



MINISTRY OF ENVIRONMENT  
AND TOURISM



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## Acronyms and Abbreviations

AD	Activity Data
AFOLU	Agriculture Forests and Land Use
AGB	Above-ground Biomass
ALAGaC	Administration of Land Affairs, Geodesy and Cartography
BAU	Business as usual
BECF	Below-ground carbon expansion factors
BGB	Below Ground Biomass
BUR	Biennial Update Report
C	Carbon stock in forest biomass
CE	Collect Earth
CBD	Convention on Biodiversity
CCPIU	Climate Change Project Implementing Unit
CI	Confidence Interval
COP	Conference of Parties
CSO	Civil Society Organization
DBH	Diameter at breast height
DW	Deadwood
EF	Emission Factor
EIC	Environmental Information Centre
ERISC	Environmental Research and Information Study Center
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resource Assessment
FRDC	Forest Research and Development Centre
FRL	Forest Reference Level
FREL	Forest Reference Level
FUG	Forest user group
GASI	General Agency for Specialized Inspection
GCF	Green Climate Fund
GCM	Global Climate Model
GDP	Gross domestic product
GFW	Global Forest Watch
GHG	Greenhouse gas
GHGI	Greenhouse Gas inventory
GIZ	Technical Cooperation Agency of the German Government
GPG	Good practice guidance
IGEB	Institute of General and Experimental Biology, Mongolian Academy of Sciences
IPCC	Intergovernmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Forestry
MET	Ministry of Environment and Tourism



MPNFI	Multi-purpose National Forest Inventory
MRV	Monitoring Reporting and Verification
NDC	Nationally Determined Contribution
NFI	National forest inventory
NFMS	National Forest Monitoring System
PAM's	Policies and Measures
QGIS	Quantum GIS
RBP	Results-based payments
RCP	Representative GHG concentration pathway
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SDG	Sustainable Development Goal
SIS	Safeguard Information System
SLMS	Satellite Land Monitoring System
SoI	Summary of Information
Stdev	Standard deviation
tCO <sub>2</sub> e	Tonnes of carbon dioxide equivalent
TCC	Tree crown cover
TFI	Mongolia's Taxation Forest Inventory
TWG	Technical Working Group
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations REDD Program



## SUMMARY

This report is Mongolia's first Forest Reference Level (FRL), one of the four main elements of REDD+, which enables the measurement of performance of REDD+ measures associated with the implementation of the national REDD+ strategy for Mongolia. It is based on up-to-date UNFCCC decisions, technical documentation, and a review of available tools and methodologies, through national Technical Working Group (TWG) meetings. Mongolia's FRL is at national scale reflecting the historical period 2005-2015. Greenhouse Gas (GHG) emissions from deforestation and forest degradation are estimated, from 4 different drivers<sup>1</sup> - fire/pest, grazing, soil erosion, logging, as well as GHG removals from afforestation and/or reforestation activities (enhancement).

The TWG made recommendations of the elements needed to construct a FRL and convened a FRL core group which has revisited all interim technical decisions to reach national consensus and developed nationally-available data and information necessary to construct the FRL. Activity Data (AD) were derived from the assessment of systematic samples to cover the entire country using FAO's Open Foris Tool Kit, Collect Earth and through visual interpretation of high-spatial resolution reference data available from various sources. Emission Factors (EF) are mostly derived from the data of the National Forest Inventory (NFI) executed in 2014-6 with updated biomass models developed by the Mongolian academy of science (IGEB). A total of 52,660 ha, 1,394,810 ha and 3,038 ha were estimated to have undergone forest loss (deforestation and forest degradation) and forest gain respectively between 2005 and 2015.

Mongolia's annual GHG emissions and removals from the forestry sector were estimated as 5,213,319 tCO<sub>2</sub>e and 47,782 tCO<sub>2</sub>e, respectively, during the reference period 2005-15.

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<sup>1</sup> Fire and Pest were not separately considered in Activity Data



## 1. INTRODUCTION

Mongolia is a landlocked country located in the center of the Eurasian continent. The climate is characterized by high fluctuations and extremes in temperature and precipitation. The annual mean temperature ranges from -8°C to 6°C across regions and the annual precipitation varies from 50 mm in the Gobi Desert to 400 mm in the northern mountainous area. It is an immense area of 1.56 million km<sup>2</sup>, largely consisting of grasslands which have traditionally supported nomadic herding lifestyles for thousands of years.

The country supports two major forest biomes, boreal forests in the north accounting for 14.2 million hectares (87%), dominated by larch and birch; and 2.0 million of saxaul forests (13%), a dryland woodland ecosystem in the southern arid regions of Mongolia that is considered under national definitions as 'forest' (CCPIU, 2017) (Figure 1.0). The boreal forest comprises deciduous and coniferous forests growing in the forest steppe, boreal forest and mountain zones. Boreal forest is dominated by six main conifer species: larch (*Larix sibirica*), birch (*Betula platyphylla*), Siberian pine (*Pinus sibirica*), Scots pine (*Pinus sylvestris*), aspen (*Populus tremula*) and spruce (*Picea obovata*), with much of the forests being dominated by larch (FRDC, 2016). The broad-leaved trees found here are mainly birch (*Betula platyphylla*), aspen (*Populus tremula*) or poplar (*Populus diversifolia*). Northern boreal forests are part of the transitional zone between the Siberian taiga forest to the north and the grasslands to the south. They typically grow on mountain slopes between 800-2500 m above sea level. According to the forest taxation inventories conducted by the Forest Research and Development Center (FRDC), larch, birch and saxaul trees account for more than 60%, 10% and 15% of forest areas respectively. In terms of growing stock, larch contributes close to 80%, while all other trees are below 10%. The average growing stock amounts to 113.9 m<sup>3</sup>/ha.

Mongolian forests have low productivity and growth, and they are vulnerable to disturbance from drought, fire and pests. Therefore forests can easily lose their ecological balance following disturbance and they have a relatively low natural regrowth rate afterwards, partly due to the boreal forests being located in the northern hemisphere's harsh continental climate, which significantly limits vegetative growth rate and soil moisture content.



**Figure 1.1.** Forest Habitat Types in Mongolia. Clockwise from top left to right: Deciduous forest - birch; Coniferous forest – larch; Mixed deciduous and conifer forest and saxaul forest.

### 1.1. Objective of FRL development

The REDD+ Readiness process commenced in June 2011 when Mongolia became a partner country of the UN-REDD programme and the implementation plan of its REDD+ Readiness Roadmap was developed afterwards. Mongolia officially adopted its national REDD+ Readiness Roadmap in 2014, followed by the UN-REDD National Programme being launched in 2016 to intensify Mongolia’s government support to the preparation of the National REDD+ Strategy. A comprehensive process of engagement with stakeholders has been undertaken and the readiness process is expected to be completed in December 2018 with completion of the “Warsaw Framework” elements for REDD+.

A Forest Reference Level (FRL) or a Forest Reference Emission Level (FREL) is one of the four elements of REDD+ according to the Cancun Agreement: Decision 1/CP.16 of the United Nations Framework Convention on Climate Change (UNFCCC) at the 16th Conference of Parties (COP) in 2010. The Cancun Agreement defined a FRL/FREL as a benchmark for assessing the performance of each country in implementing a REDD+ strategy. In addition to the Cancun Agreement, decisions relating to the rules and modalities for FRL/FREL development can be found from COP 15 in Copenhagen (Decision 4), COP 17 in Durban (Decision 12) and COP 19 in Warsaw (Decision 13, of the ‘Warsaw Framework for REDD+’). The methodological guidance for FREL/FRLs contained in these decisions included, for example, the importance of consistency and transparency of data; the recommendation for a step-wise approach to development; and the process for Technical Assessment (TA) by UNFCCC experts in the

context of result-based payments (RBPs) for REDD+. Since Mongolia included Greenhouse Gas (GHG) removal estimates from carbon stock enhancement activities, as well as GHG emission reduction estimates from deforestation and forest degradation, this submission is for a Forest Reference Level (FRL) instead of a Forest Reference Emission Level (FREL), which is understood to deal with emission reduction estimates only.

Mongolia’s national stakeholders have come to an agreement on the objectives of FRL development as follows:

- 1) to access RBPs under the REDD+ initiative,
- 2) to assess the contributions that the forest sector makes toward the Nationally Determined Contributions (NDC) to the Paris Agreement of 2015, and
- 3) to assess the impacts of REDD+ policies and measures taken to mitigate and adapt to climate change in the Agriculture, Forest and Land Use (AFOLU) sector.

## 1.2. Underlying causes of forest change

Deforestation is defined as the permanent conversion of forest cover to another type of land cover, while forest degradation is the reduction of biomass in an area of forest which, while still remaining as forest, reduces the functionality of the forest ecosystem. Drivers of deforestation and forest degradation are often a complex set of interactions between direct and indirect factors, often attributing the cause to one clear driver is not possible. Table 1.1 shows the main direct and indirect drivers of deforestation and degradation in Mongolia.

**Table 1.1.** Direct and Indirect Drivers of Deforestation and Forest Degradation in Mongolia

Deforestation Drivers		Degradation Drivers		
Permanent land use change from forests to other land use		Persistent reduction in forest ecosystem function, or in the case of REDD+, in carbon stock and canopy cover, but the predominant land use remains as forest.		
Direct Drivers				
Mining and land use change Deforestation through continued degradation		Forest Fire Unsustainable logging and subsequent degradation Minor damage from pest outbreaks Grazing Fuelwood collection		
Indirect Drivers and Underlying Causes				
Demographic Factors	Socio-Economic Factors	Institutional & Governance Factors	Environmental Factors	Policy and Legal Issues

### 1.2.1. Direct Drivers of Deforestation/Degradation

Mongolian forests have low productivity and growth, and they are vulnerable to disturbance from drought, fire and pests. Forests can easily lose their ecological balance following disturbance, and, they have a relatively low ability for expansion to currently non-forested areas, all of which are due to the boreal forests location in the southern boundary of the northern hemisphere's cold forested region with a harsh continental climate. The long-term compounded effect of several drivers, such as forest fire, followed by pest infestation and grazing, often exacerbated by soil moisture loss may lead to permanent deforestation. Once disturbed, forests increasingly degrade and ultimately, they could turn into steppe with few trees or shrubs. Since several factors are compounded in deforestation, it is difficult to identify a single factor of the major cause, therefore they should be treated as a group of factors. It is due to the long-term compounded effect of forest fires, pest damage, often triggered by improper unsustainable logging, and exacerbated by uncontrolled grazing and recurrent burning inhibiting regeneration (Tsogtbaatar, 2013). Once disturbed, the resilience of a forest ecosystem decreases, and a combination of pressures from unsustainable logging, livestock grazing, fires and pests occur together. Any of these drivers can provide an entry point to a process of increasing forest degradation. Independent to the specific driver that triggered degradation, forests increasingly degrade and ultimately turn into steppe with few trees or shrubs.

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#### Mining

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Mining can also cause deforestation when mining companies remove the top soil and open pits. To date, 2,736 mining licenses have been issued covering 11 million ha (7.0 % of the total national territory). These include 1.1 m ha of exploitation licenses and 9.9 m ha of exploration licenses (MET, 2015). In 2009, in the forest provinces the total area under exploration and mining licenses is estimated to be between 2-14 % of forest areas. Further collection of detailed datasets from the Ministry of Mining needs to be undertaken. Mine-site restoration is insufficient on much of the mining areas. Technical reclamation refers to closing the mining pit; whereas biological restoration refers to re-establishing vegetation cover by sowing of perennial plants and planting trees. The absence of grown soil makes biological reclamation difficult and often establishment of vegetation cover is unsatisfactory. A mining moratorium on new areas, declared in 2010, has drastically reduced the forest land areas affected by mining activities.

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#### Forest Fire

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Forest fires affect large areas in Mongolia, generally about 95 % of these are regarded as caused by human activities, only 5 % are due to natural factors, mainly lightning (MET, 2017b). Fires most likely occur during the spring and autumn period, the highest fire risk season, when activities such as timber harvesting, use of non-timber forest products, hunting may cause forest fires.<sup>2</sup> Forest fires burn large amounts of herbaceous plants, peat, humus layer, moss, tree crowns, shrubs, and trees on the surface of the forest soil. There can be surface, ground and crown fires depending on environmental conditions and the amount of fuel in the forest ecosystem, with crown fires resulting in effects that

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<sup>2</sup> Nyamjav, Goldammer, and Uibrig 2007

are more deleterious and may lead to many tree deaths. Once burnt, forests are more susceptible to damage from pests, and are more accessible for logging, specifically for dead wood collection and grazing, as the resulting opening of crown cover will benefit grass and therefore attract grazing animals, and may lead to the deforestation through continued degradation that is described above. The effects of fire also result in increased oxidization of organic matter in soils leading to emissions several years after the forest fire incident. Recurrent burning often compounded with grazing suppresses natural regeneration that would occur in natural forests. The potential of drier summers and increased temperature, as observed in other northern hemisphere countries, may increase the risk of forest fire.

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### *Forest Pests*

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Insect damage is caused by a complex interaction of factors that are only partly human induced. Beneficial and detrimental insects in any forests live in harmony with the ecosystem, with outbreaks often being part of the natural ecological cycles. However, the ecological balance can be lost and provide suitable conditions for pest outbreak due to weakened forest tree health because of forest fire, logging, competition for water. After fire, there is high risk of pest infestation and logged-over forests tend to attract pests. Damage can be severe, but most commonly the forest will become degraded rather than undergo a land use change. Increasing aridity because of climate change has also been said to favor mass proliferation of harmful insects (Dorjsuren 2014); climate change has also been reported to lower the abundance of insect parasites which may ultimately cause increased abundance of insect pests. Minor pest outbreaks will only slow growth for one season and these tend to lead to forest degradation, herewith classified as Minor Pest Damage. If there is no further pest outbreak, or other cause of degradation, it is expected that in following years the forests will recover. Pest damage is also one of the contributing factors of degradation (combined with fire, environmental change, logging) which can lead to 'deforestation through continued degradation'.

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### *Unsustainable Logging & Fuelwood Collection*

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Many logging practices in Mongolia are unsustainable and consequently lead to long-term forest degradation. Logging companies do not follow best practices for sustainable forest management and reduced impact logging is not practiced. Though Codes of Practice are available in Mongolia, logging safeguards are usually not implemented to reduce the subsequent effects of increased fire, pest damage, and grazing following timber extraction. Unsustainable logging compromises the forests' capacity for regeneration, by increasing the risk of soil compaction, forest fire, and grazing damage. However, it should be noted that large areas of Mongolia's forests need to be placed under a sustainable forest harvesting regime to increase ecosystem health and resilience to pests and fire, and to provide economic incentives and benefits for communities and enterprises.

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## Grazing

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Mongolia has a long tradition of raising livestock, with pastoral nomadism the prevailing form of land use and an important way of life for many communities living in forested areas. Currently around one third of Mongolia's population lives as nomads from livestock husbandry. Grazing is not a driver of forest change, but works together with several other factors contributing to deforestation through continued degradation and directly affecting areas that are assigned for carbon stock enhancement. The complexity of factors is described in the section on deforestation through continued degradation. Grazing within forests is widespread in degraded or edge forests and an important factor inhibiting regeneration; animals eat young trees and it suppresses regeneration. In well stocked forest, the impact of grazing is minimal, as reported in Mongolia's National Forest Inventory (NFI) (MET, 2017c) which reported high seedling density. However, the NFI tended to only survey well stocked forests, and these are less vulnerable to grazing. Additional NFI plots that were sampled in poorly stocked and degraded forests indicated that grazing pressure was considerably more prevalent (UN-REDD, in. prep.). Grazing is therefore a contributing factor to the degradation of already disturbed forest; it also is an inhibiting factor for any natural regeneration or planting on degraded areas. Forests that tend to be better stocked, which are usually more remote from human settlements, have less grazing pressure from livestock (MET, 2017c) compared to plots which area already more degraded or low stocked, as reported from additional NFI plots in degraded areas (UN-REDD, in. prep.).

### 1.2.2. Indirect drivers of deforestation

Underlying causes of forest change include demographic, economic, technological, policy & institutional, cultural & socio-political, and environmental factors (Chapter 6 of UN-REDD, 2016). In Mongolia, technical capacity development, regulation and policy strengthening, awareness raising, and direct funding of activities for maintaining and enhancing forest carbon stocks, and sustainable forest management have promise for addressing the drivers of forest change. These broad types of policies and measures will emerge from examining the interactions between drivers' underlying causes. All drivers provide entry points for designing useful interventions to address them.

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## Demographic Factors

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*Growing population has increased the general activity levels in forest areas; and small-scale rural activities result in fires and pervasive pressure placed upon forest resources.* Population growth is compounded by urbanization and urban expansion creates a need for wood products and construction areas.

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## Socio-Economic Factors

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*Fast economic growth in recent years resulted in more government funds available for activities enhancing forest carbon stocks, such as tree planting and pest control; though this funding has been subsequently reduced because of Mongolia's economic downturn caused by a downturn in the mining*



*industry. Prior to the economic expansion, there was higher demand for wood products leading to an increase in unsustainable logging and subsequent degradation. Lingered rural poverty continues to drive unsustainable forest management, overgrazing, forest fires (or grassland fires which impact nearby forests), illegal logging and ultimately deforestation by continued degradation.*

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### *Institutional Factors*

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*Low technical capacity for forest management exacerbates forest fires and unsustainable logging and subsequent degradation; it compromises the effectiveness of pest control and tree planting. Forest skills and capacity would benefit from updating and experience from other countries facing similar issues in North America and Scandinavia. The lack of firefighting equipment is widespread, but more importantly, forest fire management techniques are outdated. Weak governance and poor transparency around the allocation of mining permits may result in deforestation. Poor compliance with applicable environmental regulations in mining can increase deforestation, reduce restoration and cause other environmental and social impacts, including possibility of communities being relocated. The lack of transparency in public procurement for services such as tree planting, may result in the selection of ineffective service providers and lack of tree care and maintenance, which significantly compromises success rates.*

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### *Environmental Factors*

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*Climate change has led to increasing occurrence of pests and compromised forests' regenerative capacity. Reduced rainfall and the increased occurrence of droughts have created unfavorable conditions for tree plantings, led to more forest fires and increased pest occurrence. The potential change in climate in Mongolia with predicted rainfall change, permafrost melting, seasonal temperature change, including extreme winters, has the potential to increase the vulnerability of the forests to snow and ice damage, forest fire risk, pest infestation, and places inordinate ecological pressure, especially through competition for water in dense forest stands, through reduced soil moisture from reduced rainfall and lost permafrost. Melting permafrost also results in increased greenhouse gas emission from peatland soils, with Mongolia supporting the 14<sup>th</sup> largest peatland area in the world (Crump, 2017), though these emissions are not considered herewith due to lack of relevant data and research.*

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### *Policy and Legal Factors*

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*The regulatory environment and law enforcement capabilities are insufficient for fire prevention, illegal logging, grazing and mining. The insufficient regulatory environment is compounded by a low capacity for law enforcement and fire prevention, which promotes unsustainable illegal logging, fails to curtail grazing activities and leads to environmentally damaging mining practices in forest areas. The political environment has overemphasized forest protection at the expense of development of a sustainable wood industry, this can be restrictive and counter-productive preventing the legalized sustainable harvesting and resource use which would ensure better management of the forest resources. The low*

harvest rates prevent an effective forest sector from developing, yet wood processing factories still demand timber, this is either imported or comes from illegal sources within Mongolia. Most government funding is allocated to tree planting and to pest control rather than being directed to investment in more effective forest management. Forest planting has not been successful despite receiving large budgets and should be reserved for selected areas with natural regeneration processes being the focus of forest establishment.

### 1.3. Nationally agreed extent of FRL components

#### 1.3.1. Scale

Boreal forests in the northern part of the steppe and taiga zone take up most of the forested area in Mongolia. Saxaul (*Haloxylon Bunge*) trees in the southern part of the desert zone form wooded land (Enkhsaikhan, 2017). It is also considered as forest land in Mongolia (FRDC, 2017).

Mongolia's FRL is national scale, that takes into account of changes in all types of forest.

#### 1.3.2. Scope: activities, pools and gases included

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#### *REDD+ activities in the FRL*

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Deforestation and forest degradation are the significant contributors of GHG emissions from forest land and therefore have been included in the emission calculation. Fire, pest outbreaks, logging and mining are the key drivers of deforestation and forest degradation in Mongolia.

Forest areas where tree canopy cover has been reduced to below 10 % by the drivers are defined as deforestation. The forest areas converted for settlement and agricultural purposes are also considered as deforestation even if the minimum threshold of 10 % canopy cover is reached.

Forest areas with a canopy cover equal to, or above, 10 % but in which canopy cover has been reduced due to fire, pest or logging activities were considered as degraded forest. Additionally, soil erosion and grazing activities are considered as continuous degradation (UN-REDD, 2016b).

Reforestation/afforestation is included as enhancement of forest carbon stocks in the FRL calculation.

No separate calculation has been considered for GHG emissions or removals due to conservation of forest carbon stocks and sustainable forest management. However, the impacts of these the two 'REDD+ activities' are considered to be covered by the measurement of emissions due to deforestation and forest degradation and by the measurement of removals due to forest carbon stock enhancement.

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### *Carbon pools in the FRL*

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Above-ground biomass (AGB), Below-ground biomass (BGB), Deadwood carbon, Soil organic carbon (SOC) and litter pools were included in the FRL. For AGB and deadwood, direct data from the NFI was used, and for BGB default estimates (root-shoot ratio) from IPCC guidance were used. Detailed methodology is outlined in the materials and methods section. With the Soil organic carbon pool considered to be stable over the reference period in case of forest loss or degradation. This to be conservative as no accurate data on the impacts of the change on this pool was available.

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### *Gases in the FRL*

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CO<sub>2</sub> released from all 5 carbon pools was included in the FRL. Other GHGs believed to be significant in terms of emissions from the forest sector include N<sub>2</sub>O, from forest fire, and CH<sub>4</sub> from permafrost melt. Work has begun on the development of emissions of these two gases, but is incomplete at the time of this submission.

#### *1.3.3. Forest definition / definitions used*

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### *Definition used for FRL*

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For the purposes of this FRL, the definition of forest closely follows that used for the NFI carried out in 2014-6 and subsequently elaborated for the purposes of measuring the additional NFI plots in less-stocked forests in 2017 (see **Table 1.1**)

The definition of 'forest' for Mongolia's boreal areas can be summarized as follows: **"Land spanning more than 1.0 hectares and a canopy cover of more than 10 percent with trees higher than 2 meters or able to reach this height threshold in situ"**.

This differs slightly from the NFI definition, in that the minimum area threshold was 1.35 ha in that exercise. The decision to adjust the forest definition for boreal forest was made by the Mongolia Technical Working Group (TWG) for National Forest Monitoring System (NFMS) and FRL development (described in Metcalfe et al., 2016). To develop historical data on forest cover change at the national scale, which had not previously been done, the TWG decided to use FAO's Open Foris Collect Earth (CE) tool (see Methods, Activity Data section below for description of the CE method). The analysis was conducted using 30m resolution Landsat imagery. A sample plot was determined to be forest land when >10% (5) sample points fell on tree cover. The NFI area threshold of 1.35 ha was not convenient to use with this system, so the TWG recommended revising the threshold down to 1 ha. As Table 1.2 explains, the minimum height threshold was also revised downwards from the FRA definition of 5 m to 2 m, to take account of the existence of some forest tree species such as birch (*Betula exilis*, *B. Humilis*) and dwarf pine (*Pinus pumila*), which do not reach 5 m in height.

Forest definition for saxaul forest was adopted from the publication of Jalbaa and Enkhsaikhan (1991). A standard table in the study provides that minimum height class is 1 m and minimum crown cover is 4.65 %. For the purposes of the CE study, a 4% area threshold was used for Saxaul forest.

The height class cannot be accurately estimated through CE study, therefore the TWG has not yet made a decision for minimum threshold of the height of Saxaul forests.

**Table 1.2** Forest definitions used in Mongolia

Source	Minimum Area	Cover Threshold	Canopy Height	Reference	Note
<b>Collect Earth</b>	1 ha	≥10 %	2 m or has the potential to reach 2 m in height (including shrub)	-	Boreal
	≥1.0 ha	≥4 %	N/A		Saxaul
<b>NFI</b>	≥1.35 ha	≥10 %	≥2 m	(Ludwig, 2014; MET, 2016).	The NFI provides estimation of per-hectare-based forest statistics from field inventory of systematic sampling plots which is consistent with the definition used for FRL.
<b>FRA</b>	≥0.5 ha	≥10 %	≥5 m	“forest and other wooded land” definition for Mongolia’s FRA report (2014)	Minimum threshold of the height was adjusted according to Mongolian condition. There are some tree species, birches ( <i>Betula exilis Sukacz.</i> and <i>B. humilis Schrank.</i> ) and dwarf pine ( <i>Pinus pumila Pallas/Regel.</i> ) as well as scrubs which grows lower than 5 m in Mongolia (Enkhsaikhan, 2016).

#### 1.3.4. Historical Reference Period

For the national GHG inventory in the BUR, Mongolia compiled a LULUCF assessment for 30 years, covering the time period from 1986 to 2016. The proposed reference period for the FRL is the 10-years period from 2005 to 2015. This allows for consistency with FRA reporting periods.

#### 1.4. Consistency with GHG inventory reporting

Both BUR and FRL reports followed IPCC land use classification categories (IPCC, 2006). Mongolia reported both boreal and saxaul forests for emissions calculation in the BUR (MET, 2017a). In the BUR, it was estimated that total forest area was 75 % boreal and 25 % saxaul, based on data from the Administration of Land Affairs, Geodesy and Cartography (ALAGAC).

ALAGAC data does not contain spatially explicit information on forest change, therefore the estimates of changes in the FRL cannot be compared directly with the BUR. Forest area and change estimates are based on the dot-grid sample approach of the CE tool described above, which provides uncertainty estimates for forested area as well as change area. Following the use of CE data as a reference in the latest BUR, it is understood that Mongolia will use CE analysis as the main source of Activity Data (AD) for the LULUCF sector for subsequent submissions of BUR in terms of area estimates and changes (MET, 2017c, Chapter 6.1.7).

Information on AGB and growth rates was obtained from the NFI report (MET, 2016). Below-ground carbon and expansion factors (BECFs), carbon fractions, above-ground and below-ground biomass ratios (AGB/BGB) are taken from the IPCC tables (IPCC 2006, Table 4.4) in the BUR.

Mongolia analyzed NFI data including additional inventory plots which are representative for the degraded and understocked forests for biomass estimates (second edition of NFI report, 2018) and growth models (Baatarbileg et. al., 2017) in the FRL emission calculation.

## 2. MATERIALS AND METHODS

### 2.1. Activity data

#### 2.1.1. *Rationale for data selection*

The following datasets were reviewed and assessed for their reliability and accuracy in the context of construction of the FRL. Mongolia has both wall-to-wall and dot-grid sampling information available for forest cover and spatially explicit forest cover changes.

1. The Open Foris tools, Collect and Collect Earth, were used to assess 123,577 systematically gridded sample points covering the entire country. Ten percent randomly chosen sample points were independently assessed to determine the operators assessment uncertainties (CCPIU, 2017). By using dot-grid sampling to assess forest area and its change from satellite imagery, the need for time consuming and vast territorial area coverage of Mongolia's image processing workload was substantially reduced. Dot-grid sampling is conceptually simple, but appropriate sample design and dot intensity are essential to ensure estimation accuracy and precision. This method was chosen for area estimation.
2. The Environmental Research Information and Study Center (ERISC) has been producing Mongolian forest/non-forest cover maps using 60 % canopy threshold since the year 2000 based on 30 m-Landsat imagery. ERISC has produced sixteen annualized forest/non-forest maps from 2000 to 2015 (Ariunzul et.al., 2017). These annualized forest/non-forest maps could be potentially a useful database to generate activity data. The ERISC mapping do not comply with the forest definition used in the FRL. The wall-to-wall ERISC maps do not provide information on degraded forest and forest gain. Moreover, the work has not been test for a robust accuracy assessment to generate uncertainty estimates. ERISC maps are therefore of limited use as a source of AD source for the FRL.

Considering the national scale and time series of forest cover information needed, the TWG on NFMS/FRL decided to use the Collect Earth land assessment, along with NFI results, for FRL construction, according to their meeting in 2016 to review FRL decisions.

Mongolia's total land area is 156,411,556 hectares. In order to assess land use and land-use change, over 123,000 regularly-distributed sample points were created and assessed across the territory of the entire country.

The Climate Change Project Implementation Unit (CCPIU), under the Ministry of Environment and Tourism (MET) led the development of AD for the FRL between the years of 2005 to 2015 using FAO's Open Foris Collect and Collect Earth (CE) tools (Bey et. al., 2015; CCPIU, 2017).

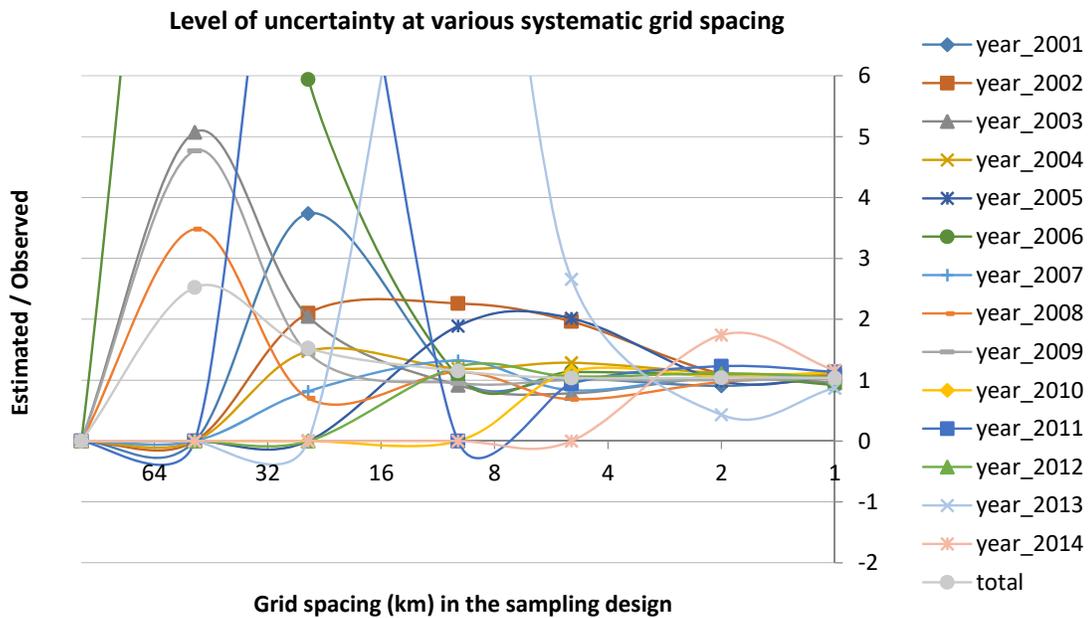
#### 2.1.2. *Sample Density*

The CE study required the selection of an optimum density of sample points that captures maximum changes of the activities within the forest, that are statistically sound, and that ensures unbiased forest change estimates. This study was used to develop forest and land use change estimates for Mongolia, not only for the FRL.

The study first examined the annual spatial changes in forests that are reported in the Global Forest Watch<sup>3</sup> (GFW) datasets and then investigated how accurately the annual area changes in GFW are captured using systematic grids at different sampling densities. The theory is that there should be an optimum sample density that serves three purposes. First, the optimum sampling density should minimise the errors in estimates. Second, the time required for analysis should be minimised. Third, it should result in an acceptable level of accuracy in estimates.

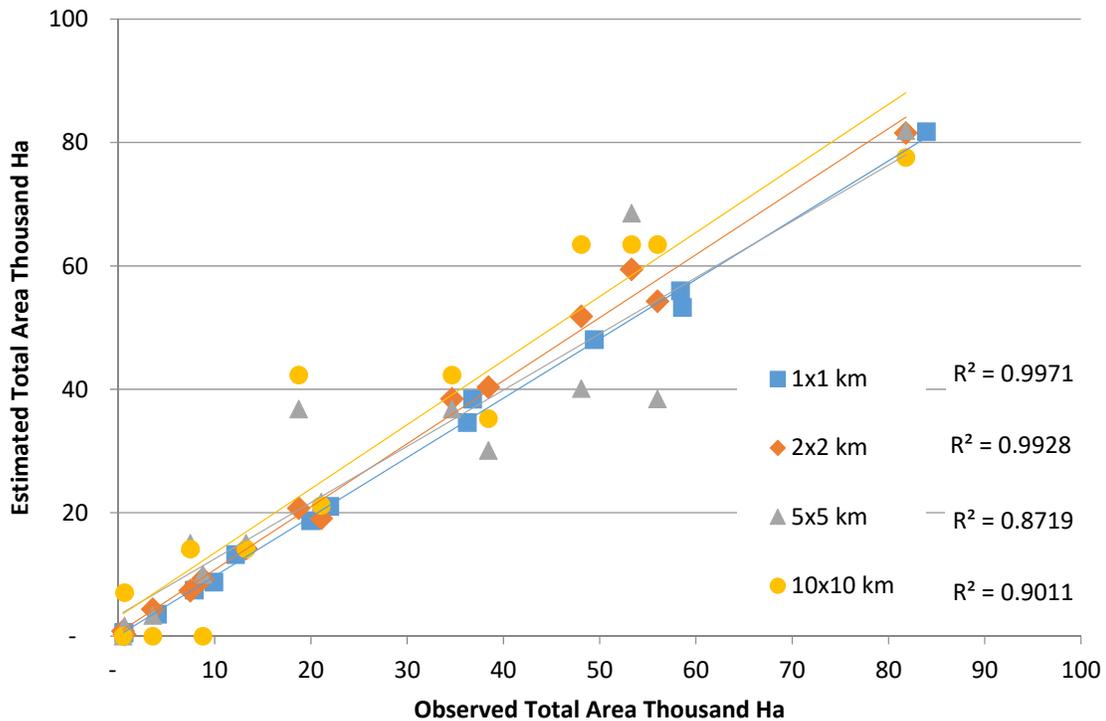
Figure 2.1 shows how the annual changes in the GFW data were actually estimated in relation to different grid point densities. It can be seen that, as might be expected, the error as expressed by the variance (the deviation from the value of 1, the ratio of estimated area to observed area) reduces as the number of points in the design increases. In the case of a country like Mongolia, with relatively small annual changes in land cover, the point at which the error is largely eliminated was shown to be a systematic grid with spacing between 1 km and 3 km. Analysis of this range suggested that, theoretically, about 99% of the changes could be captured at a systematic grid spacing between 1 km and 2 km (without consideration of operator’s error) (Figure 2.1). It was concluded that a target sample grid of 2 x 2km would be sufficient to capture annual forest changes in Mongolia.

The NFI conducted between 2014-6 used a national sampling grid of 9 x 9 km (MET, 2016). In order to enable consistency of the CE analysis with current and future NFI exercises, it was decided that the grid design for CE should be compatible with this national sampling density, hence a distance of 2.25 km between sample points was selected, as both compatible with the results of the analysis described above, and with existing national datasets.



**Figure 2.1.** Error associated with grid density and the ability of the sample grid to estimate the area of annual forest changes as recorded in the Global Forest Watch dataset for Mongolia

<sup>3</sup> <http://www.globalforestwatch.org/>



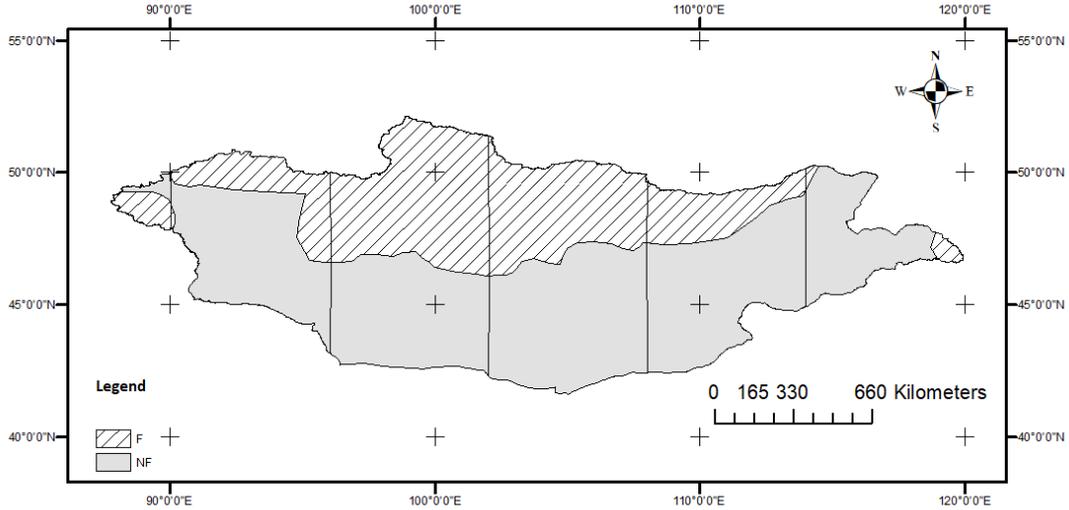
**Figure 2.2.** Analysis for optimal grid spacing design. Relationship between grid spacing and size of area change when compared to Global forest watch data as wall-to-wall information for Mongolian forest cover change.

Considering the national GHGi reporting has been conducted on a two-year cycle, it was further concluded that a grid of 2 km x 2 km (one quarter of the point density) would capture the cumulative changes taking place over a two year period with the same accuracy.

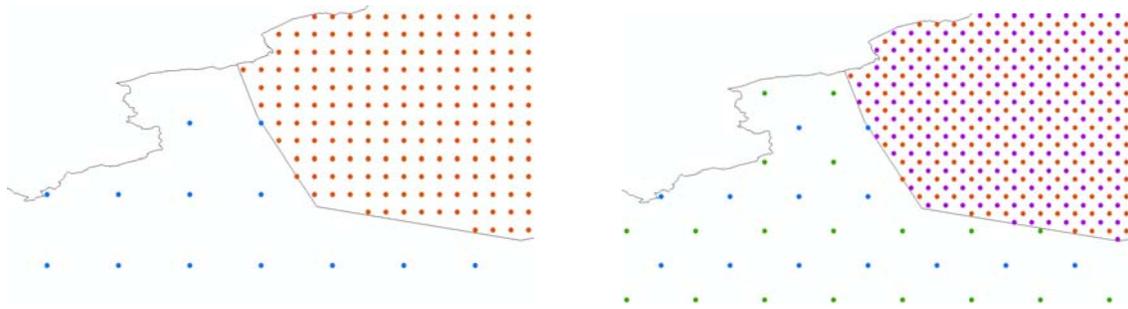
### 2.1.3. Stratification

The sample design was stratified into boreal forest zone and the rest of the country (including Saxaul forest as well as all non-forest zones). Most of the observable changes between forest and non-forest over time occur in the boreal forest zone, so the sampling density for non-boreal areas does not need to be as high.

For boreal forest areas, therefore, a 2.25 km x 2.25 km grid (as described above) was used to locate sample points and for other areas a 9 km x 9 km grid was used, with the intention that this will be consistent for all subsequent reporting of FRL and BUR. This results in a total of 123,669 sample points across the entire country. The grids have been chosen on a nested basis so that if the country decided to change density of the assessment points, the different density grids will always be coincident for any amended spacing between points. (Figure 2.3 and Figure 2.4), i.e. if the forest mask is adjusted in future, no new sample points will need to be created for non-forest areas, and new sample points for forest areas will be consistent with the existing grid.



**Figure 2.3.** Forest and non-forest strata have been used to determine the optimum density range of a systematic grid. The boundary of the forest stratum (*diagonal stripped*) was chosen to include all NFI points as well as the forest mask 2013. Gray highlighted area is non-forest.



**Figure 2.4** Coarse grids for forest 4.5 km x 4.5km and non-forest 18 km x 18km samples (*left*) and current denser grid for forest 2.25 km x 2.25 km and non-forest 9km x 9km (*right*).

#### 2.1.4. Sample Point Generation

It was decided that an equal distance sample grid would be constructed based upon the six Universal Transverse Mercator (UTM) projection zones that cover Mongolia. The alternative would be to use a grid based upon equal angular units in a geographic coordinate system (latitude/longitude), for which a single grid could be constructed for each stratum. However, in northern latitudes as in Mongolia, this results in a variable grid size and the need for a unique expansion factor for each grid point. It also creates a potential bias, in terms of the grid density (more dense in the north) and directionality of the grid (greater density in the east/west direction than north/south) which is considered undesirable.

A systematic sample design was chosen for the study. QGIS 2.14 was used to automatically generate a rectangular array of points over each zone (using a grid generator), then spatial query was used to select points from the array that fall within the stratum and UTM zone. Expansion factor for each zone is multiplied by total number of the plots to estimate total area of the polygon area (see Table 2.1).

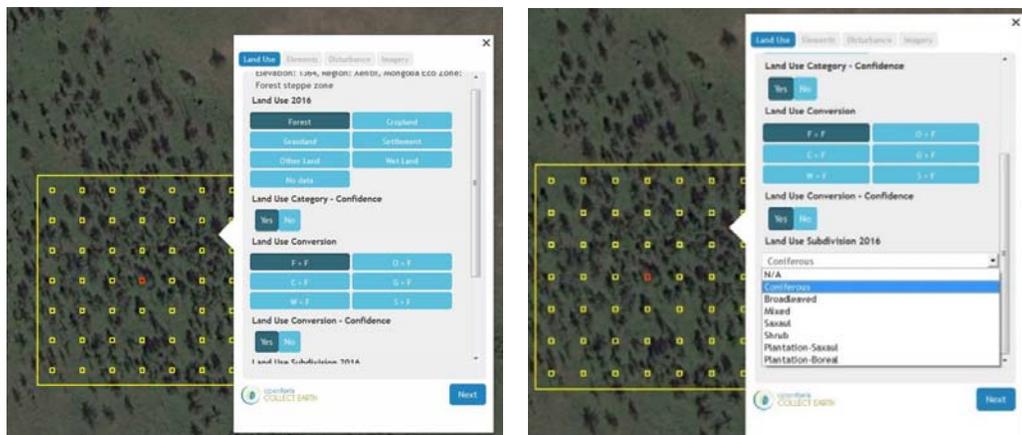
**Table 2.1** Expansion factor for each UTM zone

Strata	UTM zones	No. of points	Area (ha)	Expansion factor (ha)	Sampling density (km)
<b>Forest (boreal zone)</b>	45	3,660	1,850,126	505.50	2.25 x 2.25
	46	14,752	7,471,048	506.44	
	47	43,231	21,881,580	506.15	
	48	33,251	16,833,399	506.25	
	49	14,646	7,417,680	506.46	
	50	1,714	868,567	506.75	
	sub total	111,254	56,322,400	506.26	
<b>Non-forest (including Saxaul)</b>	45	68	579,301	8,519.13	9 x 9
	46	2,362	19,179,043	8,119.83	
	47	2,555	20,747,693	8,120.43	
	48	3,151	25,613,816	8,128.79	
	49	2,771	22,473,093	8,110.10	
	50	1,416	11,454,767	8,089.52	
	Sub total	12,323	100,047,711	8,181.30	
<b>Total</b>		<b>123,577</b>	<b>156,370,111</b>		

Detailed process of creating the sampling grids is provided in annex Collect Earth user manual (Daniel et.al., 2015).

2.1.5. Survey design

The Survey Form was designed using Collect tool to gather information in a manner consistent with the IPCC guidelines, thus enabling Mongolia to use the resulting data to address some of its data needs for reporting to the UNFCCC. Figure 2.5 shows an example of a data collection form used in this Collect Earth Land Assessment (CELA) project for collecting data on LULUCF. As shown in the figures, the CELA project used square-shaped plots of one hectare which again contains 49 sub-plot sampling points. Each sampling point, therefore, corresponds to approximately 2 % of the 1-ha sample plot. Data are analyzed at the plot level, while the sampling points can be used to quantify and characterize land cover within the plot.



**Figure 2.5.** Collect Earth land assessment form for land use and land-use change information collection.

### 2.1.6. Land-use types and use of hierarchical rules

Land use assessment follows certain rules in terms of reducing subjective effects on the result, as described in Table 2.2.

**Table 2.2** Land use assessment hierarchy and land cover thresholds

	Land use categories	Classification rule, %
1	Settlement	14
2	Cropland	14
3	Forest	
	Boreal	10
	Saxaul	4
4	Grassland	14
5	Wetland	14
6	Otherland	14
	No data	Omitted

For the historical assessment, the level of disturbance is associated with the different land use categories as a result of human impact, i.e., fire/pest, logging, grazing, soil and soil erosion. The degree of disturbance impact is determined by the operators’s own interpretation. As for the land use change, the operator has to use Google Earth Engine with different time series of Landsat imagery to determine the actual year of change from one land use conversion to another.

### 2.1.7. Response design

The desired goal of this validation was to derive a statistically robust, quantitative assessment of the uncertainties associated with the forest area change estimates. Several factors potentially impact on the quality of forest mapping (GOFCC GOLD, 2015), namely

- The spatial, spectral and temporal resolution of the imagery
- The radiometric and geometric pre-processing of the imagery
- The automated and manual procedures used to interpret the forest map category
- Thematic standards (i.e. minimum mapping unit and land use definitions)
- The availability of field reference data for evaluation of the results.

Approaches were used in the case of Mongolia’s FRL to minimize these sources of error following IPCC and GOFCC-GOLD good practice guidelines, as appropriate. However, the representativeness of reference data and sample selection of the accuracy assessment of change area were slightly compromised by the restricted availability of high-spatial resolution archived imagery in Google Earth and Bing Map across Mongolia.

Through a collect survey design form (see Figure 2.5), using *Open Foris Collect*, the six Land cover types were assessed within each sample through an expert image interpretation of medium (15-m pan-sharpened Landsat) to very high (sub-meter) spatial resolution aerial imagery and satellite data. The map and reference datasets used in the accuracy assessment are listed in Table 2.3. The reference

datasets have sufficient temporal representation consistent with the change period: 2005-2015. The collect survey design form has been set for each reference label to allow a certain confidence-level to be specified by an interpreter.

**Table 2.3.** Validation datasets used for sample assessment

Data types	Spatial resolution	Source
<b>High-resolution RGB imagery from various satellite sensors, such as SPOT, GeoEye-1, WorldView-1/2/3, Digital Globe, IKONOS, etc.</b>	10-m to 30-cm	Google Earth Pro/ Bing Maps
<b>Landsat time series archive: 2005-2015</b>	30-m (15-m pan-sharpened)	Google Earth Engine Landsat/Sentinel MSI 2 Archive

#### 2.1.8. Analysis design

Appendix 1 shows the analysis design for six IPCC land cover/use categories and forest/non-forest categories respectively. Appendix 2 illustrates the calculation of estimators for a systematic random sampling design, following the guidelines for GFOI (2016). The sample-based estimates were derived using the survey package (Lumley, 2004 and 2014) available with the statistical package R Core Team (2014). The survey package uses the standard formulae for estimation of means and variances.

## 2.2. Emission Factors

#### 2.2.1. National Forest Inventory

The multipurpose national forest inventory (NFI) carried out from 2014-6 covers boreal forests in 2014 for the purpose of state forest policy development, strategic planning and reporting (MET, 2016).

The detailed process of field inventory, creation of forest mask, allocation of sampling units for NFI, description of NFI database structure, NFI estimation methods and data models and estimation of litter and soil carbon stocks in forest areas in Mongolia are provided as annexes to the report of the Mongolian multipurpose national forest inventory 2014-2016 (MET, 2016).

Due to the NFI sampling design, there was a lack of information regarding EFs from low stocked forests in the boreal forest area because the applied Forest Mask 2013/2015 covered only the dominant well stocked forest areas, with approximately 66 % canopy cover or more. For forest cover and change data to be consistent with the national forest definition, where the canopy cover threshold is 10 %, additional NFI plots needed to be surveyed to cover lower-stocked forest areas. The reason for low stocking is usually forest fire, logging, pests or natural harsh conditions causing parse forest structure. This exercise was organized in 2017 by the Mongolia UN-REDD National Programme, with 156 new NFI clusters measured, representing 1,583,492 ha low-stocked forest area.

The updated analysis of NFI is undertaken by collaboration with FRDC, NUM, GIZ and UN-REDD programme and will be available in 2018 as the 2<sup>nd</sup> Edition of the multipurpose NFI report.

To estimate the values related to inventories parameters, including tree stem volume, dead wood biomass and above-ground carbon stock, different data models have been applied. Tutored examples

to estimations of NFI parameters are provided in the multipurpose NFI report as annex 8 (MET, 2016). None of the NFI plots were located in Saxaul forest and Shrub forest and country-specific biomass or EF data are lacking for those two forest types. Therefore, this FRL has not considered Saxaul forest and Shrub forests in emission factor calculation and this is an area for future improvement. The Saxaul forest and Shrub forest cover has been stable since 2005 (Table 3.2. Change between forest and non-forest cover types over the reference period 2005-2015) and the lack of EF data for those two forest types has hence no impact on the Forest Reference Level emission and removal estimates.

### 2.2.2. Biomass calculations

The Institute of General and Experimental Biology (IGEB) of the Mongolian Academy of Science (MAS) has carried out a field survey of biomass of the main tree species of Mongolia (Dorjsuren, 2017; MET, 2016). The allometric models (Eq. 1) were based on the relationship between above-ground biomass (AGB) and diameter at breast height (DBH) and total height of tree ( $H_{tot}$ ) measurements.

$$AGB = a * DBH^b \times H_{tot}^c \quad \text{Eq.1}$$

Where:

AGB = Above-ground live Biomass (tonnes), (= dry biomass of stem incl. bark, branch and leaves)

DBH = Tree stem diameter (m) at breast height (1,3m)

$H_{tot}$  = Tree total height/length (m)

a = Species specific factor

b = Species specific DBH exponential factor

c = Species specific  $H_{tot}$  exponential factor

The species specific coefficients can be found in MPNFI report (MET, 2016).

AGB was estimated from NFI field sample data and BGB was estimated from IPCC default value of R/S ratio in boreal forest (Eq. 2) with a criteria of equal to or above 75 tonnes of dry AGB per ha (Table 2.4).

$$BGB = AGB * RSR \quad \text{Eq. 2}$$

Where:

BGB = Below-ground Biomass

RSR = Root-Shoot ratio for Boreal forest

**Table 2.4** Below-ground living tree biomass as proportion of above-ground living tree biomass

BGB/AGB Root-Shoot ratio for Boreal forest	
AGB<75	AGB>=75
0.39	0.24

Dead wood biomass was calculated as the sum of three types of biomass: standing above-ground dead biomass, lying dead wood (branch  $\geq$  5cm DBH), and stump and below-ground dead biomass (Eq. 3). The three types of dead wood were calculated separately (Eq. 4-6).

$$DW_{total} = DW_{ground} + DW_{standing} + DW_{BGB} \quad \text{Eq. 3}$$

$$DW_{ground} = D_m^2 * \frac{\pi}{4} * L * (100 - Bd) \quad \text{Eq. 4}$$

Where:

$DW_{ground}$  = Dead Wood Ground Biomass (based on mid-log diameter, log length and decay)

$D_m$  = Diameter at middle length of a log

L = Log length

Bd = decay as percentage

$$DW_{standing} = a * DBH^b * Htot^c * (100 - Bd)/100 \quad \text{Eq. 5}$$

Where:

$DW_{standing}$  = Dead Wood Standing Biomass (*only stem*)

$$DW_{BGB} = AGB * RSR \quad \text{Eq. 6}$$

$DW_{BGB}$  = Dead Wood Underground Biomass (based on stump/tree DBH and decay)

### 2.2.3. Emission estimation

The multipurpose NFI 2014-6, and additional NFI plots measured in 2017, were used as a basis for emission factors and the calculation of carbon stock, following the general guidelines of IPCC (2006) on the gain/loss method (Eq. 7).

$$\Delta C = \Delta C_G - \Delta C_L \quad \text{Eq. 7}$$

Where:

$\Delta C$  = annual carbon stock change in the pool, tonnes C yr<sup>-1</sup>

$\Delta C_G$  = annual gain of carbon, tonnes C yr<sup>-1</sup>

$\Delta C_L$  = annual loss of carbon, tonnes C yr<sup>-1</sup>

Overall, carbon stock changes within a forest stratum are estimated by adding up the changes in all carbon pools as in Eq. 8.

$$\Delta C_{LU_i} = \Delta C_{AGB} + \Delta C_{BGB} + \Delta C_{DW} + \Delta C_{LI} + \Delta C_{SO} \quad \text{Eq. 8}$$

Where:

$\Delta C_{LU_i}$  = carbon stock changes for a stratum of a forest land-use category

$i$  = denotes a specific stratum or subdivision within the land-use category

AGB – above-ground biomass, BGB – below-ground biomass, DW – dead wood, LI – litter, and SO - soils

The following equation (9) is used to calculate the FRL in tonnes of carbon dioxide equivalent (t CO<sub>2</sub>e):

$$FRL_{Def\&Af} = \frac{\sum_t \Delta C_{Bt,Def} + \sum_t \Delta C_{Bt,Af}}{p} * \frac{44}{12} \quad \text{Eq. 9}$$

Where:

$FRL_{Def\&Af}$  = annual mean losses of carbon stocks from forest land during the reference period, in tonnes of CO<sub>2</sub>e year<sup>-1</sup>



$\Delta C_{B,t,Def}$  = change in carbon stocks in forest land converted to non-forest land, and in forest land which has undergone degradation, in year t of the reference period, in tonnes of C.

Reference is made to the reservoirs included below.

$\Delta C_{B,t,Af}$  = change in carbon stocks in non-forest land converted to forest land in year t of the reference period, in tonnes of C.

p = years in the reference period, 10 years (2005-2015)

$\frac{44}{12}$  = factor for converting carbon to CO<sub>2</sub> equivalent, t CO<sub>2</sub>e

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### *Land use change – Deforestation and Re/Afforestation*

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Forest converted to other land was considered to lose 100% of four carbon pools: AGB, BGB, DW and Litter. Non-forest land converted to forest land was calculated as 100% gain of two carbon pools: AGB and BGB.

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### *Forest remaining forest – changes of carbon stock due to disturbances*

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Mongolia does not include natural growth as gain in the calculation and only considers losses which were identified through the NFI when forests were disturbed by fire/pest and logging activities. The emission factors developed from NFI data, correlated with CE disturbance assessment, resulted in two different biomass estimates for intact and disturbed forest areas (see Table 3.3).

Due to the limited number of samples for broadleaved and mixed forests during the CE study, it was not possible to develop specific EFs for different forest categories. Therefore, the EF estimates for both intact and disturbed forests are assumed to be the same for all forest types.

EFs for degraded forest due to forest fire/pest and logging disturbances were developed by calculating mean or median values and associated confidence interval ranges, depending on the distribution of the 4,080 plot values.

AGB, BGB and DW carbon pools have intact and disturbed forest type separation. For litter and soil, single carbon stock estimates were used for both intact and disturbed forests.

The estimation of carbon in living biomass and in dead wood is estimated by converting the corresponding biomass pools to carbon with IPCC 2006 recommended carbon fraction for boreal coniferous trees, 0.51 tonnes carbon per tonne dry biomass. The carbon content per hectare values for litter and soils are adopted from the 2014-6 NFI (MET, 2016).

### 3. RESULTS

#### 3.1. Area estimates

Table 3.1 shows the total area estimates along with 95% confidence interval (CI) under the six IPCC land cover classes during 2005-2015, derived from the 123,472<sup>4</sup> systematic random samples. The area estimates (156,309,341 ha) are the sum of the expansion factors of the samples identified under each IPCC land cover class. During the reference period, the most dominant land use category is grassland, which covers approximately 80 % of the country. Forest land is the second major land use in Mongolia, which covers approximately 10 % of the total land area. The forest area was 15.5 million ha in the year 2005, with standard error (SE) of 0.1 million ha; at 95 % CI the forest cover was between 15.2 and 15.8 million ha. In 2015, the forest cover declined to 15.4 million ha, with SE of 0.1 million ha, and between 15.1 - 15.8 million ha at 95 % CI (see Table 3.1). Contrary to the forest cover trend, land area under settlements has expanded by approximately 53,700 ha during 2005-2015. The remaining land cover classes have remained relatively stable during the reference period.

**Table 3.1.** Sample-based area estimates (ha) in Mongolia under the six IPCC land cover classes in 2005, 2010, and 2015.

IPCC categories	Total area	Standard error (SE)	95% Confidence Interval	
			Lower-2.5%	Upper-97.5%
Year 2005				
Hectare (ha)				
<b>Cropland</b>	1,392,327.0	51,543.6	1,291,304.0	1,493,350.0
<b>Forest</b>	15,513,267.0	154,972.7	15,209,526.0	15,817,008.0
<b>Grassland</b>	124,336,515.0	764450.3	122,838,220.0	125,834,810.0
<b>Other land</b>	12,187,411.0	297,604.0	11,604,117.0	12,770,705.0
<b>Settlement</b>	1,333,698.0	83,456.0	1,170,128.0	1,497,269.0
<b>Wetland</b>	1,546,122.0	71,710.0	1,405,571.0	1,686,673.0
Year 2010				
<b>Cropland</b>	1,383,711.0	50,901.0	1,283,947.0	1,483,475.0
<b>Forest</b>	15,469,215.0	154,936.5	15,165,545.0	15,772,885.0
<b>Grassland</b>	124,357,252.0	764389.3	122,859,076.0	125,855,427.0
<b>Other land</b>	12,187,411.0	297,604.5	11,604,117.0	12,770,705.0
<b>Settlement</b>	1,364,112.0	84,280.2	1,198,926.0	1,529,298.0
<b>Wetland</b>	1,547,640.0	71,716.0	1,407,080.0	1,688,201.0
Year 2015				
<b>Cropland</b>	1,389,283.0	50,927.5	1,289,466.0	1,489,099.0
<b>Forest</b>	15,463,645.0	154,932.0	15,159,984.0	15,767,306.0
<b>Grassland</b>	124,341,548.0	764,404.7	122,843,343.0	125,839,754.0
<b>Other land</b>	12,187,411.0	297,605.0	11,604,117.0	12,770,705.0
<b>Settlement</b>	1,387,428.0	84,713.3	1,221,392.0	1,553,463.0
<b>Wetland</b>	1,540,027.0	71,258.3	1,400,363.0	1,679,690.0

<sup>4</sup>Of the 123,577 samples, 105 samples were omitted due to cloud cover. Assessment area sum is less than the country's total territory by 53,160 ha.

### 3.2. Rate of change

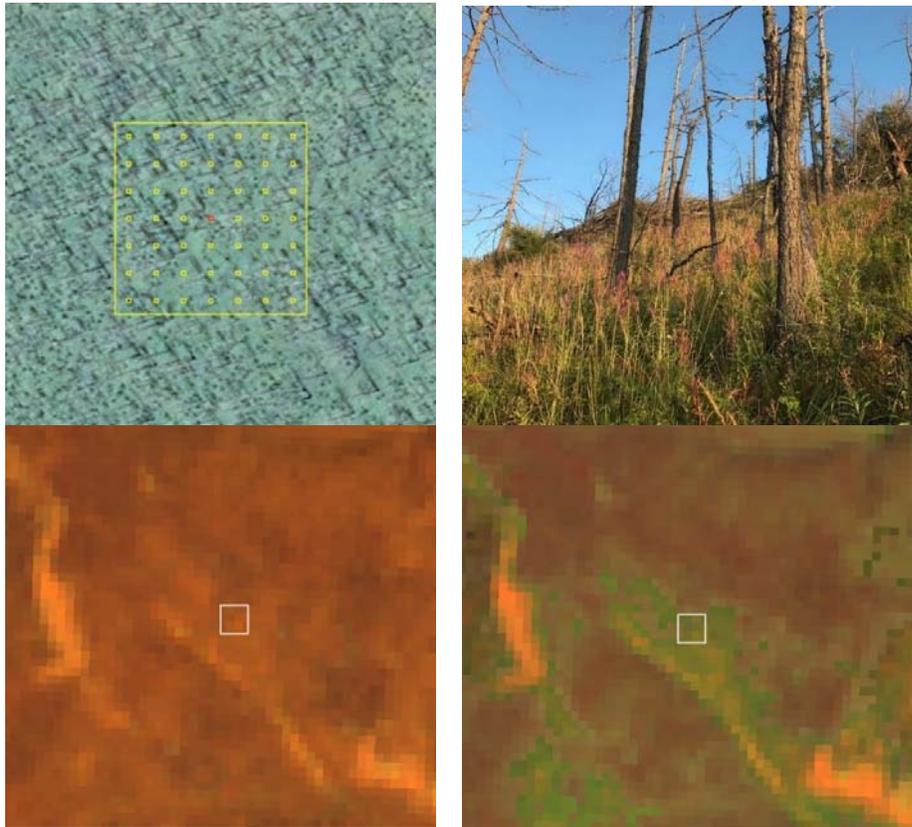
Three land cover change matrices were produced from the samples for 2005-2010, 2010-2015 and 2005-2015 for IPCC land cover classes (Appendix 3) and forest/non-forest classes (Appendix 4). According to the figures shown in Appendix 4, about 51,647 ha, (at SE 5,109 ha, 95% CI (41,632 ha, 61,662 ha)) of forest has been converted into grassland during 2005-2015, and this conversion into grassland was a major cause of forest loss during the reference period. A similar amount of grassland - 52,717 ha, (at SE 14,566 ha, 95% CI (24,173 ha, 81,261 ha)) - has been converted to settlements during the same period, reflecting a period of accelerated urban expansion.

Between forest/non-forest land cover types, the analysis shows that deforestation occurred in 104 samples (out of 123,472 total), while only 6 samples showed forest gain during 2005-2015 (see Appendix 3). Therefore, loss outstripped forest gain during the reference period. The area under Saxaul forest cover has been relatively stable since 2005, but further analysis is required to obtain accurate AD for Saxaul.

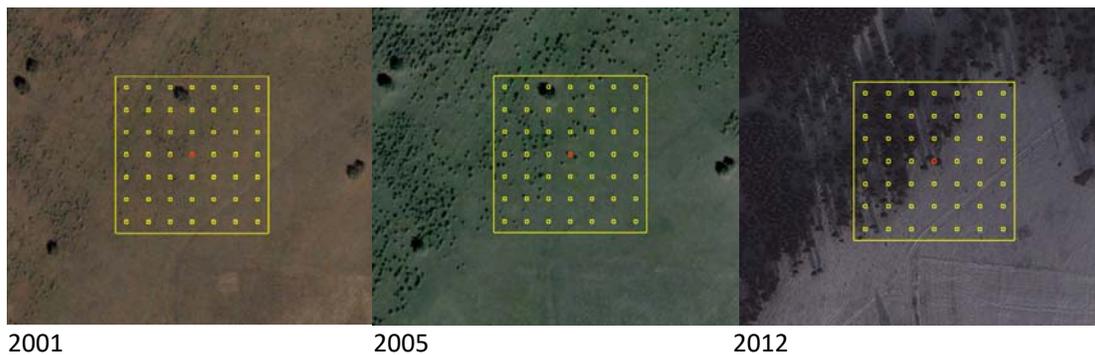
Table 3.2 shows sample-based estimates of forest changes in Mongolia from 2005 to 2015. 11.9 million ha of forest has remained intact during 2005-2015. 1.4 million ha of intact forest has been degraded during this period due to fire, repeated burning, logging and other activities. 52,660 ha of intact forest has been completely lost during the reference period. Examples of forest loss (deforestation) detected in the Collect Earth-based sample assessment are illustrated in Figure 3.1, while Figure 3.2 shows an example of forest gain, identified using high-spatial resolution Google Earth imagery.

**Table 3.2.** Change between forest and non-forest cover types over the reference period 2005-2015.

Year of assessment		Mean	Std. Error.	95% Confidence Interval		
2005	2015			2.50%	97.50%	±(%)
<i>Stable classes</i>		<b>Area in ha</b>				
<b>Intact forest</b>	Intact forest	11,902,880.0	85,783.6	11,734,740.0	12,071,010.0	1.4
<b>Disturbed forest</b>	Disturbed forest	110,867.7	7,482.2	96,202.9	125,532.4	13.2
<b>Saxaul forest</b>	Saxaul forest	2,048,003.0	128,498.3	1,796,151.0	2,299,855.0	12.3
<b>Shrub forest</b>	Shrub forest	766,739.7	38,646.9	690,993.1	842,486.3	9.8
<b>Non-forest</b>	Non-forest	140,030,300.0	808,637.4	138,445,400.0	141,615,200.0	1.1
<i>Change classes</i>						
<b>Intact forest</b>	Disturbed forest	1,394,810.0	28,504.0	1,338,943.0	1,450,676.0	4.0
<b>Intact forest</b>	Non-forest	52,659.7	5,159.5	42,547.3	62,772.2	19.2
<b>Non-forest</b>	Disturbed forest	506.5	506.3	-485.8	1,498.7	195.9
<b>Non-forest</b>	Intact forest	2,531.2	1,131.5	313.5	4,748.9	87.6

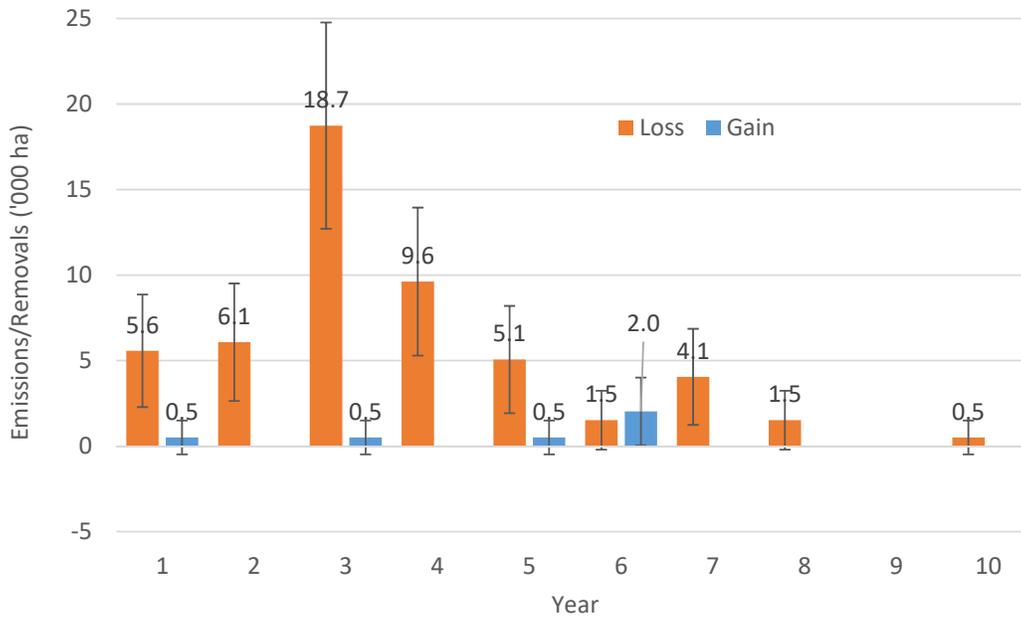


**Figure 3.1.** Forest land in 2008 converted into grassland (Set17, id: 80832) in 2009. High spatial resolution Google earth imagery (*top-left*), burnt forest photo (*top-right*) illustrates the type of land cover as a validation data for Landsat. Annual Greenest-Pixel top of atmospheric (TOA) Reflectance Composites for years 2008 (*bottom-left*) and 2009 (*bottom-right*) are displayed in false color composite (NIR\_SWIR1\_Red in RGB channels). The 1ha sample plot in the 2008 Landsat 30-m image shows forest cover (dark brown) while the 2009 image indicates grassland (green) cover.



**Figure 3.2.** Non forest converted to forest land (Set42, id: 106298, G>F 100 m \* 100 m or 1-ha plot) identified using high-spatial resolution Google Earth imagery in 2001 (*left*), in 2005 (*middle*) and in 2012 (*right*). The high-spatial resolution imagery in Google Earth (left), shows afforestation which probably occurred prior to 2001, identifiable through some scattered crowns. Therefore, an operator assessed the plot as non-forest (Grassland) in 2005, according to the dominant land cover type, but then as Forest land in 2012, due to  $\geq 10\%$  tree canopy cover.

Figure 3.3 shows the amount of sample-based forest loss and/or gain estimated per year from 2006 to 2015 where year 1 means forest change (loss/gain) estimated during 2005-2006 and so on. Most of the forest loss has been reported during 2005-2010 with a very insignificant amount of forest enhancement. The greatest amount of deforestation was recorded in year 3 (2007-2008) during the reference period, with 18,700 ha converted due to numerous incidence of severe forest fire. Compared with deforestation, gain in forest area was relatively scarce, occurring only in years 1, 3, 5 and 6.



**Figure 3.3.** Annualized sample-based forest loss (deforestation) and forest gain (enhancement) estimates over the reference period: 2005-2015. The error-bar showing lower and upper limit of forest change estimates for corresponding year at 95% confidence interval.

Over the period 2005-15, forests have been converted to non-forest land at an average annual rate of 5,266 ha. Conversely, 304 ha of forest per year have been gained, based on the assessment of 123,457 samples during the reference period: 2005-2015. These figures are not consistent with the FRA report on forest change during 1990-2015 (FAO 2015), which used forest cover data derived from the Taxation Forest Inventory (TFI). The TFI estimates forest cover over a 10 year period rather than an annualized forest cover map, through visiting the same area at 10-year intervals. In addition, the TFI estimates forest cover based on ocular methods and defines forest based on relative stem density at equal to or higher than 0.3. Therefore, the change estimates from TFI are less reliable compared with the CE sample-based assessment used for this FRL submission, which was also aligned with data from the 2014-6 NFI and is therefore considered more accurate.

### 3.3.Result of Emission Factors

Figure 3.2Table 3.3 shows the biomass values for above-ground, below-ground and deadwood carbon pools estimated from the 4,080 NFI plots which were aligned with the CE study. The dry carbon content (tC per ha) of all five carbon pools are presented in

Table 3.4. Intact forest and disturbed forest classes contain 147.2 tC per ha and 139.4 tC per ha, respectively. The difference between the intact forest and disturbed forest categories was because of the differences in AGB, BGB and DW pools.

**Table 3.3.** Biomass estimates (tons per ha) for above-ground, below-ground and dead wood carbon pools in the intact and degraded plots, respectively.

Variables	Observations	Mean	Std. Err.	[95% Confidence Interval]	
				Lower-2.5%	Upper- 97.5%
<b>Disturbed forest plots</b>	Number			Biomass (t. ha <sup>-1</sup> )	
<b>Above-ground</b>	843	52.6	1.5	49.6	55.6
<b>Below-ground</b>	843	16.0	0.4	15.2	16.7
<b>Dead wood</b>	843	23.5	1.0	21.5	25.4
<b>Intact forest plots</b>					
<b>Above-ground</b>	3,237	67.7	0.8	66.1	69.3
<b>Below-ground</b>	3,237	19.6	0.2	19.3	20.0
<b>Dead wood</b>	3,237	13.3	0.4	12.5	14.0

**Table 3.4.** Estimation of organic carbon content (tC per ha) in five different carbon pools for intact and disturbed forests plots, respectively.

Variables	Observations	Mean	Std. Err.	[95% Confidence Interval]	
				Lower-2.5%	Upper- 97.5%
<b>Disturbed forest plots</b>	Number	Carbon (tC. ha <sup>-1</sup> )			
<b>Above-ground</b>	843	26.8	0.7	25.3	28.4
<b>Below-ground</b>	843	8.1	0.2	7.7	8.5
<b>Dead wood</b>	843	4.7	0.3	4.1	5.3
<b>Litter</b>	196	15.9	1.1	13.7	18.1
<b>Soil</b>	196	83.8	3.6	76.7	90.9
<b>Total</b>		<b>139.4</b>	<b>1.0</b>	<b>137.4</b>	<b>141.3</b>
<b>Intact forest plots</b>					
<b>Above-ground</b>	3,237	34.5	0.4	33.7	35.4
<b>Below-ground</b>	3,237	10.0	0.1	9.8	10.2
<b>Dead wood</b>	3,237	3.0	0.1	2.7	3.3
<b>Litter</b>	196	15.9	1.1	13.7	18.1
<b>Soil</b>	196	83.8	3.6	76.7	90.9
<b>Total</b>		<b>147.2</b>	<b>0.5</b>	<b>146.2</b>	<b>148.3</b>

**Table 3.5** shows EFs from four change classes: from intact forest to disturbed forest (7.8 tC/ha, ±38.5% at 95% CI), intact forest to non-forest (63.4 tC/ha, ±1.7% at 95% CI), non-forest to disturbed forest 34.9 tC/ha, ±2.3% at 95% CI) and non-forest to intact forest (44.5 tC/ha, ±4.5% at 95% CI). Although the EF from deforestation (intact forest > non-forest) is about eight times higher than that for degraded forest, a significantly larger area of intact forest (1.4 million ha) has been converted to disturbed forest during the reference period than has been subject to deforestation. An estimated 85% of the net emissions, therefore, are estimated to originate from degraded forest during 2005-2015. Compared with degraded forest, deforestation resulted in approximately 15% of annual CO<sub>2</sub> emissions from forests.

**Table 3.5.** Emission factors (tC per ha) for four different REDD+ activities during the reference period 2005-2015 in Mongolia.

Year 2005	Year 2015	Mean	Std. Err.	95% Confidence Interval		CI range (%)
				Lower 2.5%	Upper 97.5%	
Land cover type		Area in ha				
<b>Intact forest</b>	Non-forest	63.4	0.5	62.4	64.5	1.7
<b>Intact forest</b>	Degraded forest	7.8	0.4	4.8	10.8	38.5
<b>Non-forest</b>	Intact forest	44.5	0.5	43.5	45.6	4.5
<b>Non-forest</b>	Degraded forest	34.9	1.0	33.0	36.8	2.3

**Table 3.6.** Carbon emissions and removals in Mongolia during the reference period: 2005-2015 from various change areas as a result of various drivers of change classes.

Reference period: 2005-2015	Area (ha)	Carbon emissions (tC/ha)	C emissions/ removals (tC)	CO <sub>2</sub> emissions / removals (tCO <sub>2</sub> )	CO <sub>2</sub> emissions/ removals (tCO <sub>2</sub> /yr)
Change	AD	EF	AD*EF	[AD*EF] * [44/12]	
<b>Intact forest &gt; Non-forest</b>	52,659.7	63.4	3,338,625.0	12,241,624.9	1,224,162.5
<b>Intact forest &gt; Degraded forest</b>	1,394,810.0	7.8	10,879,518.0	39,891,566	3,989,156.6
<b>Non-forest &gt; Intact forest</b>	2,531.2	44.5	-112,638.4	-413,007.5	-41,300.8
<b>Non-forest &gt; Degraded forest</b>	506.5	34.9	-17,676.9	-64,815.1	-6,481.5
Net emissions					<b>5,165,536.8</b>

Note: (-) indicates removals and no sign indicates emissions.

### 3.4. The Forest Reference Level

Total CO<sub>2</sub> emissions from deforestation and forest degradation, and removals from carbon enhancement, from areas within forests during the historical reference period from 2005 to 2015 are presented in Table 3.6. During the reference period, net CO<sub>2</sub> emissions of the three REDD+ activities does not show any clear trend (see Figure 3.4). It is therefore considered most appropriate that the annual average value of 5,165,536.8 tCO<sub>2</sub>e should be used for Mongolia's FRL. Mongolia's annual GHG emissions and removals from the forestry sector were estimated as 5,213,319 tCO<sub>2</sub>e and 47,782 tCO<sub>2</sub>e, respectively, during the reference period 2005-15.



**Figure 3.4.** Mongolia’s annual CO<sub>2</sub> emissions from deforestation and forest degradation and removals through afforestation activities during 2005-2015.

### 3.5. Uncertainty analysis for Activity data

A total of 123,577 sample plots were used to assess Mongolia’s land use and land use changes. Among the total number of sample plots, 105 plots were not used for uncertainty assessment due to no data. Accuracy assessment of different operators was done using a 10 % random sample of the total sample plots. Samples were randomly selected and independently re-assessed by the most experienced operators among the team (CCPIU, 2017). Results show a 93 % consistency between the operators and the independent re-assessors of the six IPCC land use categories. A field quality control measurement was undertaken in different types of land use and disturbance factors. Results show that 11 % of differences occurred in forest land when counting tree elements.

In terms of activity data and emissions factors, the sampling error and associated uncertainties were estimated by using systematic random sample design estimators. The uncertainty of each IPCC land use category was assessed. Uncertainty analysis in various conversions among the forest, degraded forest and non-forest classes occurred during the reference period were conducted and the results were reported in the previous sections.



## 4. NATIONAL CIRCUMSTANCES

National circumstances in Mongolia are different from most other REDD+ countries as the major drivers of deforestation and degradation are a complex mixture of anthropogenic and natural impacts, compounded by poor forest management which has increased the forests' vulnerability. These drivers can aggravate forest vulnerability when combined with the impact of ongoing climate change, which is already 3 times more serious than the global average, in terms of mean temperature change (Chapter 6.6 Environmental Factors of UN-REDD, 2016b; Chapter 1.2 Natural Resources of MET, 2017b). Impacts include increased severity of winters, prolonged dry season, modified rainfall pattern, glacier and permafrost thawing, which may in turn lead to changes in vegetative growth pattern and forest health. It is therefore important for the establishment of the FRL, and for the medium-term prediction of GHG emissions over the next 20-30 years, to extrapolate what the effect of these already expected changes will be on predictions of land cover change. Although this first FRL submission does not suggest an adjustment to take these national circumstances into account, the extent to which future emissions can effectively be reduced through climate change related policies and measures should be investigated in the next cycle of FRL submission.

## 5. FUTURE IMPROVEMENT

### 5.1. Improvement in quality of the Saxaul NFI

Saxaul Forest data inclusion in the modification process of FRL or the next submission is now being considered. The following actions are proposed to construct emission factors and estimate emissions and removals from Saxaul forest areas by setting Permanent Sampling Plots and configuring Saxaul population area:

1. Identify CE samples with saxaul forest
2. Check the distribution of the CE samples with saxaul forest in the digital elevation model
3. Check with ecoregions and soil type maps/information
4. Review various published studies/reports on saxaul forest to understand the ecology of this forest types
5. Develop methods for mapping, EF and monitoring saxaul forest.

### 5.2. Diversifying carbon pools

Mongolia collected soil and litter samples which represent degraded and low stocked forests during the additional NFI in 2017 (MET, In Prep). Therefore, soil and litter layer carbon contents will be analyzed for the additional samples and modified calculations will be complete for these two carbon pools.

### 5.3. Fraction of biomass loss from disturbance

The proportion of biomass loss from each disturbance event can be defined to reflect level of decaying or oxidization in trees.

### 5.4. Inclusion of non-CO<sub>2</sub> GHGs

Initial studies have been carried out on the relative importance of non-CO<sub>2</sub> GHGs, including CH<sub>4</sub> from the impact of deforestation and degraded forest on the permafrost layer, and NO<sub>2</sub> from degraded forest caused by forest fire. These studies indicate that further work is required to develop data with a view to including these two gases in future FRL submissions.

### 5.5. Enhancement in consistency between BUR and FRL

Despite some differences between the BUR (MET, 2017a) and FRL assessment being attributable to the difference in methodology and the more recent data used for the FRL, the majority of the difference between the net removals from LULUCF reported in the BUR and the net emissions from the forest sector as assessed for this FRL report lies in removals in forest land remaining forest land. The FRL only considers reforestation/afforestation as enhancement of forest carbon stocks, i.e. enhancement if non forest land converted to forest land, but does not include enhancement in forest land remaining forest land. Mongolia has a vast growing forest area which sequesters a very large amount of carbon (Dulamsuren et al., 2016). To assess these removals in an accurate manner, additional information on age structure is needed which is currently lacking and for this reason Mongolia has not included enhancement of forest carbon stocks in forest land remaining forest land. In addition, no major changes in removals in forest land remaining forest land are expected - though concerning a vast amount of removals, the growing forest is expected to sequester a similar amount of CO<sub>2</sub> during the results reporting period as during the historical FRL period.

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## APPENDIXES

### Appendix 1

Structure of change sample assessment matrix for Forest/Non-forest cover classes

		Time 2					Total	
Time 1	IPCC land cover types	Cropland	Forest	Grassland	Other land	Settlements	Wetland	
	Cropland	$p_{11}$	$p_{12}$	$p_{13}$	$p_{14}$	$p_{15}$	$p_{16}$	$p_{1.}$
	Forest	$p_{21}$	$p_{22}$	$p_{23}$	$p_{24}$	$p_{25}$	$p_{26}$	$p_{2.}$
	Grassland	$p_{31}$	$p_{32}$	$p_{33}$	$p_{34}$	$p_{35}$	$p_{36}$	$p_{3.}$
	Other land	$p_{41}$	$p_{42}$	$p_{43}$	$p_{44}$	$p_{45}$	$p_{46}$	$p_{4.}$
	Settlements	$p_{51}$	$p_{52}$	$p_{53}$	$p_{54}$	$p_{55}$	$p_{56}$	$p_{5.}$
	Wetland	$p_{61}$	$p_{62}$	$p_{63}$	$p_{64}$	$p_{65}$	$p_{66}$	$p_{6.}$
	Total	$p_{.1}$	$p_{.2}$	$p_{.3}$	$p_{.4}$	$p_{.5}$	$p_{.6}$	123,577

Structure of change sample assessment matrix for Forest/Non-forest cover classes

Period: Time1 to Time 2	Types of land cover	Time 2		Total
		Forest	Non-forest	
Time 1	Forest	Stable forest ( $p_{11}$ )	Loss ( $p_{12}$ )	( $p_{1.}$ )
	Non-forest	Gain ( $p_{21}$ )	Stable non-forest ( $p_{22}$ )	( $p_{2.}$ )
<b>Total</b>		( $p_{.1}$ )	( $p_{.2}$ )	123,577

## Appendix 2

### **Estimating the population mean**

The population means ( $\mu$ ) is estimated with  $\hat{\mu} = \frac{\sum_{i=1}^n y_i}{n}$

Where  $y_i$  is the value for each unit in the sample and  $n$  is the number of units in the sample.

The population variance  $\sigma^2$  is estimated with the sample variance  $s^2$  which has an unbiased estimator:

$$s^2 = \frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n - 1}$$

Variance of the estimate  $\hat{\mu}$  is:  $v\hat{a}r(\hat{\mu}) = \left(\frac{N-n}{N}\right) \frac{s^2}{n}$

The standard error of the estimate is the square root of variance of the estimate, which as always is the standard deviation of the sampling distribution of the estimate. Standard error is a useful gauge of how precisely a parameter has been estimated for a population size  $N$ .

Standard error of  $\hat{\mu}$  is  $SE(\hat{\mu}) = \sqrt{\left(\frac{N-n}{N}\right) \frac{s^2}{n}}$

### **Estimating the population total**

The population total  $\tau$  is estimated with  $\hat{\tau} = N\hat{\mu} = \frac{N}{n} \sum_{i=1}^n y_i$

Variance of the estimate  $\hat{\tau}$  is:  $(\hat{\tau}) = N^2 v\hat{a}r(\hat{\mu}) = N^2 \left(\frac{N-n}{N}\right) \left(\frac{s^2}{n}\right)$

Standard error of  $\hat{\tau}$  is:  $v\hat{a}r(\hat{\tau}) = \sqrt{N^2 \left(\frac{N-n}{N}\right) \left(\frac{s^2}{n}\right)}$

Confidence limits:

$$\hat{\mu} \pm SE(\hat{\mu}) \cdot t_{df, \alpha/2}$$

## Appendix 3

IPCC land cover change matrix among three different temporal estimates: 2005, 2010 and 2015.

		Year 2010						Total
IPCC land cover types		Cropland	Forest	Grassland	Other land	Settlements	Wetland	
Year 2005	Cropland	2,254	0	16	0	0	0	2,270
	Forest	0	26,146	87	0	2	0	26,235
	Grassland	14	2	88,102	0	29	3	88,150
	Other land	0	0	0	3,730	0	0	3,730
	Settlements	0	0	1	0	1,099	0	1,100
	Wetland	0	0	0	0	0	1,987	1,987
Total		2,268	26,148	88,206	3,730	1,130	1,990	<b>123,472</b>

		Year 2015						Total
IPCC land cover types		Cropland	Forest	Grassland	Other land	Settlements	Wetland	
Year 2010	Cropland	2,262	0	5	0	1	0	2,268
	Forest	0	26,133	15	0	0	0	26,148
	Grassland	17	4	88,154	0	30	1	88,206
	Other land	0	0	0	3,730	0	0	3,730
	Settlements	0	0	0	0	1,130	0	1,130
	Wetland	0	0	1	0	0	1,989	1,990
Total		2,279	26,137	88,175	3,730	1,161	1,990	<b>123,472</b>

		Year 2015						Total
IPCC land cover types		Cropland	Forest	Grassland	Other land	Settlements	Wetland	
Year 2005	Cropland	2,248	0	21	0	1	0	2,270
	Forest	0	26,131	102	0	2	0	26,235
	Grassland	31	6	88,050	0	59	4	88,150
	Other land	0	0	0	3,730	0	0	3,730
	Settlements	0	0	1	0	1,099	0	1,100
	Wetland	0	0	1	0	0	1,986	1,987
Total		2,279	26,137	87,421	3,730	1,161	1,990	<b>123,472</b>

## Appendix 4

Forest and non-forest change matrix during 2005-2010, 2010-2015, and 2005-2015.

2005-2010	Types of land cover	Year 2010		Total
		Forest	Non-forest	
Year 2005	Forest	26,876	89	25,965
	Non-forest	2	99,505	97,507
<b>Total</b>		26,878	97,594	123,472

2010-2015	Types of land cover	Year 2015		Total
		Forest	Non-forest	
Year 2010	Forest	25,863	15	25,878
	Non-forest	4	97,590	97,594
<b>Total</b>		25,867	97,605	123,472

2005-2015	Types of land cover	Year 2015		Total
		Forest	Non-forest	
Year 2005	Forest	25,861	104	25,965
	Non-forest	6	97,501	97,507
<b>Total</b>		25,867	96,605	123,472

## Appendix 5

Land cover change: 2005-2010	Total area	Standard error (SE)	Confidence Interval	
			Lower- 2.5%	Upper- 97.5%
Stable classes	Hectare (ha)	Hectare (ha)	Hectare (ha)	Hectare (ha)
<b>Stable cropland</b>	1,376,623.0	50,867.4	1,276,925.0	1,476,321.0
<b>Stable forest</b>	15,468,200.0	154,935.6	15,164,530.0	15,771,870.0
<b>Stable grassland</b>	124,297,000.0	764,408.4	122,798,800.0	125,795,200.0
<b>Stable settlements</b>	1,333,192.0	83,454.5	1,169,624.0	1,496,760.0
<b>Stable other land</b>	12,187,410.0	297,604.5	11,604,120.0	12,770,700.0
<b>Stable wetland</b>	1,546,122.0	71,710.9	1,405,571.0	1,686,673.0
Change classes				
Forest to Non-forest (Forest Loss)	<b>45,064.6</b>	<b>4,773.3</b>	<b>35,709.1</b>	<b>54,420.1</b>
<i>Forest &gt; Grassland</i>	44,052.1	4,719.4	34,802.2	53,302.0
<i>Forest &gt; Settlement</i>	1,012.5	715.7	-390.2	2,415.2
Non-forest to Forest (Forest Gain)	<b>1,012.6</b>	<b>715.8</b>	<b>-390.2</b>	<b>2,415.5</b>
<i>Grassland &gt; Forest</i>	1,012.6	715.8	-390.2	2,415.5
<b>Grassland &gt; Cropland</b>	7,087.9	1,893.5	3,376.7	10,799.0
<b>Cropland &gt; Grassland</b>	15,704.2	8,340.5	-642.8	32,051.2
<b>Grassland &gt; Settlements</b>	29,907.3	11,775.3	6,828.1	52,986.4
<b>Grassland &gt; Wetland</b>	1,518.5	876.3	-199.1	3,236.1
<b>Settlement &gt; Grassland</b>	506.3	506.1	-485.6	1,498.1

Land cover change: 2010-2015	Total area	Standard error (SE)	Confidence Interval	
			Lower-2.5%	Upper-97.5%
Stable classes	Hectare (ha)	Hectare (ha)	Hectare (ha)	Hectare (ha)
<b>Stable cropland</b>	1,380,673.0	50,887.0	1,280,937.0	1,480,410.0
<b>Stable forest</b>	15,461,620.0	154,930.2	15,157,960.0	15,765,280.0
<b>Stable grassland</b>	124,323,300.0	764,382.3	122,825,100.0	125,821,500.0
<b>Stable settlements</b>	1,364,112.0	84,280.2	1,198,926.0	1,529,298.0
<b>Stable other land</b>	12,187,410.0	297,604.5	11,604,120.0	12,770,700.0
<b>Stable wetland</b>	1,539,520.0	71,256.6	1,399,860.0	1,679,181.0
Change classes				
Forest to Non-forest (Forest Loss)	<b>7,595.1</b>	<b>1,960.2</b>	<b>3,753.2</b>	<b>11,437.0</b>
<i>Forest &gt; Grassland</i>	7,595.1	1,960.2	3,753.2	11,437.0
Non-forest to Forest (Forest Gain)	<b>2,025.0</b>	<b>1,012.1</b>	<b>41.3</b>	<b>4,008.7</b>
<i>Grassland &gt; Forest</i>	2,025.0	1,012.1	41.3	4,008.7
<b>Grassland &gt; Cropland</b>	8,609.2	2,087.1	4,518.6	12,699.8
<b>Cropland &gt; Grassland</b>	2,531.4	1,131.6	313.5	4,749.3
<b>Grassland &gt; Settlements</b>	22,809.5	8,570.2	6,012.2	39,606.9
<b>Grassland &gt; Wetland</b>	506.2	506.0	-485.5	1,497.8
<b>Cropland &gt; Settlements</b>	506.2	506.0	-485.5	1,497.8
<b>Wetland &gt; Grassland</b>	8,119.8	8,116.7	-7,788.6	24,028.3



Land cover change: 2005-2015	Total area	Standard error (SE)	Confidence Interval	
			Lower- 2.5%	Upper- 97.5%
Stable classes	Hectare (ha)	Hectare (ha)	Hectare (ha)	Hectare (ha)
<b>Stable cropland</b>	1,373,586.0	50,853.0	1,273,916.0	1,473,255.0
<b>Stable forest</b>	15,460,610.0	154,929.3	15,156,950.0	15,764,260.0
<b>Stable grassland</b>	124,263,000.0	764,401.3	122,764,800.0	125,761,200.0
<b>Stable settlements</b>	1,333,192.0	83,454.5	1,169,624.0	1,496,760.0
<b>Stable other land</b>	12,187,410.0	297,604.5	11,604,120.0	12,770,700.0
<b>Stable wetland</b>	1,538,002.0	71,251.5	1,398,352.0	1,677,652.0
Change classes				
Forest to Non-forest (Forest Loss)	<b>52,659.7</b>	<b>5,159.6</b>	<b>42,547.2</b>	<b>62,772.3</b>
<i>Forest &gt; Grassland</i>	51,647.2	5,109.8	41,632.3	61,662.2
<i>Forest &gt; Settlements</i>	1,012.5	715.7	-390.2	2,415.2
Non-forest to Forest (Forest Gain)	<b>3,037.6</b>	<b>1,239.6</b>	<b>608.1</b>	<b>5,467.2</b>
<i>Grassland &gt; Forest</i>	3,037.6	1,239.6	608.1	5,467.2
<b>Grassland &gt; Cropland</b>	15,697.0	2,817.8	10,174.2	21,219.9
<b>Settlements &gt; Grassland</b>	506.3	506.1	-485.6	1,498.1
<b>Cropland &gt; Grassland</b>	18,235.5	8,416.8	1,738.8	34,732.2
<b>Grassland &gt; Settlements</b>	52,716.8	14,563.3	24,173.1	81,260.4
<b>Grassland &gt; Wetland</b>	2,024.6	1,011.9	41.3	4,007.9
<b>Cropland &gt; Settlements</b>	506.2	506.0	-485.5	1,497.8
<b>Wetland &gt; Grassland</b>	8,119.8	8,116.6	-7,788.5	24,028.1



## UN-REDD PROGRAMME



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