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MULTIPURPOSE NATIONAL FOREST INVENTORY IN MONGOLIA, 2014-2017 -A TOOL TO SUPPORT SUSTAINABLE FOREST MANAGEMENT

ABSTRACT. Mongolia's first Multipurpose National Forest Inventory, 2014-2017, was implemented by the Forest Research and Development Centre, in collaboration with international expertise and the country's main forestry institutions, universities and research organisations.

The long-term objective of the multipurpose NFI is to promote sustainable management of forestry resources in Mongolia, to enhance their social, economic and environmental functions.

The NFI findings show that there are 11.3 million hectares of Boreal Forest in Mongolia. 9.5 million hectares are Stocked Boreal Forest Area, of which 69 percent is located outside of protected areas, 4 percent are designated for green-wood utilisation through forest enterprise concessions, and another 16 percent designated for fallen dead-wood collection through forest user group concessions. The non-protected stocked forests (i.e. production forest) have an average growing stock volume of 115 m³ per hectare, compared with an optimal growing stock volume of 237 m³ per hectare, and there is an additional 46.5 m³ of dead wood per hectare. The growing stock age distribution shows that 24 m³ per hectare are over 200 years (i.e. economically over-aged). The main tree species in stocked forest are *Larix sibirica* (81%), *Pinus sibirica* (7%), *Betula platyphylla* (6%) and *Pinus sylvestris* (5%), of which all, except for *P. sibirica*, are classified as legally harvestable tree species. Wild fire is the current main environmental factor decreasing the forest tree biomass.

The NFI helped identifying priority areas for the forestry sector, and to guide the implementation of sustainable forest management at the local level. The main forest management challenges of Mongolia's boreal forest will be to address that they are a) under-stocked (less than 50% of production potential), b) over-aged (31% of growing stock volume in stocked production forest is above optimal production age), and c) under-utilised (4% of forest area designated to green-wood utilisation).

KEY WORDS: NFI; Forest policy; Forest management

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INTRODUCTION

Mongolia's first systematic sample-based national forest inventory (NFI) was conducted in 2014-2017 under the lead of the Ministry of Environment and Tourism (MET). The NFI was implemented by the Forest Research and Development Centre, in collaboration with international expertise and the country's main forestry institutions, universities and research organisations. The inventory covered all of Mongolia's boreal forests and it assessed the forests' multiple functions and also the threats the forest currently is facing. The multipurpose NFI was specifically requested to generate information compatible with the national reporting to UNFCCC and to address the information needs for coherent forest policy development to support sustainable forest management in Mongolia. The background to MET's request was the lack of national-wide holistic forestry information to respond to the many new reporting requirements, and the urgent need to generate necessary baseline information on the status of Mongolia's boreal forest, and to evaluate the challenges ahead in a changing climate (MET 2019).

Existing national-level information on the forestry resources has been derived through compilations of provincial forest assessments, which were based on remote sensing data in combination with ocular inspections (i.e. not objective nor measurement-based) (MET 2019). Other publications on national-level status of ecosystems and their degradation, like the Atlas "Ecosystems of Mongolia" (Vostokova et al. 2005) have not been derived through systematic field data collection, but rather through case study areas, so an objective and systematic national level boreal forest inventory would be the first study presenting country-level representative and accurate information on the status of the boreal forest resources and the actual environmental challenges they are facing.

Mongolia, as many other countries in the region, had previously not implemented

national-level forest inventories based on objective measurements, so new methodologies had to be developed, experts had to be trained, and an inventory organisation had to be mobilised. The German government and the UN-REDD Programme backed MET in mobilising funding and a large pool of both international and national experts, which provided the needed expertise and capacity development to support the design and the implementation of the forest inventory.

Mongolia counts a number of forestry-related universities and research institutes, which together organised to design the NFI, with input from international expertise. The Forest Research and Development Centre (FRDC), under MET, was identified to take the lead and to coordinate the NFI, and in collaboration with international expertise and Mongolia's main forestry institutions, universities, research organisations and private forest inventory companies, the NFI was implemented.

The objective of this article is to present a summary of the forest inventory and derive conclusions from it for the development of sustainable forestry in the country.

MATERIALS AND METHODS

To address the need to generate information on the multiple functions of forest, also multiple data sources were needed (Fig. 1). A sample-based field inventory and a series of remote sensing surveys form the basis for an accurate and cost-effective multi-purpose forest inventory, and the first cornerstone in Mongolia's forest monitoring system.

Forest Characteristics Assessment

In order to design the field inventory, a "wall-to-wall" remote sensing survey, based on Landsat 8 ETM data from 2013, generated a "Forest Mask 2013" illustrating the geographic extent of Mongolia's boreal forests (Fig. 2), e.g. "stocked"

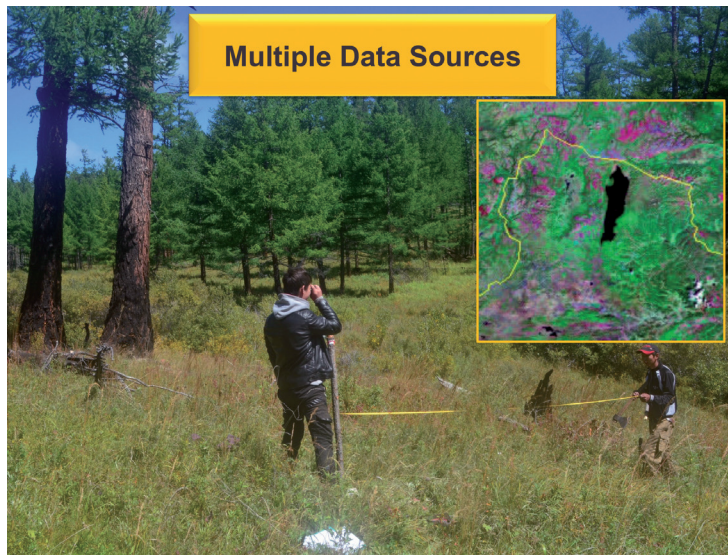


Fig. 1. Both field inventory and remote sensing surveys were conducted to collect the data for Mongolia's multi-purpose national forest inventory (Altrel unpublished)

boreal forest, meaning forest area which currently has a tree canopy cover of at least 10 percent. A team of national and international experts defined the main forest inventory regions (Fig. 3), based on existing national vegetation zones and knowledge on forest typologies.

These forest inventory regions defined the geographic extent for pre-stratification of the field sample, where the Altai region has the densest inventory grid, 1.5 km x 1.5 km, followed by Khuvsgul, Khangai and Khentii regions, 4 km x 4 km, and the remaining boreal forest area 9 km x 9 km.

All of the sample grids are systematic with distribution of sample units (field clusters) North-South and West-East respectively, and totally 4367 field clusters were established throughout Mongolia's boreal forest, both in stocked forests (Erdenejav 2014) and in temporarily un-stocked forest areas (UN-REDD 2017) (Figure 4).

Each sampling unit for the field data collection represents a cluster of three field plots, where the centre of the first plot is placed on the coordinates of the sampling unit and the centres of the second and third plots are located 100 meters North of the centre of the first

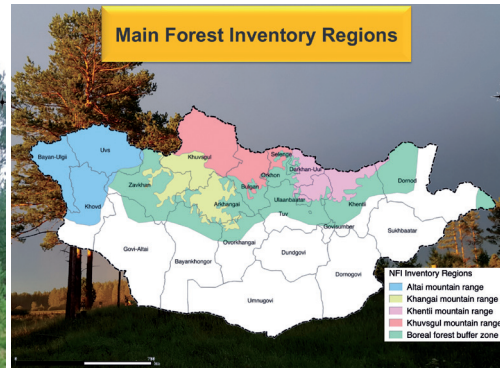
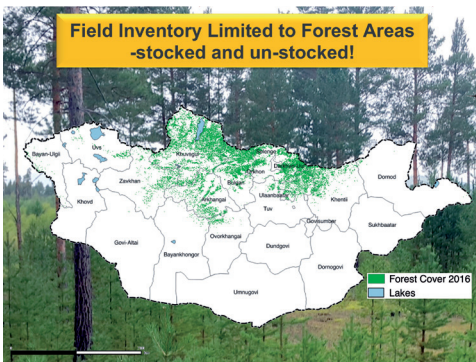


Fig. 2 (left). Forest Mask 2013, which defined the geographic extent of Mongolia's stocked boreal forest in 2013 (Altrel unpublished)

Fig. 3 (right). Geographic extent of Mongolia's five boreal forest inventory regions (Altrel unpublished)

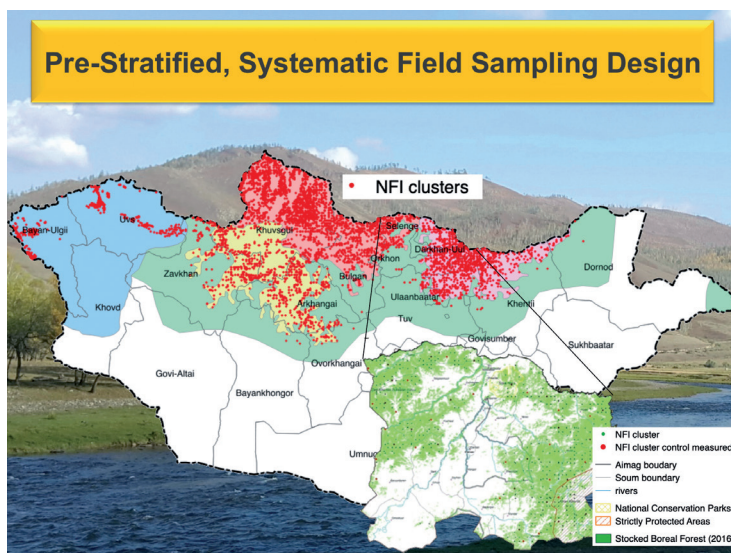


Fig. 4. Pre-stratified field samples distributed in boreal forests, according to the five forest inventory regions (Altrell unpublished)

plot, and 50 meters to the West and to the East respectively (Fig. 5). Each of the three field plots is represented by a set of nested circular plots, where the 20-, 12- and 6-meters radius plots have the same centre, and the centres of the two 2-meters radius plots are placed respectively six meters to the West and to the East of the concentric plots' centre (Fig. 6).

The measured and observed plot parameters are described by plot size (plot radius) and Plot Element in Table 1

Internationally standardised methods for data collection (i.e. FAO 2012) were adapted to the Mongolian context and defined in a manual for field data collection, so that the methods were equally applied throughout the country by the inventory teams.

Data from the field inventory were aggregated from tree-level to plot-/cluster-level, and ratio estimation (estimator/area) (McRoberts et al. 2014) was applied to calculate the inventory results at stratum level (Fig. 7), i.e. per-hectare values, and the Variance of the ratio estimates were calculated according Equation 1 (see all related NFI data models in Altrell 2015 and MET 2019).

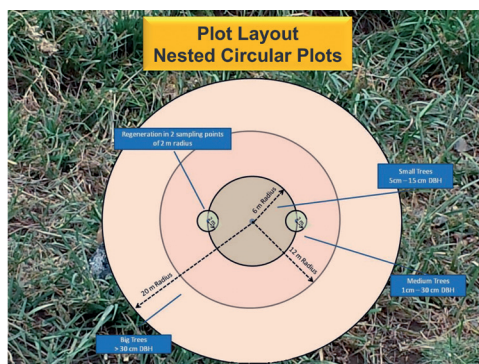
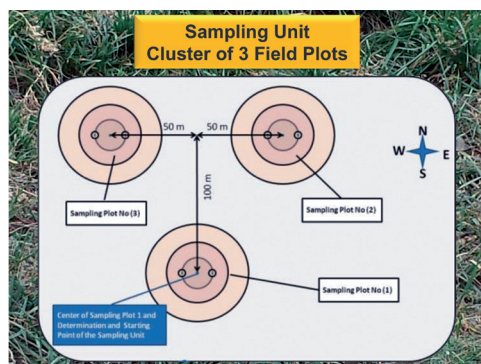


Fig. 5 (left). Design of field-sampling unit composed by three field plots (MET 2019)
Fig. 6 (right). Field plot composed by three concentric circular plots with radius 6 m, 12 m and 20 m respectively, plus two 2-m radius plots located 6 metres to the West and to the East of the centre of the concentric plots (MET 2019)

**Table 1. Measurement and Observation of Plot Elements by plot size (plot radius)
(MET 2019 and Altrell unpublished)**

Plot radius	Plot Elements	Measurements and Observations
20 meter	Trees (standing) with Dbh $\geq$ 30 cm	Dbh, Height, Species, Health, Causative agent, Stem quality, Age class, Position in plot
	Stand Structure	Canopy layers
	Forest Fire	Occurrence
	Grazing	Severity
	Erosion Protection status	Severity
	Slope	Inclination, Aspect
	Landscape	Relief
	Area Protection	Protection status, Protection implementation, Protection recommendations
12 meter	Trees (standing) with Dbh of 15 – 29.9 cm	Dbh, Height, Species, Health, Causative agent, Stem quality, Age class, Position in plot
6 meter	Trees (standing) with Dbh 6 – 14.9 cm	Dbh, Height, Species, Health, Causative agent, Stem quality, Age class, Position in plot
	Red-listed species	Species
	Plant species	Species count
	Ground Vegetation	Coverage by: a) Lichen, b) Mosses, c) Bracken/Fern, d) Herbs, e) Grasses, f) Large lianas, g) Sub-shrubs, h) Shrubs <0.5 m, i) Shrubs 0.5-2 m, j) Shrubs >2 m, k) Trees <0.5 m, l) Trees 0.5-2 m, m) Trees 2-4 m
	Dead Wood (fallen and stumps)	Mid-diameter, Length, Decomposition degree
	Soil	Thickness of Horizon A, B, C, Soil type, Soil texture
	Litter	Layer thickness, Moisture class
2 meter	Tree Regeneration (small) 10 – 50 cm	Stem count by species
	Tree Regeneration (medium) 50 – 150 cm	Stem count by species
	Tree Regeneration (high) >150 cm and Dbh< 6 cm	Stem count by species

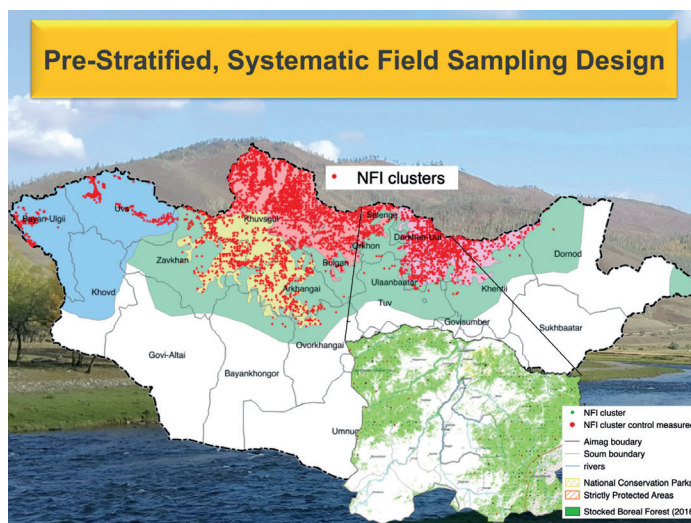


Fig. 7. Illustration of a circular plot with field data, which were aggregated from tree-level to plot-/cluster-level, applying ratio estimation (estimator/area) to calculate the inventory results (Altrell unpublished)

Equation 1: Variance of Ratio estimate (VR).

$$V_R = n * \frac{\sum_1^n (x_i)^2 + \left(\frac{\sum_1^n x_i}{\sum_1^n y_i} \right)^2 * \sum_1^n (y_i)^2 - 2 \frac{\sum_1^n x_i}{\sum_1^n y_i} \sum_1^n x_i y_i}{(\sum_1^n y_i)^2 * (n-1)}$$

Where x is the measured variable (ex. tree volume) in the sample and y is the auxiliary variable (i.e. forest area) in the sample (i.e. plot area with forest). i indicates the individual measurement value of the variable of a total number of n measurements (=sample size). (ex. to estimate tree volume in forest area, n is the number of sample units with forest area).

Totals were extrapolated by multiplying the **per-hectare** values with the corresponding forest area estimates defined through the remote sensing sampling survey (Figure 8) When available, national data models were applied to calculate the statistical estimates (Equation 2 and 3).

Equation 2 and 3: Examples of national data models for estimation of Growing Stock Volume Density and Biomass Stock Density.

$$GS_{Vol} = \Sigma(a * D_{bh}^b * H^c) / \Sigma(\text{plot area}) \quad \text{-(Equation 2: Growing Stock Volume density [Dorjsuren 2017])}$$

$$BS = \Sigma(a * D_{bh}^b * H^c) / \Sigma(\text{plot area}) \quad \text{-(Equation 3: Biomass Stock density [Dorjsuren 2017])}$$

Where:

GS_{Vol} = Growing Stock Volume density

D_{bh} = Tree Breast-Height Diameter

H = Tree Total Height

BS = Biomass Stock density

A_{plot} = Plot Area

a = Coefficient of the exponential function $D_{bh}^b * H^c$

b = Exponent of D_{bh}

c = Exponent of H

Forest Area Assessment

To estimate the size of the area covered by stocked boreal forests in Mongolia in 2014 a sample-based remote sensing survey was conducted in the northern part of Mongolia, applying the Collect Earth Tool, from the Open Foris Toolbox (FAO 2014), and assessing the remote sensing data available through Google Earth (Erdenejav 2014a). The sampling design was systematic and, applying an equal ground distance between the remote sensing plots within each UTM zone, ranging from 10 km x 10 km to 29 km x 29 km, north-south and west-east respectively, totalling 1,623 sampling plots (Fig. 8). Each sampling plot represented a reference square area of one hectare, in

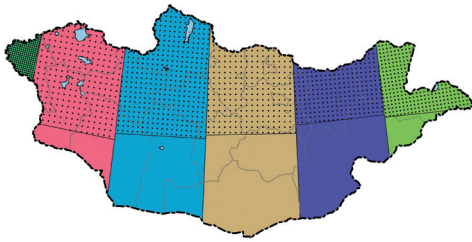


Fig. 8 (left). Sampling design of remote sensing survey to make a preliminary assessment of the size of the stocked boreal forest area in 2014 (Altrel unpublished)

Fig. 9 (right). Remote sensing plot layout with 25 indicative dots, systematically distributed within a reference area of a 1 ha square (Altrel unpublished)

which 25 equally distributed dots (Fig. 9) indicated where presence of tree canopy cover should be assessed. Applying the threshold of ten percent canopy cover for forest in Mongolia led to defining all plots with at least 3 dots on tree canopy as forest plots.

In order to improve the forest area estimate, and to also include temporarily un- or low-stocked forest area, saxaul forest and other land uses, a nation-wide remote sensing survey was completed in 2017. Also this survey applied the Collect Earth Tool and was sample-based by UTM zone, but applying denser sampling grids (totally 123,577 remote sensing plots) and with the same ground distance 9 km x 9 km between the plots through all UTM zones (Fig. 10). The sampling design was

also pre-stratified with 16 times higher sampling intensity in the boreal forest zone (2,250 m x 2,250 m). Each sampling plot is represented by a reference square area of one hectare, in which there are 49 equally distributed dots (Fig. 11) indicating where the presence of tree canopy cover should be assessed. Applying the threshold of ten percent canopy cover for forest in Mongolia led to defining all plots with at least 5 tree canopy cover dots as forest plots.

Forest Cover Mapping

A map illustrating the geographic distribution of the boreal forest cover in 2015 was prepared by applying a wall-to-wall remote sensing survey, employing Landsat ETM remote sensing data from

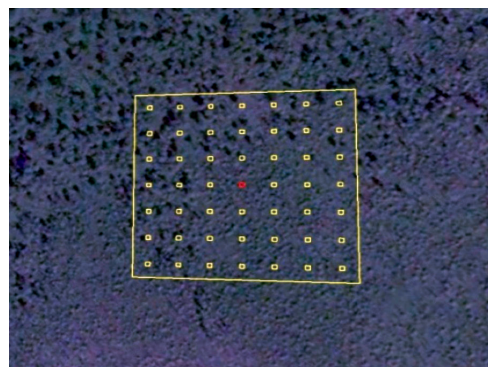
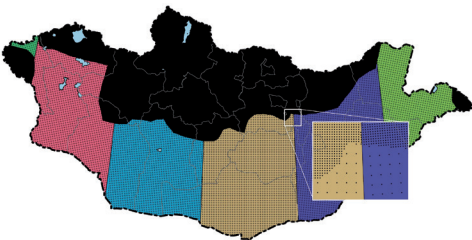


Fig. 10 (left). Sampling design of nation-wide forest/land use area assessment in 2016 (Altrel unpublished)

Fig. 11 (right). Remote sensing plot layout with 49 indicative dots, systematically distributed within a reference area of a 1 ha square (Altrel unpublished)

2015, and applying machine-learning techniques used by R-studio (RStudio 2015, R 2015) and QGIS (QGIS 2015), where the forest interpreter defined “training areas” of forests that were clearly visible in Google Earth data, to train the R-script “randomForest” (Breiman 2001) in recognising forest areas in the Landsat ETM data. The automatic interpretation was continuously evaluated and the training areas were improved until a satisfactory product was produced, and validated using 1680 reference points chosen in Google Earth data.

Quality Assurance and Capacity Development

In order to address the quality of the NFI information and to limit the errors of the estimates, the NFI was built on a robust systematic design, national experts were trained to carry out their related NFI duties (field data collection, remote sensing survey, quality assurance, data analysis and reporting) quality controls were carried out for each phase of the NFI, and accurate equipment was used. Experts from private field inventory companies formed field inventory teams and were equipped with high-accuracy measurement equipment and thoroughly trained to conduct the field data collection. Experts at Mongolia’s universities, research institutes and governmental institutions were trained and equipped to conduct the remote sensing surveys and also formed dedicated control teams to carry out re-measurements at five percent of the NFI field clusters. They were also trained to undertake the NFI data analysis, including the scrutinising of collected data to access the quality of the NFI information. Both national and international experts were taught the capacity developments.

The NFI design errors were limited by applying systematic sampling approaches for both remote sensing surveys and field surveys, and by applying conventional methods that are well tested. The measurement errors (field and remote sensing) were limited by applying a) the high-accuracy measurement equipment

and user-friendly computer applications, b) defining all the measurement and observation procedures in manuals for data collection, and c) thoroughly training all involved experts in conducting the data collection. In addition the field measurement errors were somehow estimated through re-measurements by control teams. Sampling errors were calculated for all per-hectare estimates, even though not all of them have been officially published through the NFI reports.

Results

The field inventory and the corresponding remote sensing surveys started in 2014, when also the major part of the field data was collected, and concluded in 2017 with the inventory of temporarily un-stocked forest areas. All data, both from field inventory and remote sensing surveys, were compiled in NFI databases and processed to generate the requested information for both national and international reporting.

All reporting from the Multipurpose NFI was done in a transparent manner and the results are published online, at the Forest Research and Development Centre’s web portal <http://www.forest-atlas.mn> (FRDC 2019).

Forest Area estimates and mapping

Among the main NFI findings are the size of the boreal forest area, which was determined to 11,3 million hectares (UN-REDD 2018), of which 9.5 million hectares correspond to stocked boreal forest (i.e. tree canopy cover $\geq 40\%$) and 1.8 million hectares correspond to un-stocked, or low-stocked, boreal forest (MET 2019) distributed through the northern parts of Mongolia (Fig. 12).

Khuvsgul aimag was the most forested area, with more than 3 million hectares stocked boreal forest, followed by Bulgan and Selenge aimags, with 1.4 million and 1.5 million hectares respectively. Arkhangai, Tuv and Khentii aimags had between 0.7 and 0.8 million hectares of boreal forest, and

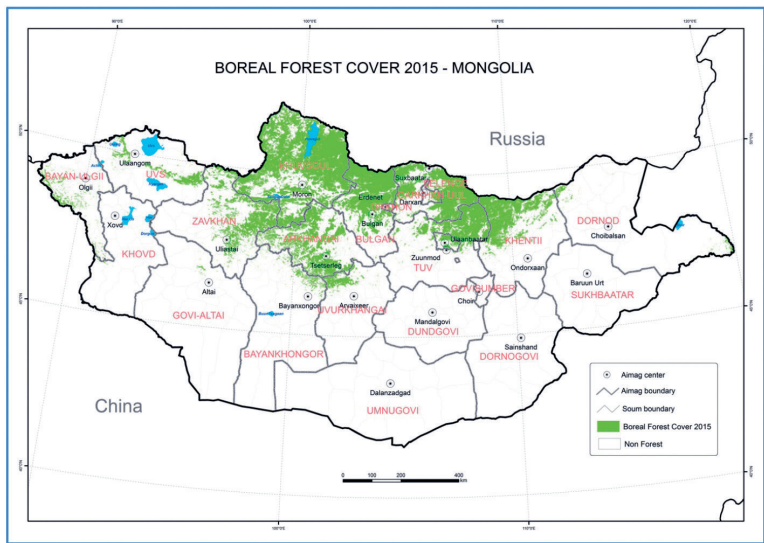


Fig. 12. Boreal Forest Cover Map 2015 (MET 2019)

Zavkhan aimag has 0.5 million hectares of stocked boreal forest. In total boreal forest have been registered in 17 country's Aimags. 2.9 million hectares of the boreal forest area were located inside state protected area, which corresponds to 31 percent of the total boreal forest area. 2.0 million hectares (21%) of the forest were designated for production purposes (Fig. 13), of which 1.6 million hectares were managed through agreements with forest user groups (915 officially registered in 2016), and 0.4 million hectares were managed through private enterprise concessions (76 concessions in 2016). The remaining boreal forest area, 4.3 million hectares, was officially not protected and has not yet been designated for any exploitation in 2016.

The area distribution of the different boreal forest (stocked) types is shown in Fig. 14. Siberian Larch (*Larix sibirica*) is the most dominant forest type with 5.7 million hectares, or 62.4 percent of the total stocked boreal forest area, followed by Mixed Coniferous and Mixed Forests with 9.9% and 9.7% respectively.

Growing Stock Volume

The Growing Stock Volume per hectare in stocked forest was on average 114 m³, or more than totally 1 billion m³ (MET 2019). The forest regions with the highest average growing stock are Khangai and Khuvsgul with 130 m³/ha and 121 m³/ha respectively in their stocked forest (Fig. 15). Altai region stands out with the lowest

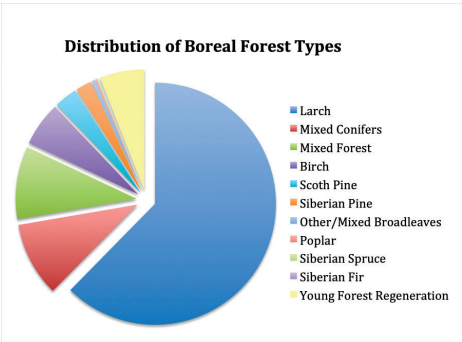
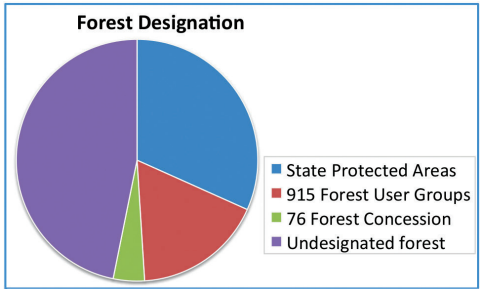


Fig. 13 (left). Forest Area by Designation (MET 2016)

Fig. 14 (right). Boreal Forest Types Distribution, according to Tree Species Composition (MET 2016)

growing stock, 74 m³/ha in stocked forest, mostly due to relatively small volumes in the higher diameter classes.

The national average growing stock volume for the un/low-stocked boreal forest areas is only 31 m³/ha, underlining the heterogeneous volume density in Mongolia's boreal forests. The overall national average growing stock volume is 96 m³/ha.

Siberian Larch (*Larix sibirica*) is dominant in the boreal forest of Mongolia, and it represents 92 m³/ha, or 81 percent of the average growing stock volume (Fig. 16) in stocked boreal forest. Siberian Pine (*Pinus sibirica*) comes on second place with 7.6 m³/ha (6.7%), then the White Birch (*Betula*

platyphylla) with 7.3 m³/ha (6.4%) and Scots Pine (*Pinus sylvestris*) with 5.6 m³/ha (4.9%). The other tree species, all together, represent less than 1.5 percent of the growing stock volume in stocked boreal forest (MET 2016).

The volume density of Mongolia's Boreal forest is around 50 percent of the optimal volume density in healthy and well-stocked forest stands, taking into consideration present tree species compositions and stand heights, as defined by the former Botanical Institute in the handbook for forest mensuration (Dorjsuren et. al. 2012). The volume density of forests in the utility zone is similar to the volume density of forests in protected areas, and Fig. 17 illustrates the

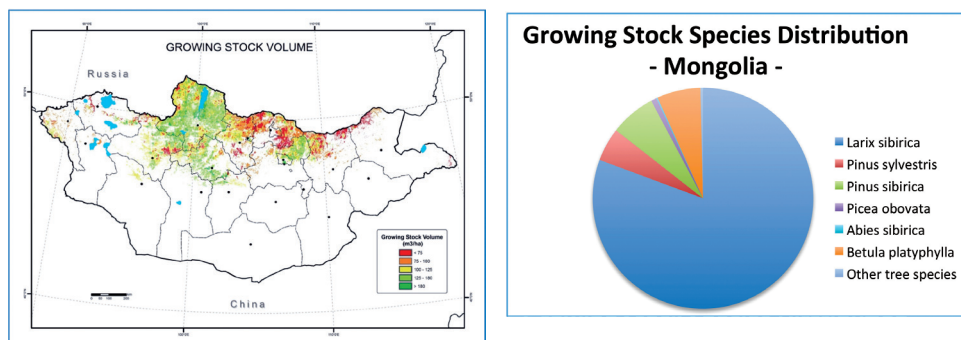


Fig. 15 (left). Distribution of growing stock densities in boreal forest (MET 2019)
Fig. 16 (right). Average tree species distribution by stocked GS volume (MET 2016)

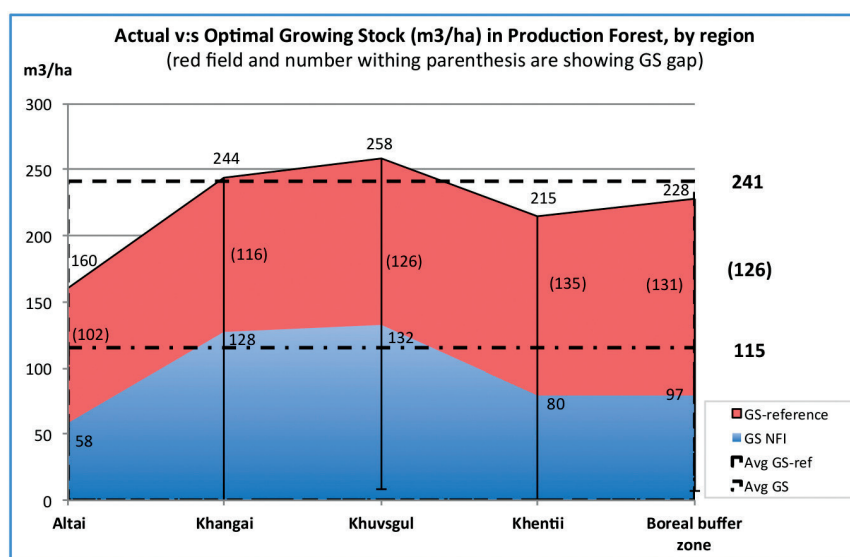


Fig. 17. Actual v:s Optimal Growing Stock Volume in Production Forest, by Forest Inventory Region (MET 2016)

actual and optimal Growing Stock densities by inventory region for forests in the utility zone (production forests).

The optimal national growing stock average in production forest was 237 m³/ha, while the actual growing stock density in stocked production forest was 115 m³/ha, which leaves a gap of roughly 124 m³/ha. The growing stock "gap" was more or less similar in all regions. However, Altai region had the relatively biggest growing stock gap, as its optimal growing stock only was over 190 m³/ha (MET 2016).

Growing Stock Age Distribution

Most of the growing stock in the stocked boreal forests was found in the age classes between 50 and 200 years, 73.7 m³/ha (Fig. 18). 23.8 m³/ha is found in the age classes over 200 years, and 15.8 m³/ha in the classes less than 50 years (MET 2016).

Harvested wood volume was estimated through the stumps assessed in the field inventory, without considering if the stumps were found in protected forest or in the productive forest area. The degree of decay was assessed for each stump, and this was used as a proxy for the age of the stump, i.e. the time since the tree was harvested.

Assuming that the time for a full decomposition of an average stump in Mongolia's boreal forest is around 50 years

(Shorohova and Kapitsa 2014, 2016), and that the rate of decomposition is constant throughout the stump's lifecycle, then the degree of decay (%) divided by two, is the equivalent to years since the tree was harvested. With this assumption of totally 15 m³ stem volumes have been logged per hectare in the boreal forest during the last 50 years period (1964-2014), which corresponds to an average annual logging rate of about 0.3 m³ per hectare per year, or totally 3.4 million m³/year. The average wood harvest during the last 10 years (2005-2014) was slightly less, 0.24 m³ per hectare per year (Fig. 19) (MET 2016). Note that the NFI data cover all stumps independent of their legal or illegal origin, so the results presented do not make any difference between formally (i.e. legally) or informally (i.e. illegally) harvested wood.

Forest Health

The health of the stocked boreal forests is similar to other natural boreal forest, and 71 percent of the stocked boreal forest was very healthy, and only 6.8 percent of the forest is damaged (> 90% of the total basal area) (Fig. 20a-b) (MET 2019).

Of the causative agents affecting the health of forest/trees, Wildfire is the environmental hazard most affecting the health of the growing stock, 8.0 m³/ha, followed by Snow or Ice 3.7 m³/ha (Fig. 21) (MET 2019). Among the assessed causative agents there was also direct human-induced damage (e.g.

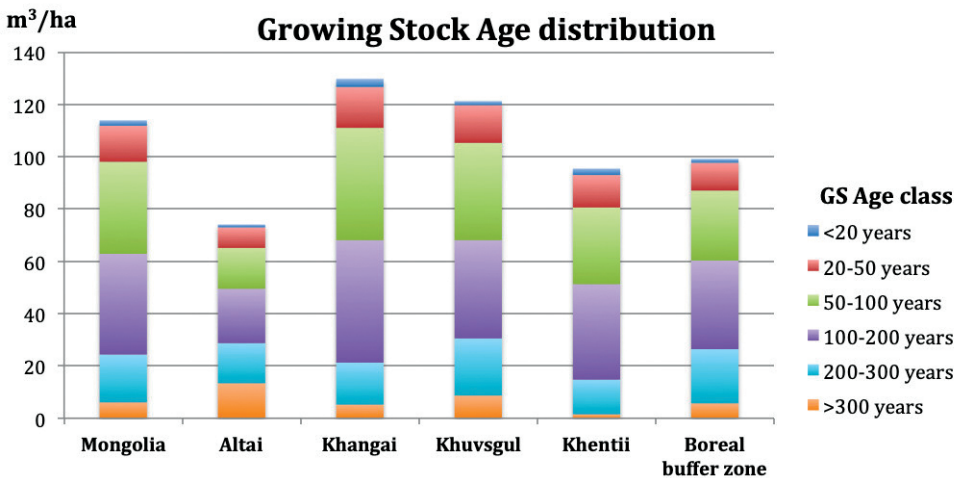


Fig. 18. Growing Stock Volume (m³/ha) by Age class (MET 2016)

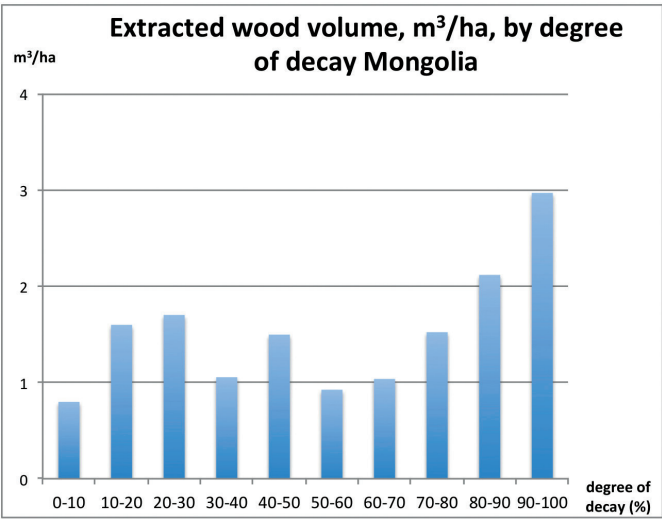


Fig. 19. Average logged wood volume (m³/ha), by degree of decay (MET 2016)

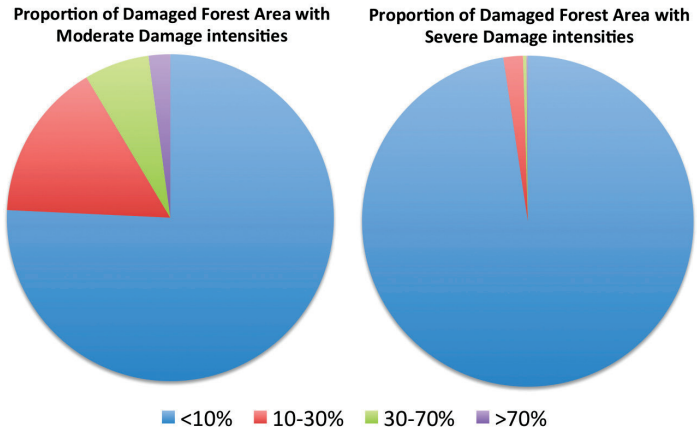


Fig. 20a-b. Damaged Boreal Forest Area Distribution (%), according to Moderate Damage intensities (left) and Severe Damage intensities (right) (MET 2019)

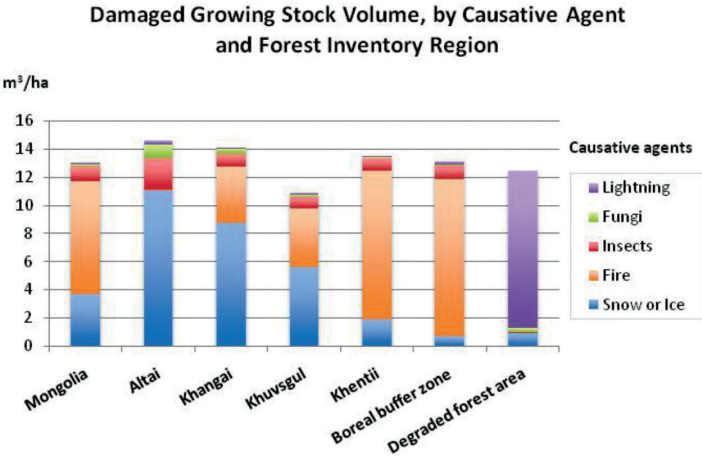


Fig. 21. Damaged Growing Stock Volume (m³/ha), by Causative Agent and Forest Inventory Region (MET 2019)

mechanical damage on tree stems). However, no such damage was recorded during the field survey. Other direct or indirect human-induced damage, like starting wildfires or managing livestock in forest were not assessed.

A summary of the training events related to Mongolia's National Forest Inventory and to Forest Management Planning in Mongolia is presented in Table 2, including the number of training events by topic and the number of trainees by topic.

These findings and many more can be found in the Mongolian Multipurpose National Forest Inventory reports (MET 2016 and MET 2019) and at the Web Portal <http://www.forest-atlas.mn> (FRDC 2019).

DISCUSSION

Mongolian forests are overaged and understocked

The new information provided by the Multipurpose NFI reveals that a big proportion of Mongolia's boreal forests biomass is relatively old. The age distribution of the stocked forests indicate that around 30 percent of the commercially viable growing stock volume (Larch, Scots Pine and Birch) in production forest is economically deemed as over-aged (MET 2019), which not

only is economically suboptimal, but also constitutes a potential risk for environmental hazards as pest outbreaks and wildfires, as old-growth trees are weakening and thus producing more dying and dead wood.

The NFI information also shows that Mongolia's boreal forests are significantly under-stocked compared with optimally managed forests, (described in Dorjsuren et. al. 2012), and vast forest areas remain un-stocked for long time, risking being permanently un-stocked (deforestation) or poorly stocked (forest degradation). As indicated in the NFI results, the growing stock densities varies a lot throughout the boreal forest area, which of course partly has to do with the different development stages of the forest, but not only. Some forest areas are very dense. So dense that the natural self-thinning results in a major portion of dead wood in the forest stand. While other forest areas are practically un-stocked, or very poorly stocked in relation to the average tree height (MET 2019). There are no significant differences in the forest characteristics inside or outside of protected areas (MET 2019).

There are many possible reasons for Mongolia's poorly-stocked boreal forest areas; a) unsustainable wood harvesting, where not enough efforts have been made to guarantee a successful regeneration of the forest, b) pest or disease outbreaks

Table 2. Capacity Development Events for Mongolia's National Forest Inventory and Forest Management Planning

Training Event	Number of training events	Number of Trainees
National Forest Inventory		
Field Data Collection	3	48
Forest Area Assessment	5	30
Forest Cover Mapping	1	12
Data and Database Management	5	25
Forest Management Planning		
Field Data Collection	2	22
Forest Types Mapping	1	11
Data and Database Management	1	11

decreasing the trees' biomass production, or eventually leading to tree death, c) damage caused by animals (domestic or wildlife) or humans, leading to decreased biomass production or tree death, d) climatic or other natural catastrophes directly damaging the trees, or indirectly by damaging their habitat. However, the causative agent with the overall largest impact on tree biomass degradation is currently the presence of wildfires which is behind most of the damage tree biomass in Mongolia's boreal forests (MET 2019).

How to tackle environmental problems with silvicultural measures

The estimated mean annual harvesting rate in Mongolia's boreal forest during the last decade corresponds to 0.23 m³/ha (MET 2019), which is very much below the mean annual wood increment, estimated at just over 1 m³/ha (FRDC 2017). It indicates an underutilisation of the forest production and that the tendency of dead and dying wood will continue increasing, and which creates environmental risks, mainly through the effects of wildfire. There is a very high pressure on the forestry resources close to urban centres and to wood markets (Hijaba 2010), so locally there can be an overexploitation of wood for heating and construction. However, the NFI findings indicate that this overexploitation is geographically very limited, and at a whole a rare event today in Mongolia's boreal forests.

The rational way to solve many present and future environmental problems of Mongolia's boreal forests, and at the same time increase their productivity in terms of living tree biomass, would be to actively manage the forests towards a more species-diverse, vital and resilient tree composition (Schmidt-Corsitto et al 2019). Much of the forest should undergo some kind of logging activity: a) to curb self-thinning in over-dense forest stands with high inter-tree competition (crown thinning), b) to remove "old wolfs" (e.g. big old-growth trees) and over-aged trees, which inhibit a homogeneous development of the forest stand, c) to remove dying trees (sanitary cutting) to curb potential pest outbreaks, d) to guide a more diverse tree species composition (selective cutting), e) to rehabilitate poorly stocked forest areas

(clearcutting) f) to harvest wood from mature forest stands (selective-, shelterwood-, or clearcutting) to stimulate forest regeneration. However, current legislation and government directive needs to be amended to allow a wise and adequate management of the boreal forests. Like many other boreal forests, Mongolia's Larch- and Pine- dominated forests are well adapted to fire dynamics, and thus naturally often regenerate after huge wildfires. Clearcutting mimics severe wildfires, in the sense that it decreases, if not all, large parts of the living biomass in an area. Contrary to wildfires, which can affect up to several thousands of hectares, clearcutting restricts its impact to a limited area, and the wood is used as valuable greenwood for timber instead of literally going up in smoke. Light-loving pioneer species are favoured by clearcutting, which initially clears the area from competitive vegetation and opens up for full sun exposure, which benefit these species, which quickly get re-established. However, not all boreal forest areas are apt for final harvesting through clearcutting due to the topography, soil characteristics, microclimate, and not least the species composition. Shade tolerant species often benefit from a protecting canopy layer to regenerate. Selective cutting maintains continuous, and possibly, multiple canopy layer, to protect the new regenerations from direct sun exposure. For forests in-between the extremes of sun loving species and shade tolerant species shelterwood systems can then be the best option, where the dominating canopy layer(s) are being phased out little by little in order not to lose too much of the protective impact of the tree canopies before a successful regeneration has been well established. Worth noticing is that clearcutting is currently not allowed in Mongolia, so a revision in related legislation would be necessary to allow large parts of the boreal forest to be managed in a close-to-nature manner.

The removal of weak and dying trees will decrease the risk of pest outbreaks, and will not add more deadwood to Mongolia's boreal forests, which is already well-represented there. By thinning the over-dense forest stands and by removing over-ages trees, the growth of the remaining trees will be stimulated, and their vitality will be strengthened.

It might sound strange, but totally removing remaining tree biomass on very degraded forest areas and assisting the regeneration to create homogeneous well-stocked forest stands is a long-term approach to increase the forest biomass production, and thereby also the carbon sequestration which was described in the Forest Act of Sweden in 1948 (SKS 2019) as a tool to successfully rehabilitate degraded forest areas in Sweden.

OUTLOOK

In a future, when climatic changes are foreseen, and the market for forestry products and services are yet to be confirmed, it is wise to diversify, to be prepared for whatever outcome. So, by guiding a diversified tree species composition, not only in the regeneration phase of the forest, but also in its young and premature phases, by selective cutting the forest would become more resilient to future climatic changes and to changes in the market of forestry products and services.

To better satisfy future information needs on the status and trends of Mongolia's forestry resources, the national forest inventory should consider all of the countries forests, i.e. also include the southern semidry "saxaul forests". The sampling design should also be stricter and should not allow shifting of cluster or plot locations, in order to avoid bias. To permit full flexibility for post-stratification, the sampling design, preferably based on the uniform 9 km x 9 km grid, should also cover the whole territory, where the non-forestry clusters can be excluded from field inventory after a pre-assessment using very high resolution remote sensing data (e.g. Collect Earth application). This would also make the field inventory data representative for direct area, i.e. the totals could be estimated without further auxiliary information.

CONCLUSIONS

Mongolia's Multipurpose National Forest Inventory aimed at stimulating Sustainable Forest Management in Mongolia, not only by feeding policy formulation processes with accurate information, but also by supporting the development of assessment methods for

forest management planning. Drawing from the experiences and the information from the NFI, recommendations and guidelines on measurement-based forest management planning were made to prepare more reliable forest management plans, and silviculture guidelines for Mongolian forestry were developed to direct forest management measures towards a more effective and adequate treatments.

Mongolia's boreal forests produce less than half the biomass of well-managed boreal forests. Less than one fourth of the yearly biomass production is being cut, resulting in a lot of selfthinned- (dead trees) and over-aged trees, posing a potential risk for pest outbreaks and severe wildfires. There is a need to revise Mongolia's forest policies to address the overall suboptimal state of the boreal forest, and at the same time the under-utilisation of their boreal forests, by actively manage the forests for healthy green-wood production.

Current multipurpose national forest inventory is part of a continual process and is the first one of a series of consecutive assessments to monitor Mongolia's boreal forest resources. The value of the NFI data will increase with every cycle, as information on trends and changes (increment and losses) will be generated.

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