest, by Forest Inventory Region*

The results show that Mongolia's boreal forests have less than half of the optimal volume that could be obtained if the forest stands would be kept healthy and well-stocked. With existing species composition, the optimal growing stock would be 237 m^3/ha, which is 124 m^3 more per hectare than the actual growing stock. OBS! These figures do not include the temporarily un-stocked forest areas.

3.4. FOREST AGE AND REGENERATION

Trees between 50 and 200 year-old dominate the growing stock with 73.7 m^3/ha (65%). Trees older than 200 years represent 23.8 m^3/ha of the growing stock density, while trees younger than 50 years constitute 15.8 m^3/ha. Tree age distribution is rather similar in all forest regions, except for the Altai region, where relatively much of the growing stock is found in the higher age classes and 13.4 m^3/ha is even found in the class over 300 years.

Regarding forest area by tree ages, 87.1 percent of the stocked forest area has an average age between 50 and 200 years-old, and only 5.1 percent of the forest has an age under 50 years-old. In this respect, regeneration of forests is a very important factor not only for economic aspects, but also for assuring a healthy ecosystem in the longrun.

***Table 3**: Growing Stock Volume (m3/ha) in Stocked Forest Area, by Age Class and Forest Inventory Region*

Growing Stock Volume by Age Class and Forest Inventory Region, m^3/ha						
Region	**Age Class (years)**					
	<20	**20-50**	**50-100**	**100-200**	**200-300**	**>300**
Mongolia	2.0	13.8	35.2	38.5	18.3	6.1
Altai	1.1	7.9	15.6	20.8	15.3	13.4
Khangai	3.1	15.7	43.0	46.8	16.1	5.2
Khuvsgul	1.5	14.5	37.2	37.6	21.8	8.7
Khentii	2.4	12.4	29.3	36.5	13.3	1.5
BBZ*	1.4	10.6	26.8	33.9	20.7	5.7

* Boreal Buffer Zone

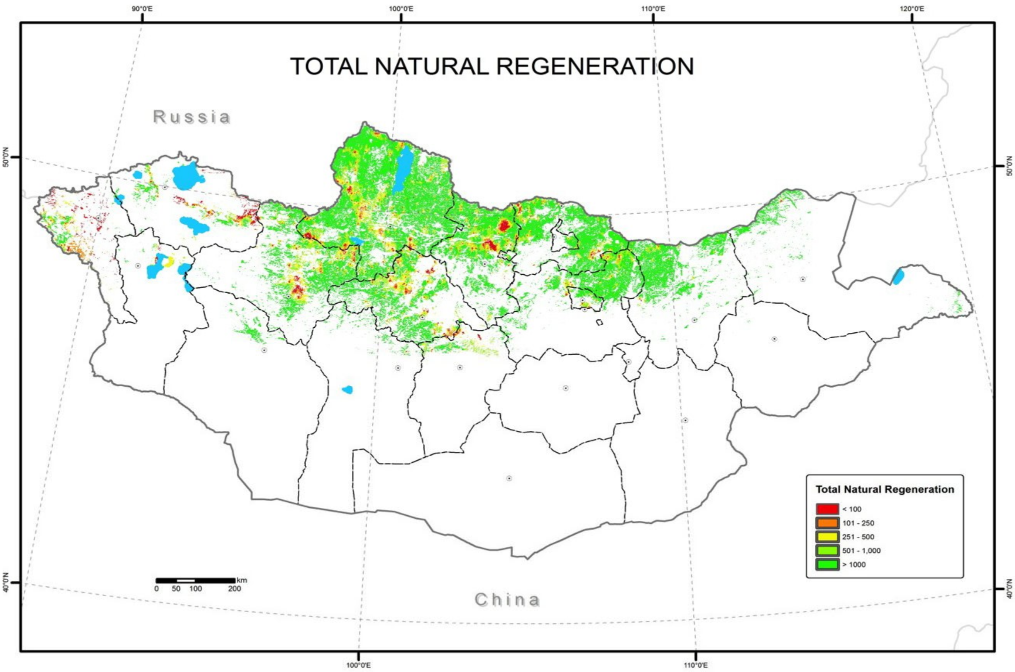

***Figure 10**: Distribution of All (>50cm) Natural Tree Regeneration in the Boreal Forest*

Siberian Larch is the overall most common tree species in Mongolia's boreal forest regenerations, with an average of 1282 stems/ha. In the Khentii region, however, the Asian White Birch dominates the tree regenerations, with 1386 stems/ha and in the un-stocked forest areas the Asian White Birch, Aspen and Siberian Larch hold almost equal shares of the tree regeneration, each almost 900 stems/ha.

3.5. FOREST AREA DESIGNATION AND MANAGEMENT

According to the Mongolian Forest Law (2012), forests are designated into two administrative forest management zones; a) the Protected Forest zone and b) the Forest Utilization zone. The Protection Zone, includes 3.7 million hectares of stocked forest area, of which 2.9 million hectares are located in protected areas, special protected areas, national parks, nature reserves and cultural monuments, where limited exploitation is permitted to meet local subsistence needs for fuel wood and NTFPs (Non-Timber-Forest-Products).

0.8 million hectares of forest in the Protected Forest zone are located outside of the officially protected areas, but are protected, as they are located next to water bodies, such as rivers and lakes, or next to cities, roads and railways, or because they are growing on slopes more than 30 degrees. In the Protected Forest zone, commercial logging is strictly controlled and harvesting of fuel wood and NTFPs for domestic consumption is permitted only to a limited degree.

In the Forest Utilization zone, forests are managed through concession rights, and at the end of 2016 there were 76 private enterprise concessions and 915 officially registered forest user groups (FUGs) with concession rights. In total 1.9 million hectares (21%) of the forest has been assigned for production purposes through concession rights, of which 1.5 million hectares are managed by FUGs and 0.4 million hectares by private forest companies. To carry out forestry operations, corresponding licenses are required, and today it is mostly forest companies who are licenced to harvest standing trees (alive or dead), while FUGs are limited to forest cleaning (collecting fallen dead wood) and forest regeneration operations.

4.4 million hectares of boreal forest area remain unprotected and have still not been assigned for any exploitation through timber/wood concession. However, in this report this forested area has been perceived as a part of the production forest, through potential future extension of management agreements to private sector.

3.6. WOOD HARVESTING

The calculation of potential timber and fuel wood supply is limited to three “harvestable” tree species (Siberian Larch, Scots Pine and Asian White Birch) and to the area of production forest. Siberian Larch is the most dominant timber species followed by Scots Pine.

***Table 4**: Timber volume (m^3/ha) by tree species and Forest Inventory Region*

Timber volume (m^3/ha) by tree species and Forest Inventory Region				
Forest Inventory region	**Tree species**			
	Siberian Larch	**Scots Pine**	**Asian White Birch**	**Total**
Altai	32.8	-	-	32.8
Khangai	73.5	0.01	0.01	73.6
Khuvsgul	68.3	1.6	0.6	70.5
Khentii	18.6	15.5	1.1	35.2
Boreal buffer zone	52.7	2.8	0.1	55.6
Mongolia	56.2	4.6	0.5	61.3

3.7. FOREST DIVERSITY

Tree species composition and canopy stratifications are important indicators of forest diversity. A forest with a variety of tree species, and with multiple canopy layers, offers diversified habitats for animals and plants, and thereby it is also more resilient to environmental impacts such as those caused by climate change.

3.7.1. DARK TAIGA

In Mongolia, the "Dark Taiga" tree species are the Siberian Pine, Siberian Spruce and Siberian Fir. Only 3% of Mongolia's boreal forest is classified as Dark Taiga forest (at least 75% Dark Taiga species). Khentii region has the highest proportion of Dark Taiga species, where 7.4% of the forest is classified as Dark Taiga forest, and where 22% of the forests contains at least 25% Dark Taiga species.

3.7.2. MONGOLIAN RED BOOK SPECIES

The Multipurpose NFI includes observations of threatened species, as listed in the "Red book" of Mongolia, and 15 threatened species of plants and animals (by tracks, droppings or sound of the species) were observed (Figure 11).

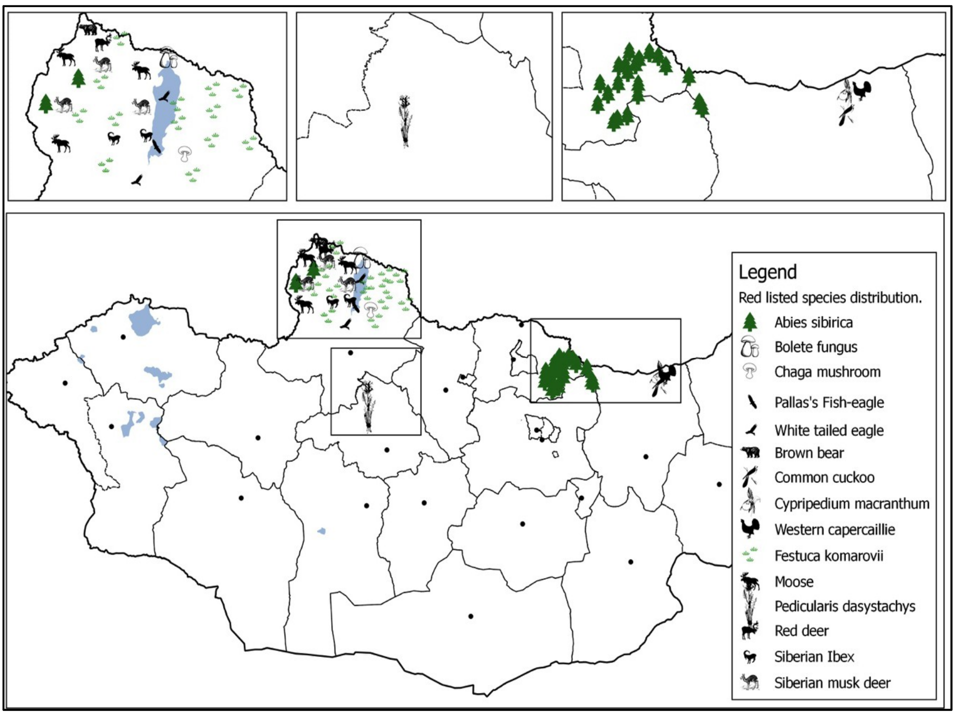

***Figure 11**: Distribution of Mongolian Red-listed Species (from the "Mongolian Red Book"), identified during the NFI field survey*

3.7.3. FOREST STAND STRUCTURE (TREE CANOPY LAYERS)

Stand structure was classified into four different classes and the most common structure in boreal forests is the two-layer stand structure (two distinct major canopy layers), which represents 53% of forested area. In Khangai, Khuvsgul and Khentii regions, 20% or more of the forest area have three-layer or multi-layer structures.

3.8. DEAD WOOD

The quantity and quality of dead and decaying wood are considered to be important indicators of biodiversity forest ecosystems. Both lying (fallen parts, or whole trees lying on the ground, and stumps) and standing dead wood are important components of the natural life cycle of forest ecosystems. Dead wood also contributes to soil nutrient, to global carbon storage and to forest fire dynamics. Dead wood is a habitat for fauna and flora specialized in using this habitat, like fungi, lichen, insects and birds that live by, or in dead wood, using it as food, shelter and breeding places.

Mongolia's boreal forest contains 46.5 m^3 dead wood per hectare, of which 40% (18.7 m^3/ha) is standing dead wood, 56% (25.8 m^3/ha) fallen dead wood, and 4% (2.0 m^3/ha) are stumps. Dead wood represents 30% of the total wood volume in the boreal forests.

3.9. FOREST HEALTH AND ENVIRONMENTAL CHALLENGES

The NFI also assessed the impacts of environmental hazards in forest. Results show (Fig. 12) that the most significant impact on the growing stock are snow or ice breakage (especially, in Khuvsgul and Khangai regions), wildfires, forest pests (insects) and grazing. Soil erosion and lightning have only a minor impact on the overall forest health.

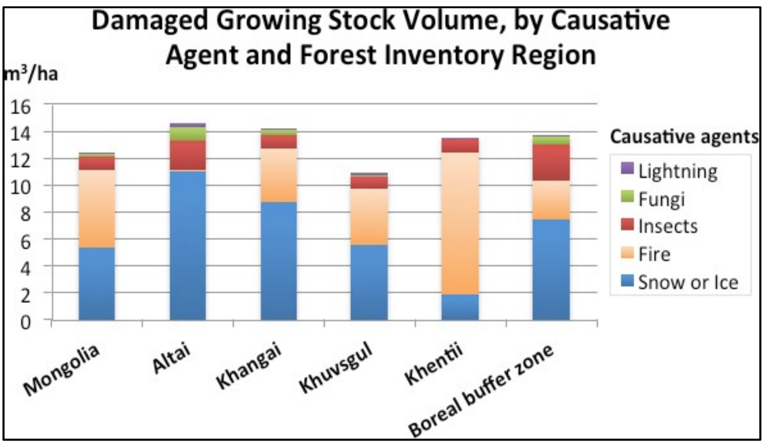

Figure 12: Damaged Growing Stock Volume (m^3/ha), by Causative Agent and *Forest Inventory Region*

Forest damage is quantified through the proportion of affected basal area. Results show that 70.9% of the boreal forest is very healthy, where more than 70% of the basal area show no sign of damage, and only 6.8% of the forest is severely damaged (more than 90% of the total basal area is damaged). The amount of damaged growing stock volume per hectare is quite similar in all of the five forest regions, varying between 11 m^3/ha and 15 m^3/ha.

3.10. BIOMASS AND CARBON POOLS

Forests sequester carbon from the atmosphere (CO_2) through photosynthesis, and store the carbon in its biomass. Carbon stored in living and dead tree biomass, litter and soil were estimated from the NFI field measurements and by analysing soil and litter samples collected during the NFI.

The total carbon stock in Mongolia's boreal forest is estimated at 148 tonnes carbon per hectare (C/ha), of which the soil organic carbon pool represents 84 tonnes C/ha, which is more than all other carbon pools combined. The total carbon pool varied by forest regions from 122 tonnes C/ha in the Khentii region to 162 tonnes C/ha in the Khuvsgul region. The average carbon pool in the above-ground living tree biomass corresponds to 30.7 tonnes C/ha. In the below-ground living tree biomass the carbon pool is 9.3 tonnes C/ha, which is slightly higher than those in dead wood biomass, 8.0 tonnes C/ha.

3.11 FORECAST ON FUTURE FOREST DISTRIBUTION IN MONGOLIA, UNDER A SCENARIO OF CLIMATIC CHANGE

A study on the climatic change impact on Mongolia's four dominant tree species, Siberian Larch *(Larix sibirica),* Asian White Birch *(Betula platyphylla)*, Scots Pine *(Pinus sylvestris)* and Siberian Pine *(Pinus sibirica)*, based on Mongolia's multipurpose national forest inventory data (NFI 2016) and dynamically downscaled climate change projections models (ECHAM5 and HadGEM) for Mongolia, indicate a long-term (period 2081-2100) decrease in the spatial distribution of Siberian Larch and Siberian Pine, 1-2% and 2-6% decrease respectively, while the long-term trends for Asian White Birch and Scots Pine were more ambiguous; -3% to +2% and -4% to +1% respectively, see Figure 1 and Figure .

On average, the two models indicate that the future net area distribution of all four mentioned tree species will decrease by 1.0 - 2.8%. There are big regional differences, and Khuvsgul and Khentii mountain regions were predicted to have the biggest increase in Asian White Birch distribution in the long-term (Figure). Similar to White birch, a net increase in the distribution of Scots pine is also predicted in Khuvsgul and Khentii mountain regions by end of century (Figure). The model outputs indicate a significant decrease in the distribution of Siberian Larch in the Khangai and Khentii regions, by end of the century (Figure). The distribution of Siberian pine is predicted to have the biggest long-term decease in the Khuvsgul and Khentii regions (Figure).

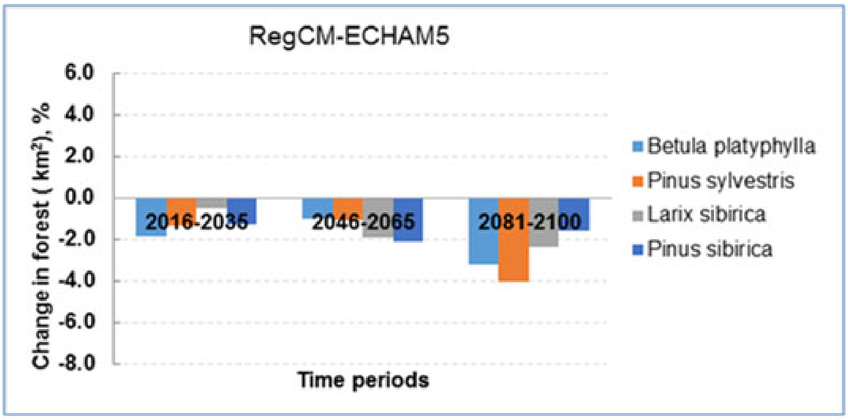

Figure 13. Change in forest cover, by tree species and time period, using RegCM-ECHAM5 model.

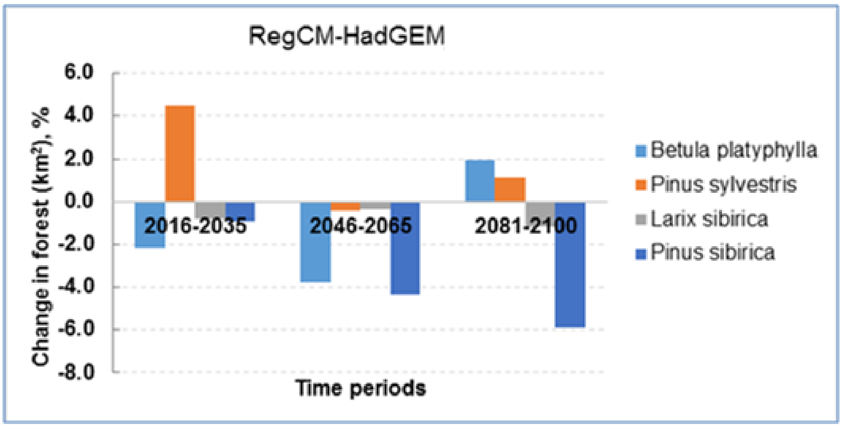

Figure 14. Change in forest cover, by tree species and time period, using RegCM-HadGEM model.

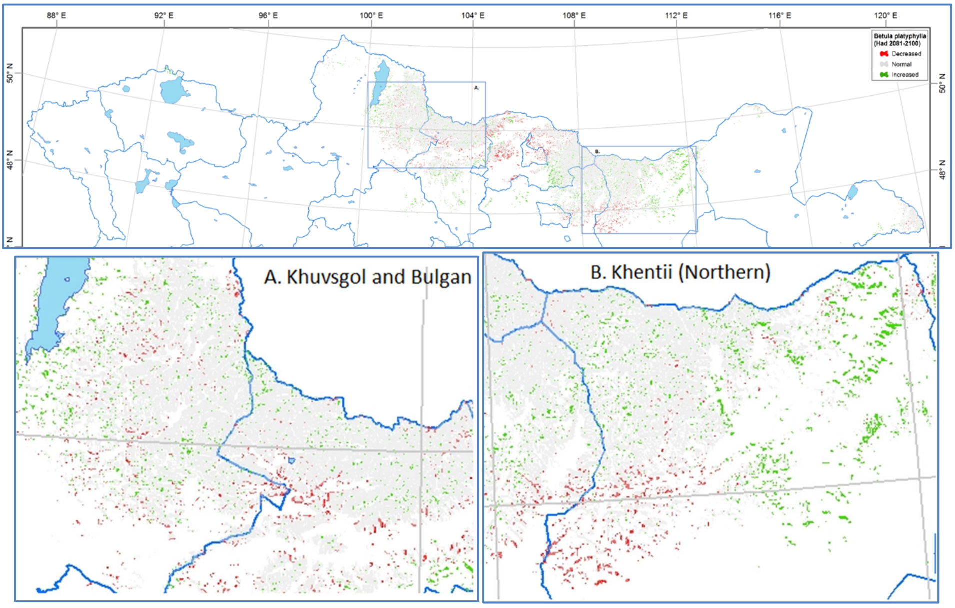

Figure 15. Predicted (HadGEM2 climate model with NFI data) potential changes in Asian White Birch (Betula platyphylla) distribution in (A) Khuvsgul and Bulgan aimags and (B) Khentii aimag, until the end of century, 2081-2100. Red colour indicates a reduction and green colour indicates an increase.

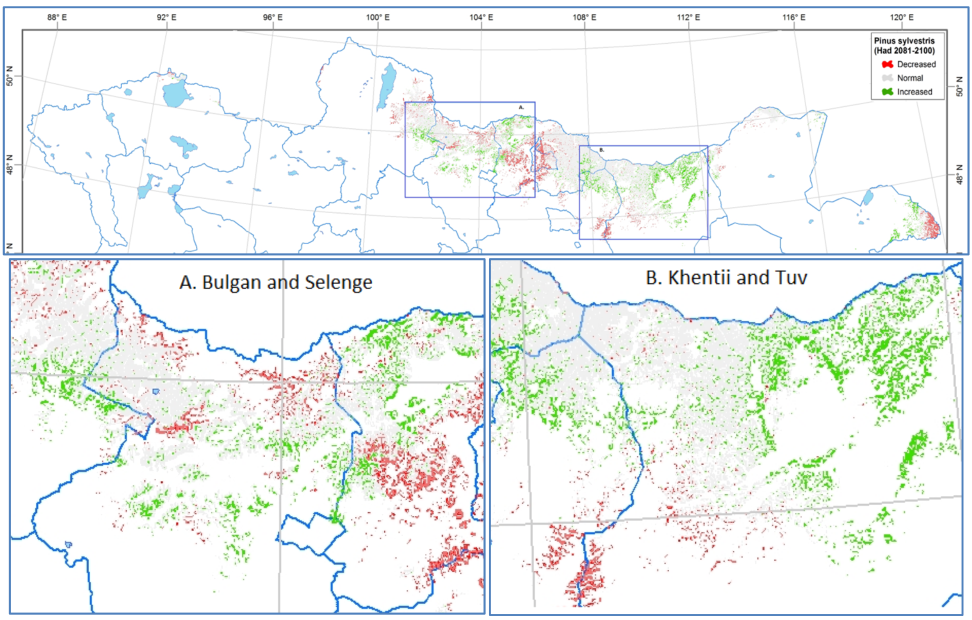

Figure 16. Predicted (HadGEM2 climate model with NFI data) potential changes in Scots Pine (Pinus sylvestris) distribution in (A) Bulgan and Selenge aimags and (B) Khentii and Tuv aimags, until the end of century, 2081-2100. Red colour indicates a reduction and green colour indicates an increase.

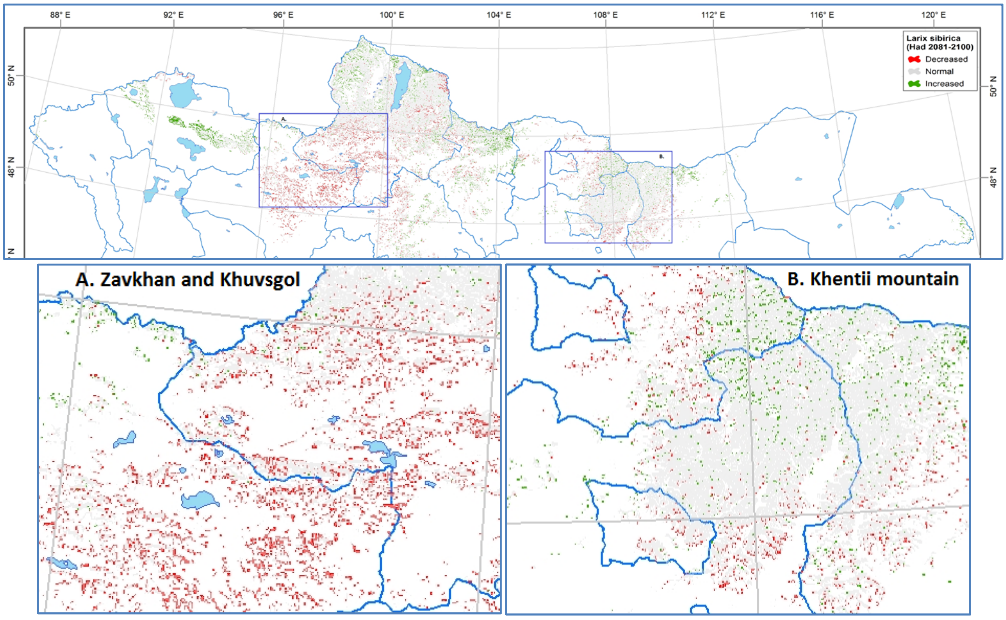

Figure 17. Predicted (HadGEM2 climate model with NFI data) potential changes in Siberian larch (Larix sibirica) distribution in (A) western Khuvsgul and Zavkhan aimags and (B) Khentii mountain region, until the end of century, 2081-2100. Red colour indicates a reduction and green colour indicates an increase.

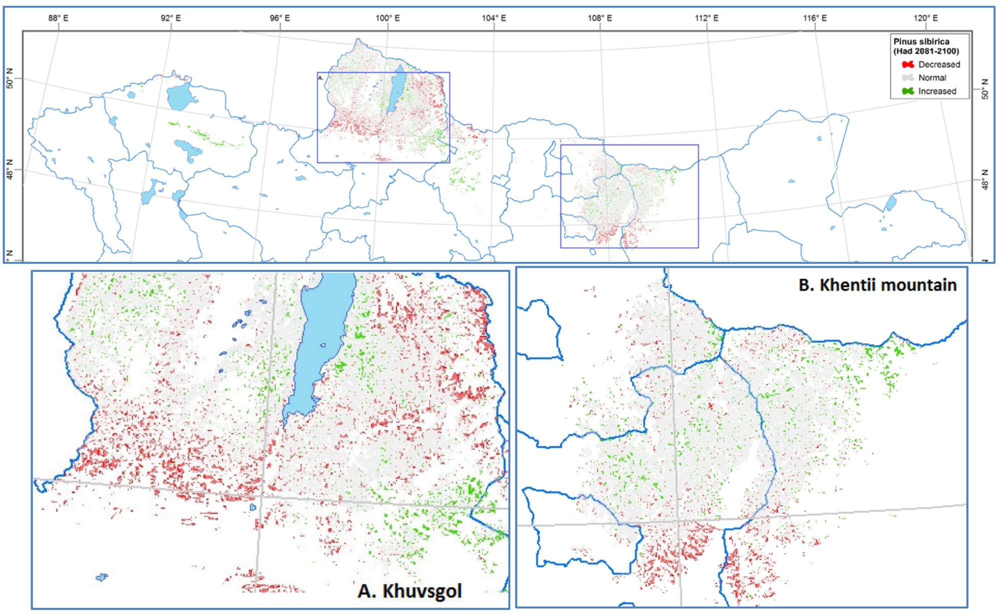

Figure 18. Predicted (HadGEM2 climate model with NFI data) potential changes in Siberian Pine (Pinus sibirica) distribution in (A) western Khuvsgul aimag and (B) Khentii mountain region from present distribution until the end of century, 2081-2100. Red colour indicates a reduction and green colour indicates an increase.

The forecasting models predict significant decrease in the distribution of Siberian Pine and Siberian Larch at from lower latitudes, especially in the Khuvsgul and Khentii regions, which will have a bigger change in precipitation and temperature caused by the increased carbon dioxide concentration.

Changes in species' habitat can direct future forest management policies and long-term management planning for the related species. It is however difficult to predict future changes in forest distribution, as it depends on various factors, ranging from climatic and biologic to economic and political, at local to global scales. Related study (Gomboluudev et al. 2017) found that the annual mean temperature and annual precipitation, together with slope, aspect, and altitude are the most important predictors of tree species distribution.

3.12 COST AND TIME ANALYSIS

The NFI was implemented from 2012 to 2017, starting with preparations of methodology and capacity development for data collection, followed by field data collection, control measurements and remote sensing surveys, concluding with data analysis and reporting.
The total budget of the multipurpose NFI was 8 300 000 000 MNT (€3 560 000). Approximately 1,900,000 MNT was spent per sampling unit (SU) (€820/SU) out of which 400,000 MNT/SU (€170/SU) covered the costs for field works (including supervision and control, but excl. procurements). The average time spent in each sampling unit was approximately 6-7 hours, including transportation time.

4. CONCLUSIONS AND RECOMMENDATIONS

The Multipurpose National Forest Inventory is the main tool to update the information on the status and trends of the nation's forests. Generated forest statistics and maps feed national policy processes with timely and accurate information to develop and revise forest policies and long-term strategies. Being internationally harmonized the NFI information is also invaluable for reporting to international processes.

Being the first of its kind in Mongolia, the Multipurpose NFI process has strengthened the capacities at FRDC and other collaborating national institutions, universities and organizations, and not least, strengthening the dialogue between them.
Current NFI is part of a continual process and is the first of a series of consecutive assessment to systematically monitor Mongolia's forestry resources. The value of the NFI data will increase with every cycle, as information on trends and changes (increment, losses,…) will be generated.

The NFI is part of an institution which ensures its continuity, maintains and strengthen the capacities of the NFI team, and maintains the NFI database and the network of permanent sample plots for future inventories.

In order to maintain and develop NFI competences with limited annual resources, the NFI should be carried out on a continuous basis, where a representative proportion of the data will be collected each year. The cycle of re-measuring plots should be ten years, to optimise the ratio of information value/cost, and a mix of both permanent and temporary plots should be inventoried. It is further important that adjustments in the methodologies be made, to adapt to future information needs.

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