National Forest Reference Level of Nepal (2000 – 2010)

December 2016

Ministry of Forests and Soil Conservation
Singh Durbar, Kathmandu
Nepal

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Contents

List of Figures

List of Tables

SUMMARY

Nepal's Forest Reference Level (FRL), one of the four main elements of REDD+ according to the UNFCCC, enables the measurement of performance of results based REDD+ activities associated with the implementation of national REDD+ strategy for Nepal. After stakeholder consultations and technical discussions, it has been determined that Nepal's FRL will be at national level, reflecting the historical period 2000-2010, and will focus on the activities such as deforestation, forest degradation due to fuelwood extraction and grazing and forest enhancement (afforestation/reforestation). Based on historical and national level data availability, consistency and reliability, the FRL will include only CO_2 and the carbon pools of above and below ground biomass.

FRL construction followed the guidance and guidelines of IPCC and the UNFCCC Decisions 12/CP.17 and 13/CP.19. Accordingly, the appropriate nationally-available data and information were collected from relevant thematic ministries. National Forest Inventory (NFI) data of 2010 and national forest cover assessment served as the fundamental sources of biomass estimates across different forest types and physiographic strata. Remote sensing data of Landsat TM for the period 2000-2010 and visually interpreted sample data (reference data) often of higher resolution was used to develop activity data on deforestation and afforestation. A total of 22,040 hectare and 13,510 hectare were estimated to have undergone deforestation and afforestation respectively during 2000-2010.

Due to the absence of data allowing the direct measurement of degradation, proxy approaches were used to assess degradation by its cause for both fuelwood and grazing. Degradation due to unsustainable fuelwood collection was estimated by applying the Woodfuels Integrated Supply/Demand Overview Mapping (WISDOM) methodology. Activity data for degradation from fuelwood extraction is based mainly on the forest land remaining as forest from forest cover change assessment, NFI based biomass data and Central Bureau for Statistics' (CBS) data from the National Living Standard Survey (NLSS 2010).

An assessment of feed and fodder supply from forest, agriculture and rangeland resources, biomass removed by grazing/browsing animals and associated impact on forest degradation due overgrazing has been undertaken. The activity data for degradation from grazing is based on NFI plot level data (DFRS) as well as on livestock and grasslands statistics from Ministry of Agriculture, Government of Nepal. The emission factors as provided by the NFI were used. Degradation by other causes (e.g. timber extraction or fire) are believed to be of little significance and have not been included in this submission due to the lack of reliable data.

The annual emissions and removals due to deforestation and afforestation is estimated at **917,743 t Co_2e** and **150,110 t CO_2e** respectively. It is estimated that the annual degradation due to unsustainable fuelwood extraction in Forest-remaining-Forest (FRF) resulted in emissions of **341,000 t CO_2e.** The forest degradation assessment due to unsustainable grazing and fodder consumption practices resulted in an estimated annual degradation of **1,767,273** t C**O_2e**. At national level, the country is found with net emission of **2,875,906 t CO_2e/year** owing to these four activities.

1 INTRODUTION

1.1 Context of development of Nepal's forest reference level (FRL)

Decision 12/CP.17 provides modalities for forest reference emission level/forest reference level (FREL/FRL) construction and the Annex to this decision contains guidance on the information to be reported in FREL/FRL submissions. Decision 13/CP.19 establishes the process to enable the technical assessment of proposed FREL/FRLs once they are submitted.

Within the context of the United Nations Framework Convention on Climate Change (UNFCCC), the reduction of emissions from deforestation and forest degradation, and the increase in removals through the role of conservation, sustainable management of forest and enhancement of forest carbon stocks, are measured against the FREL/FRL. The FREL/FRL thus sets a benchmark for assessing the performance of forest-related mitigation activities allowing countries to measure, report and verify (MRV) emission reductions resulting from their mitigation efforts.

Nepal therefore welcomes the opportunity to submit a FRL for a technical assessment in the context of results-based payments for reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) under the UNFCCC.

Nepal's FRL is prepared on the basis that the submission of the FRL and subsequent Technical Annexes with results are voluntary and for the purpose of obtaining and receiving payments for REDD+ actions, pursuant to decisions 13/CP.19, paragraph 2, and 14/CP.19, paragraphs 7 and 8.

1.2 Problem Statement

According to Nepal's REDD+ Readiness Preparation Proposal (R-PP), developed as part of a Readiness Programme under the World Bank's Forest Carbon Partnership Facility (FCPF), population growth and forest product and land demands are likely to aggravate deforestation and degradation in the years to come, affecting the livelihoods of a large number of forest-dependent people and Nepal's environmental sustainability (Government of Nepal, 2010).

The Government of Nepal is therefore committed to REDD+ through reversing deforestation and forest degradation, conservation of existing forest and enhancement of forest carbon stocks, while addressing livelihoods concerns at the same time. These activities are included in Nepal's REDD+ strategic goals.

Preliminary analysis conducted during the preparation of Nepal's R-PP indicated that the drivers of deforestation and forest degradation in Nepal are diverse, complex and different in the various physiographic regions. The preliminary analysis identified nine direct drivers and several indirect drivers, including socio-economic factors such as population increase and its distribution, poverty, land scarcity and the status of Nepal's level of economic growth and commercial development.

1.3 Goal and Objective

The key objective of Nepal's FRL process is to enable the measurement of performance of results-based REDD+ activities associated with the implementation of a national REDD+ strategy for Nepal.

1.4 Area covered by this forest reference level

The FRL presented here relates to the entire forest land contained within the borders of Nepal, comprising the five physiographic regions: Terai, Siwaliks, Middle Mountain, High Mountain and High Himalayas (Fig-1). In the context of generating an estimate of FRL at the national scale, updated land cover maps were created. The land cover maps (for the defined time points) generated for development of this FRL are wall-to-wall and therefore the approach is consistent for the entire country.

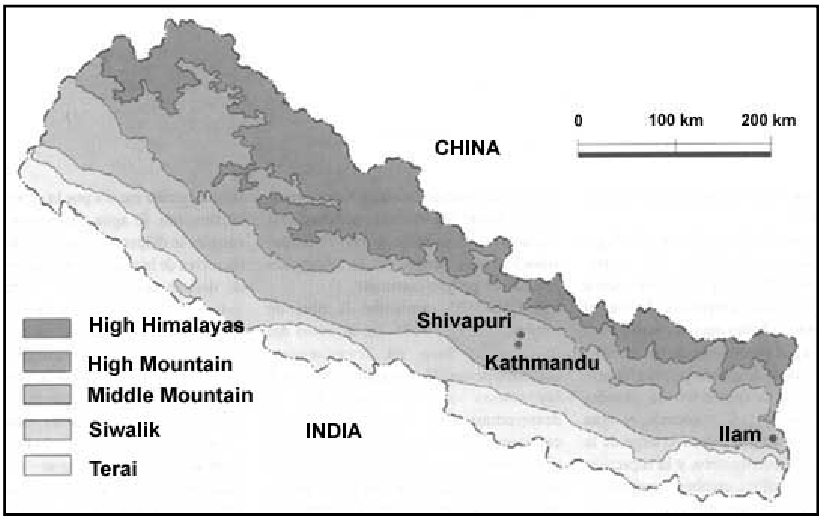


Figure 1: FRL national coverage

1.5 Sources of information and steps in constructing the forest reference level

1.5.1 Sources of information

This submission of the FRL focuses on net CO_2emissions and removals and includes emissions from the above and below-ground biomass carbon pools. Sections 2.3 -2.5 in this submission provide more detailed information regarding activities, carbon pools and gases included in the FRL.

The construction of the FRL for reducing emissions from deforestation and forest degradation and quantification of removals from enhancement of carbon stocks in the forest ecosystem of Nepal was based on the average emissions and removals of the historical time period 2000 – 2010. The FRL has been calculated following the step-wise approach, where available national data, allometric equations and IPCC default values have been used. The FRL was constructed combining remote sensing data, national forest inventory data and national statistical data relating to timber/round wood, fuelwood extraction, and forest grazing.

Besides emissions from deforestation, the FRL includes an estimate of net emissions from forest degradation as well as removals resulting from forest enhancement (afforestation/reforestation). Land use/ land cover change analysis obtained from a combination of wall-to-wall mapping and reference data collection (sample data) was used to generate Activity Data (AD) for deforestation and afforestation/reforestation (2000 – 2010).

Forest degradation was quantified by using proxy indicators of fuelwood extraction and grazing and fodder collection practices for livestock management. The Government of Nepal implemented the Forest Resource Assessment Nepal (FRA Nepal) project from 2010 to 2014 with support from the Government of Finland. It provides a wide range of information including forest cover, forest type, growing stock, biomass, and forest carbon. A national report presents the results of the forest resource assessment of the entire country and separate physiographic region-wise detailed reports for Terai, Churia, and Middle Mountains, and a combined report for High Mountains and High Himal physiographic regions presents region specific details on methodology and results.

The FRA Nepal study has provided basic plot level related information for calculating biomass, different emission factors data and were suitably used for the degradation assessment. The emission factor information on crop, grassland and forest which are not available through FRA study were collected from other relevant published literature, government reports and were detailed in relevant subsections. In addition census data on human and livestock population, which are generated as part of periodic national level census being conducted by different government departments, are used.

Emission/removal factors associated with land-use conversion are presented in units of metric tons of carbon dioxide per hectare (tCO_2 ha-1) for deforestation and afforestation/reforestation.

1.5.2 Compliance with the principles of FRL development

Transparent, complete, consistent and accurate information used in the construction of the forest reference level

1.5.2.1 Transparent and complete information

In view of providing transparent information, Nepal has included a detailed explanation of all assumptions, data sources, equations, land cover/forest cover change analysis methodological approach and tools, default equations and derivation of emission/removal factors. To ensure the information can be considered complete, Nepal has provided the following:

i. All the satellite images used for 2000 and 2010 to map deforestation and afforestation/reforestation;
ii. Forest cover changes through the use of change matrices for the two time points;
iii. An overview of the distribution of collected reference data for the accuracy assessment and the resulting error matrix;
iv. Proxy indicators to assess degradation;(Details provided in Annex and online report on wood fuel is provided at : http://wisdomprojects.net/public/WISDOM_Nepal_Update_&_upgrade_ver_Dec2016.zip)
v. Data from national forest inventory;
vi. IPCC default values used;
vii. The calculation of emission/removal factors for each of the physiographic regions.

The deforestation/afforestation information is provided in the form of GIS/Remote Sensing data and spreadsheets in the custody of the Nepal REDD Implementation Center (RIC) and which will be made available through a data sharing platform. A detailed explanation of the analysis of land cover and forest cover change is provided in section 3.1. Furthermore, for the purpose of enhancing transparency, Nepal has calculated confidence intervals around estimates whenever possible. Confidence intervals provide a measure of precision of the data, and a 95% confidence interval provides a range of values which with 95% certainty includes the true value of the population. Confidence intervals around the area of deforestation/afforestation have been provided, as well as confidence intervals around carbon stock estimates derived from analyzing NFI data. Due to the use of proxy values for estimating degradation, no true confidence intervals could be computed for the degradation estimates but still a range around this estimate has been provided by changing assumptions and exploring several likely scenarios.

1.5.2.2 Consistency

The UNFCCC guidelines for submission of information of the FRL indicate that the information should be consistent with guidance agreed by the Conference of the Parties (Annex of Decision 12/CP17). Furthermore, Paragraph 8 in Decision 12/CP.17 decides that FRLs shall maintain consistency with anthropogenic forest-related GHG emissions by sources and removals by sinks as contained in the country's national GHG inventory. This estimation of emissions by sources and removals by sinks followed the methodological guidance in the IPCC Good Practice Guidance for Land Use, Land-use Change and Forestry (IPCC, 2003). Moreover, Nepal adopted approach 3 for land representation, meaning that all the land conversions and lands remaining in the same land category between inventoriesare spatially explicit. The basis for all AD as well as the assessment of deforestation, for the purposes of this submission, relies on the use of remotely-sensed data of similar spatial resolution (Landsat-class, up to 30 meters).

Both GHG inventory and FRL estimation considered CO_2as the majorgas, and above groundand below ground biomass as the major carbon pools. Both have consideredunsustainable harvesting of fuelwood and over grazing and fodder collection in forests as the major variables while estimating emissions and removals due to forest degradation. However, the FRL has used new data (see section 1.5/1.6) developed recently and estimated emissions and removals more rigorously while the GHG inventory relied mostly on older data (i.e. MPFS 1989).

1.5.2.3 Accurate Information

According to IPCC, accurate estimates concern estimates that are systematically neither over nor under true emissions or removals, for as far as can be judged. Systematical over- or underestimation is in statistical terms referred to as bias. Providing accurate (i.e. unbiased) estimates is defined by IPCC as good practice. Nepal has sought to apply statistical inference methods for the unbiased estimation of activity data and emission factors. For the estimate of AD for deforestation and afforestation, Nepal has followed the approach suggested by the Global Forest Observations Initiative's (GFOI) Methods and Guidance Document, version 2.0 (section 5.1.5). This approach seeks to remove bias deriving from map classification errors. As suggested by GFOI, reference data has been used create "bias-corrected" area estimates using a combination of map and reference data (see section 4.4).

2 SCOPE AND SCALE OF NEPAL'S REFERENCE LEVEL

2.1 Scale of FRL development

Nepal's FRL is at national level. According to UNFCCC decision 12/CP.17, countries should aim to implement REDD+ at the national level, but may implement at sub-national level as an interim measure if necessary. Advantages of implementing at national level are to avoid internal displacement of emissions and to ensure that the impact of national policies and measures can be properly assessed. The critical datasets are available at national level: Nepal carried out a National Forest Inventory (NFI) between2010-14,updated land cover maps generated with national coverage and related national level ancillary databases. There is therefore no clear need for Nepal to establish a sub-national FRL as an interim measure.

2.2 Definition of 'forest'

The UNFCCC guidance provided through the COP decisions require that Parties include *"the definition of forest used in the construction of forest reference emission levels and/or forest reference levels and, if appropriate, in case there is a difference with the definition of forest used in the national greenhouse gas inventory or in reporting to other international organizations, an explanation of why and how the definition used in the construction of forest reference emission levels and/or forest reference levels was chosen"* in their FRL submission.

IPCC distinguishes between land cover and land use, the first relating mainly to the biophysical characteristics of the land while the second considers the predominant use and potentially administrative characteristics of the land. In respect to the definition of forest, the IPCC land category description mentions that thresholds need to be nationally defined. Land cover definitions used in national Forest Resource Assessments (FRAs) use three thresholds, in accordance with FAO recommendations: minimum area, minimum crown cover and minimum potential height. Accordingly, the definition of forest used for Nepal's FRA, which is consistent with the FAO definition, has been adopted for REDD+ in Nepal: the definition is consistent and has been similarly adopted for institutionalizing the measuring, reporting and verification (MRV) system for REDD+.

The definition adopted for developing the FRL therefore is:

> Land with tree crown cover of more that 10 percent and area covering more than 0.5 ha, with minimum height of the trees to be 5 m at maturity and in-situ conditions. The land may consist either of closed forest formations where trees of various storied and undergrowth cover a high proportion of the ground, or of open forest formations with a continuous vegetation cover in which tree crown cover exceeds 10 percent. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10 percent or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily un-stocked as a result of human intervention or natural causes but which are expected to revert to forest. This includes forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas within the forest; forest in national parks, nature reserves and other protected areas such as those of special environmental, scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and a width of more than 20 m. Land predominantly used for agricultural practices are excluded.

This definition was subsequently used to inform all the forest cover maps developed for the two time periods.

2.3 Activities included in the FRL

Nepal's Readiness Preparation Proposal (R-PP), drafted for the World Bank's Forest Carbon Partnership Facility (FCPF) in 2011, states that the country's REDD+ strategic options aim to contribute to reducing GHG emissions, through the conservation of existing forests and enhancing forest carbon stocks in line with paragraph 70 of the Bali Action Plan (UNFCCC Decision 1/CP.13). According to this, and subsequent decisions, national REDD+ strategies should include one or more of five 'activities'. Nepal's FRL includes three of these five:

a) Reducing emissions from deforestation;

b) Reducing emissions from forest degradation from fuelwood harvesting and unsustainable grazing and fodder collection practices;

e) Enhancement of forest carbon stocks from afforestation/reforestation, and to convert gross degradation estimates to net estimates.

In the context of Nepal's FRL, deforestation, degradation and enhancement are defined as follows:

Deforestation: Deforestation is the long term or permanent conversion of forest to other (non-forest) land.

Degradation: Degradation is the long term or permanent reduction of biomass in forest land remaining forest land.

Enhancement: Enhancement of forest carbon stock, for the purposes of the FRL, is divided into two categories:

(a) Afforestation/reforestation: This is the positive complement to deforestation and refers to the conversion of non-forest land use categories to forest,

(b) Restoration (Enhancement of forest land remaining as forest land): This is viewed as the positive complement to forest degradation, i.e. long term or permanent improvement of carbon stocks in forest land that remains as forest land.

Rationale for inclusion of the above activities:

Deforestation and afforestation/reforestation can be readily detected through comparison of digital data on land cover available for the years 2000 and 2010.

Degradation and enhancement in forest remaining as forest cannot be detected from available digital data. However, studies of Nepal's forest sector (including the R-PP prepared under the FCPF programme) indicate that fluxes in forest biomass, and therefore GHG emissions, in forests remaining as forests, are at least as significant, at the national level, as emissions due to deforestation. Furthermore, since the Forest Act of 1993, Nepal has implemented a nationwide programme of decentralized forest management (see section 2.4) which has resulted in significant long-term permanent enhancement of forest biomass in many forests under this programme, managed by Community Forest Users' Groups (CFUGs) and similar local-level bodies. The FRL has focused on proxy measurements for degradation that can be assessed through data available at national level, and that are related to the main subsistence benefits of forests for rural communities and the focus of CFUG management strategies. Out of the nine direct and eleven underpinning drivers of forest degradation (MFSC, 2010), two have been considered the highest contributors to forest degradation:

(a) Harvesting of fuelwood
(b) Grazing and fodder collection practices for livestock management

In the context of assessing emissions from degradation, Nepal has estimated average historical emissions from these two activities.

The methodologies used to measure the impact of these practices on GHG emissions over the reference period are described under section 6. The forests of Nepal have a strong regenerating capacity, therefore to avoid over-estimation of emissions from degradation as a result of fuelwood collection, Nepal considered the regenerating capacity of the forest to calculate net emissions.

Drivers of forest degradation which are not included in Nepal's FRL are Degradation from forest fire, and unsustainable harvesting of timber and other forest products mainly due to lack of sufficiently robust data.

The fact that fuelwood collection and grazing are considered the highest contributors to degradation does not mean that other drivers like forest fire and unsustainable harvesting of timber have negligible contributions. The only reason behind the exclusion of these drivers in the context of FRL estimation, is a lack of reliable information. As soon as required and reliable information are available, remaining drivers of forest degradation will also be assessed for their emissions contribution and incorporated in the FRL.

The challenge associated with estimating degradation from unsustainable timber extraction is, firstly, the lack of reliable statistics on national timber production and, secondly, the lack of information on how much of this production came from sustainably managed forests which would not result in net emissions. A study was on undertaken timber estimates by REDD IC (REDD IC Report,2012) but this provided timber production estimates based on timber demand associated with house construction and repair, which was approximated by the increase in households (increase in population). A population-driven timber estimate does not adequately allow for estimates of associated emissions that depend strongly on the silvicultural practices used for timber production and extraction. As such, Nepal felt it was not able to include degradation from unsustainable timber extraction in this submission.

Restoration

Enhancement of carbon stocks in forest land remaining forest land (restoration) is considered as one of the most important activities in Nepal (see further information in the following section 2.4), but Nepal does not yet possessdata which allows estimation of GHG removals from restoration in a sufficiently robust and reliable manner. However, the inclusion of data on fuelwood use and grazing practices allows for proxy measurement of both degradation (due to unsustainable practices) and restoration (due to reduced demand, improved or sustainable practices). Restoration is therefore partly covered in this FRL as part of a net calculation of the impact of fuelwood and grazing on GHG emissions from forests.

Conservation of forest carbon stocks

This REDD+ activity is understood either as (a) activities that ensure that forests are not converted to other land use categories, in which case it is covered by 'deforestation', as defined above or (b) activities that ensure that carbon stocks in forests are not reduced over the reference period, in which case it is covered by 'degradation', as defined above. There is therefore no need to define or use this activity in the context of this FRL.

Sustainable management of forests

This REDD+ activity is understood either as (a) activities that replace formerly unsustainable forest management strategies that were resulting in reduction of forest carbon stocks, in which case it is covered by degradation as defined above or (b) activities that are introduced to increase carbon stocks in formerly unmanaged forest areas, in which case it is covered by 'restoration' of forests remaining as forests, as defined above. There is therefore no need to define or use this activity in the context of this FRL.

2.4 Restoration through Nepal's Community Forestry Programme

Over the past decades, Nepal has handed over state-owned forest land to communities with the objective of enhancing forest protection and sustainable management while at the same time improving livelihoods. Community forests have existed in their modern form in Nepal since 1987, when the government began the phased handover. To incentivize conservation and restoration of forest land, Nepal has put in place a policy (the Forestry Act 1993) under which communities can apply for an extendable 10-year concession managed by community forestry user groups (CFUGs). CFUGs are legal, autonomous corporate bodies, governed by a general assembly consisting of all households in the boundaries of the applicant community, and an executive committee chosen by the CFUG through consensus or election. This policy has achieved high engagement from the communities and currently over 39.7% of the country's forest area has been managed under Community Based Forest Management (CBFM). 29% is managed directly by about 19,000 CFUGs in land under the Department of Forests (DoF), 9.1% by CFUGs in Buffer Zones under the Department of National Parks and Wildlife Conservation (DoNPWC), 0.9% jointly by communities and DoF staff under Collaborative Forest Management modalities and 0.7%under the Leasehold Forest Programme by poor and disadvantaged groups (MFSC, 2015). Figure 2 shows the increase in forest area managed by CFUGs between 1988 and 2010.

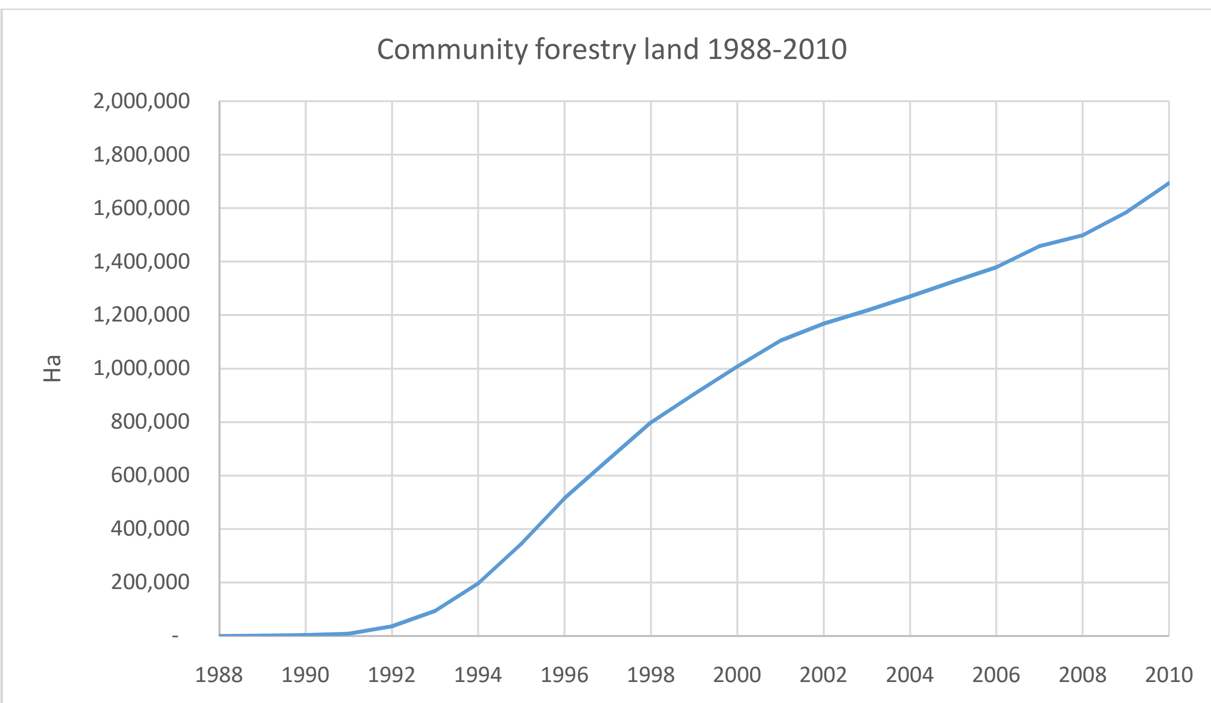


Figure 2: Community Forestry handover information from (Source: DOF CF Division Database 2015)

In many parts of the country, CBFM has achieved significant results in reducing, and reversing, forest degradation. Community forests in Nepal can be considered a success story with evidence of restoration over time (enhancement of forest carbon stocks in forest land remaining forest land). Picture 1 shows some examples of restoration happening on previously state-owned land which has come under the management of CFUGs. The success of Nepal's community forests is documented in several publications (e.g. Dahal &Chapagain 2008; FERN 2015).

Picture 1: Illustrating changes in forest condition before and after the intervention of community forestry in Nepal

(Source: Community Forestry Division, Department of Forest Nepal)

The GHG removals through long-term sustainable improvements in management as a result of CBFM are considered to be significant and as such they should be included as one of the REDD+ activities in the FRL. However, currently Nepal lacks sufficient reliable data to adequately estimate GHG removals from community forests and in future with appropriate field and remote sensing measurements could help to make CBFM based carbon removals. Nepal is currently investigating what data it needs to collect to estimate removals in the community forests in a robust and reliable manner.

2.5 Pools included

The UNFCCC Decision in Durban (COP12/CP.17, Annexc), indicates that significant pools should not be excluded from FRLs and that parties are required to give reasons for omission of pools. Nepal considers good reasons for omitting a pool could be:

a. If the pool represents a very small proportion of the total emissions (e.g. <5% of total);
b. Where costs of data collection and analysis exceed the benefit of including the specific pool or gas in the FRL, even if such pools are significant;
c. If no credible data is available/can be collected for that pool;

d. If data available suggests that despite being significant, the given pool is not expected to significantly change during the monitoring period and therefore not be significant in terms of emissions from the pool.

Furthermore, in view of future REDD+ results reporting, both the reference level and subsequentestimations based on the MRV system established must include exactly the same pools (Decision 14/CP19, p.3).

The sources of emissions considered for Nepal are deforestation and forest degradation. The sources of removals are enhancement through afforestation/reforestation.

Based on the above-mentioned guideline as well as stakeholder consultations, only Above Ground Biomass and Below Ground Biomass carbon pools of forests and shrub land are included in the FRL.

Annual change in carbon stocks in Dead Organic Matter (DOM) due to land conversion can be calculated with Equation 2.23 (IPCC 2006, Volume 4, and Chapter 2). DOM exists of litter (all litter plus fine woody debris up to a diameter limit of 10 cm) and dead wood (> 10 cm diameter). Default values are provided by IPCC for litter excluding fine woody debris up to a diameter limit of 10 cm (Table 2.2 in IPCC 2006) but no default values have been provided for dead wood due to the paucity of published data.

Based on NFI analysis, it is found that litter and debris contribute 1.19 t C/ha against an average above ground forest biomass of 108.88 t C/ha. As such, litter does not seem to constitute a significant pool and lacking country specific estimates Nepal has decided to omit litter from this FRL calculation.

The excluded pools are:

- Dead Organic Matter (DOM) because reliable estimates are lacking and above default calculation for litter suggests the pool to be not significant;
- Soil Organic Carbon (SOC) because no credible data is available for SOC whilst the cost of data collection is likely to exceed the benefit of including SOC.

2.6 Gases included

Only the major GHG, i.e. carbon dioxide (CO_2) was considered in the construction of the FRL.

Flooded lands may emit methane (CH_4) and nitrous oxide (N_2O) in significant quantities, depending on a variety of characteristics such as age, land-use prior to flooding, climate, and management practices (IPCC, 2006). Emissions of $CH_4$and N_2O are known to occur in mangrove areas as well as seasonally or permanently flooded areas. Nepal has no coastline hence no mangroves are present; thus there are no CH_4 or N_2O emissions associated with organic and mineral soils for the management activities of extraction (including construction of aquaculture and salt production ponds), drainage and rewetting and revegetation as provided in the 2013 Wetlands Supplement to the 2006 IPCC Guidelines. Experience under the Kyoto Protocol's CDM also suggests that emissions from using fertilizer and planting leguminous plants and trees will not be significant (FCPF Decision Support Tool Part 1).

A large proportion of CH_4 emissions in Nepal come from enteric fermentation, solid waste disposal and waste water treatment as well as from the rice fields as reported by the Initial National Communication (2004). These are not associated with forestry though, so they are not relevant for the FRL calculation.

Fires in Nepal are more frequent outside the forest than in forest lands (FAO 2015). Most forest fires will not be followed by land conversion but regenerate over the years leading –in the long term- to no net change in emissions/removals. To understand whether non-CO_2 emissions associated with forest fires provide a significant contribution to total emissions from forests, Nepal performed an estimation of annual non-CO_2 emissions from fire using equation 2.27 (IPCC 2006, Volume 4, Chapter 2). Input data in the equation was derived from the Global Forest Resources Assessment 2015 burned forest area estimate for Nepal (the average for the years 2003-2010), the average above ground biomass (mass of fuel available for combustion) as obtained from Nepal's National Forest Inventory (2010) and IPCC default values for fuel biomass consumption, the combustion factor and emission factor of dry matter burnt per mass. This calculation suggests a total of non-CO_2 emissions of 281,470 tCO_2e, which consists of 12% of the total annual emissions included in Nepal's FRL. As such, Nepal concludes the contribution of non-CO_2 gases is not significant and considering the country doesn't dispose of reliable fire data it is decided to omit non-CO_2 gases associated with fire.

The excluded GHGs therefore are:

- CO, CH_4 and N_2O because:
    - There are no mangroves in Nepal
    - There are no seasonally or permanently flooded forest areas in Nepal
    - Fires are not a significant source of emissions

3 ACTIVITY DATA – LAND COVER CHANGE ASSESSMENT

Activity data used for FRL construction for Nepal is taken from a land cover change assessment conducted between the years 2000 and 2010. The focus of change assessment is primarily on changes between forest and non-forest categories. Landsat Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM) data downloaded from the United States Geological Survey (USGS) Global Visualization Viewer (GloVis) were used to develop land cover data. In addition, the Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) and Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) with 30 m and 90 m resolutions were used as supplementary data (ICIMOD 2010). The land cover data for 2000 and 2010 have been prepared under a NASA-SERVIR/ICIMOD collaborative program.

Assessment of accuracy of forest change was done through comparing map data with higher quality data (reference data) through a sampling approach. The comparison of reference and map data allowed for bias-corrected area estimates with associated confidence intervals.

3.1 Land Cover Classification and Forest Change Assessment:

Land cover change information provides the background for estimating emissions and removals from human activity (activity data - AD). Based on IPCC guidelines (IPCC 2003) for estimating GHG emissions and removals from forest change, AD is multiplied with coefficients that quantify emissions per unit activity (emission factors – EF). AD should follow IPCC good practice guidelines that advocate neither over- nor under-estimating GHG emissions or removals and reducing uncertainties as far as is possible (IPCC 2006, GFOI 2003, 2016). Uncertainties are determined through the unbiased estimation of standard error and quantified in terms of confidence intervals.

To estimate accurate and consistent AD for Nepal, forest change assessment and accuracy assessment have been carried out. The work has been conducted with financial and technical assistance from FAO through UN-REDD Programme Targeted Support, with guidance from the REDD+ Implementation Centre (RIC) under the Ministry of Forests and Soil Conservation (MoFSC) of Nepal and in close collaboration with ICIMOD and the members of the national technical team on Forest Reference Level (FRL) for REDD+.

The following 4 steps best describe the overall methodology adopted for accuracy assessment of forest change. This approach is based on IPCC good practice guidelines and is recommended by Olofsson *et. al* (2014) and the Global Forest Observation Initiative (GFOI 2016, section 5.1.5.).

3.2 Methodology and Data used

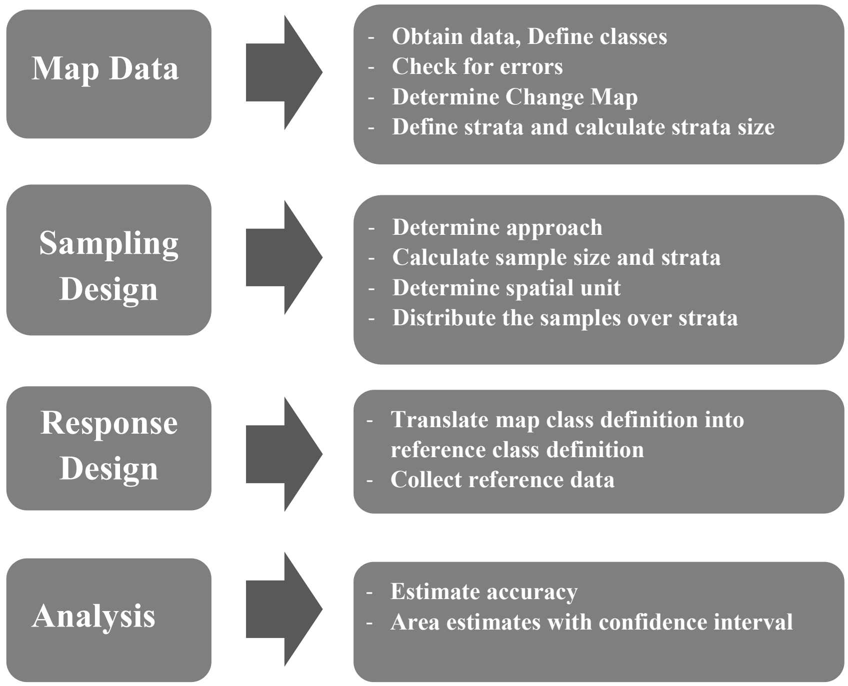


Figure 3: Methodology for forest change accuracy assessment

3.2.1 Rationale for Map Data Selection

Map data refers to the input maps used for forest change assessment. Considering the requirement of historical data for FRL construction, a review of existing wall-to-wall landcover and forest spatial datasets at global and national level was conducted. The following criteria were adopted based on expert consultation for selecting the appropriate map data source:

- Historical coverage
- Wall to wall coverage
- Derived from same or similar sensor configuration
- Consistent in scale and spatial extent
- Proven accuracy measures
- Consistent with previous NFI and assessments
- Well accepted by the FRL team and REDD IC Nepal

Data produced from previous forest inventories and government approved data were reviewed. Department of Forest Research and Survey (DFRS), the apex government body for managing and producing the data, lacks consistent historical forest data that could be used for change assessment. At national level, historical wall-to-wall land cover map data for year 2000 was only available from Landsat with 30m resolution prepared by ICIMOD. While for year 2010, two national level assessments were undertaken, first using Landsat with 30m resolution prepared by ICIMOD and second using RapidEye with 5m resolution prepared by DFRS. After a thorough review based on the above criteria, land cover data products for the years 2000 and 2010, prepared by ICIMOD using Landsat sensor with 30m resolution, were selected as the primary map data source.

3.2.2 Consistency of Land coverMap data

During the data preparation phase from 2000 to 2010, different national consultation workshops were held to develop consistent and harmonized regional temporal land cover databases. For image classification, the object-based image analysis technique was adopted using e-Cognition developer software and standard methodology as explained in *Kabir et. al* (2015). Multi-resolution segmentation was used for delineating image objects, and mean indices were calculated within each segment.

Land cover accuracy assessment based on systematic random sampling method was conducted for land cover data of 2000 and 2010. For 2000 and 2010, 450 random sample points were selected and verified with historical data in Google Earth, while for year 2010, an additional 300 government-verified (DFRS) field sample plots were also included. This resulted in accuracy measures as follows:

Description	Year 2000	Year 2010
Total number of samples	450	750
No. of accurate samples	390	644
Overall Accuracy (%)	86.67	85.87
Kappa	0.82	0.80
Standard error kappa	0.0211	0.018
95% confidence interval	0.78-0.86	0.77-0.84
Maximum possible un-weighted kappa	0.93	0.92

Table 1: Accuracy report for land cover 2000 and 2010

A comparison study was further conducted using data from previous forest inventories of Nepal, Forest Resource Assessment (FRA Nepal 2010) and Landsat TMland cover data.

Study	Year	Forest and Shrub %	Total Forest Cover %
Forest Resources Survey (DFRS): 1:6000 Aerial Photos	1953-58 1963-64	Forest: 45.5%	45.50%
LRMP (LRMP/WECS): 1:50,000 aerial photos	1978-79	Forest: 38.2% Shrub: 4.7%	42.9%
Master plan for forest sector (MPFS), MoFSC : LRMP data, Forest Inventory	1985-86	Forest: 37.4% Shrub: 4.8%	42.2%
National Forest Inventory DFRS: Landsat TM	1994	Forest: 29% Shrub: 10%	30.0%
Forest Resource Assessment (FRA): Rapideye 5m	2010	Forest: 40.36% Shrub: 4.38%	44.7%
land cover 2000 : Landsat TM 30m	**2000**	**Forest: 41.8% Shrub: 2.4%**	**44.2%**
land cover 2010 : Landsat TM 30m	**2010**	**Forest: 42.2% Shrub: 2.3%**	**44.5%**

Table 2: Comparison of previous studies with Landsat TMland cover

Based on the above comparison, Landsat TM land cover shows forest cover slightly above 44%, which is very similar to the RapidEye 5m (FRA 2010) results of 44.7%. Since the data preparation methods are also similar for both RapidEye 5m data and Landsat 30m data, similar forest area results are considered justifiable. Based on the above analysis, overall forest area estimations between Landsat TM 2000-2010 data and previous national forest inventories were observed to correspond closely, and hence Landsat land cover 2000 and 2010 data products were selected as primary map data for FRL development of Nepal.

3.2.3 Map data quality control

For quality control of land cover data, a three-step procedure was followed. Firstly, the maps were verified for each 10x10km (100km^2) grid of Landsat imagery from the same year. Secondly, visual inspection was conducted with the 10x10km grid for obvious error removal, absurd transitions and data anomalies using high resolution Google Earth imagery. Finally, detailed inspection and updating was conducted using high resolution Google Earth imagery at the polygon level.

In addition, map data were further reviewed against spatial data quality elements such as lineage, positional accuracy, attribute accuracy, metadata etc, and map errors were identified and removed.

3.2.4 Minimum Mapping Unit for Change reporting

Considering the LANDSAT TM resolution of 30m, a minimum window of 3x3 pixels was used to report statistics for each year. Land classification was done at individual pixel resolution in order to retain and leverage the advantage of pixel level spectral purity. However, considering the hilly terrain and the 30m resolution and reported positional accuracies of LANDSAT TM images, a minimum window of 3x3 pixels was used for reporting of statistics through extraction of major land cover classes. This window size is equivalent to one ha, adhering to a minimum mapping unit of 2x2 mm at 1:50,000 scale. For the purpose of change reporting, a 5x5 pixel window (equivalent to 2.25 ha) was considered, such that mis-registration of errors at the single pixel level and classification noise between two images could be avoided. This size of 2.25 hectare was found to be more practical for change reporting, adhering to mapping standards. Consequently, the minimum mapping unit for change assessment is considered as 2.25 ha, such that real change is only labeled when the patches contain at least a group of 5 pixels or 150m x 150m of change on the ground. It may also be noted that due to these data and analysis constraints, the study has considered coarse size of 2.25 ha for reporting as against national forest definition size of 0.5 ha.

3.3 Forest Change Assessment

A forest change map was produced representing land cover change between years 2000 and 2010 using the ArcGIS spatial analysis tool. Stratification was done based on forest cover, as the priority land cover classes to be assessed for change. The following 4 strata were identified to assess the change:

Forest Loss (FL)

Forest Gain (FG)

Stable Forest: Forest Remaining as Forest

Stable Non Forest: Other land cover classes remaining as others

The following figures show an example of the change assessment work conducted between land cover maps of 2000 and 2010 followed by verification of the change areas in Google Earth high resolution imagery.

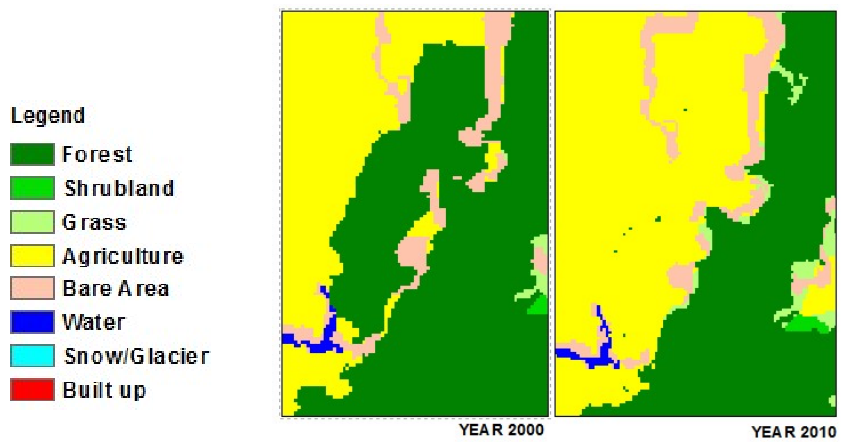


Figure 4: land cover map of year 2000 and 2010 showing forest loss

March 2001 November 2006 May 2012

Figure 5: Google imagery for verification of forest loss for year 2000 and year 2010

Source: Google Earth, Location: Jhalari-Pipladi, Kanchanpur District, Far-Western Nepal.
Area: 185 hectare, Coordinate: 28°55’39” N, 80°22’46” N

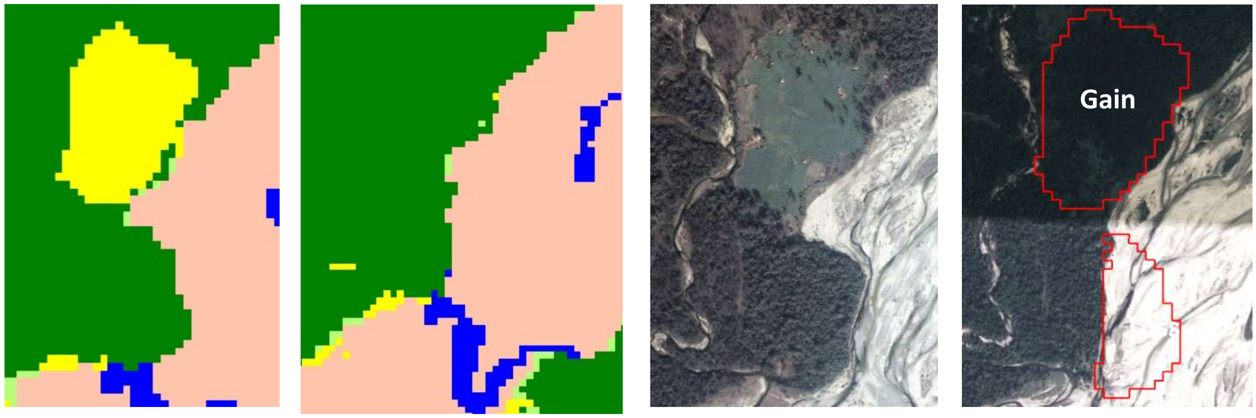


Figure 6: Forest loss and gain areas identified in Land cover of year 2000 and 2010 and verified in Google Earth

Source: Google Earth, Location: Krishnapur, Kanchanpur District, Far-Western Nepal.
Gain Area: 26 hectare Loss area: 12 hectare,, Coordinate: 28°53'23" N, 80°27'33" N

Adopting the minimum mapping unit of 2.25 ha, areas above 2.25 ha are reported as change. The following statistics show the distribution of change area and stable forest/non-forest area across physiographic regions of Nepal.

Physiographic Regions	Forest Loss		Forest Gain		Total Change		Stable Forest		Stable Non Forest	
	Area Ha	%	Area Ha	%	Area Ha	%	Area Ha	%	Area Ha	%
High Himal	382.49	1.4%	494.60	2.6%	877.09	1.9%	368528.00	6.2%	3343911.00	38.2%
High Mountain	3366.34	12.5%	4064.22	21.0%	7430.56	16.0%	1293111.00	21.8%	1190673.50	13.6%
Middle Mountain	1720.77	6.4%	7923.92	40.9%	9644.69	20.8%	2337169.00	39.5%	2067543.40	23.6%
Siwalik	7600.91	28.2%	2739.93	14.1%	10340.84	22.3%	995818.00	16.8%	545517.80	6.2%
Tarai	13900.08	51.5%	4171.74	21.5%	18071.82	39.0%	923624.00	15.6%	1605108.70	18.3%
Grand Total	**26,970.60**		**19,394.41**		**46,365.01**		**59,18,250.00**		**87,52,754.40**	

Table 3: Forest change across physiographic regions of Nepal (Area in hectare).

The following chart show distribution of change area (hectares) in different physiographic regions:

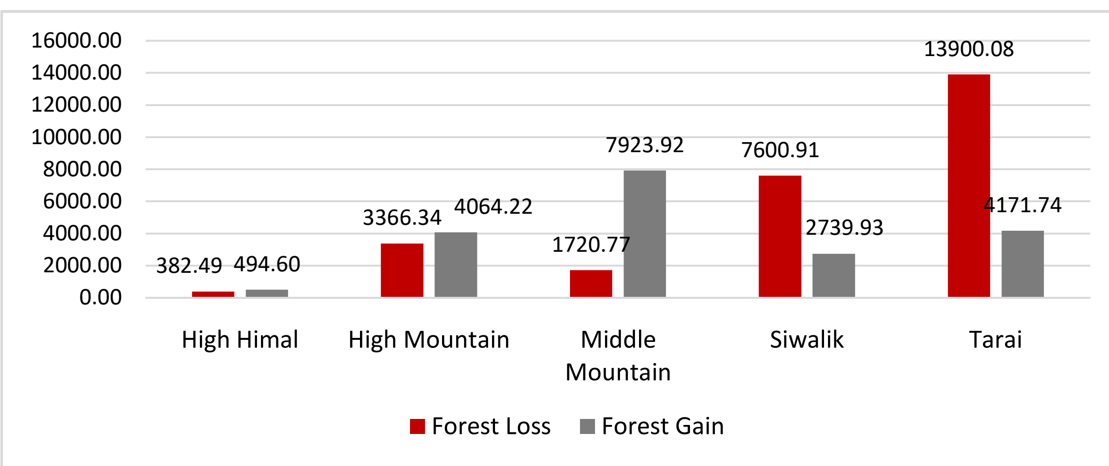


Figure 7: Forest Change over reference period 2000 -2010 across physiographic regions of Nepal

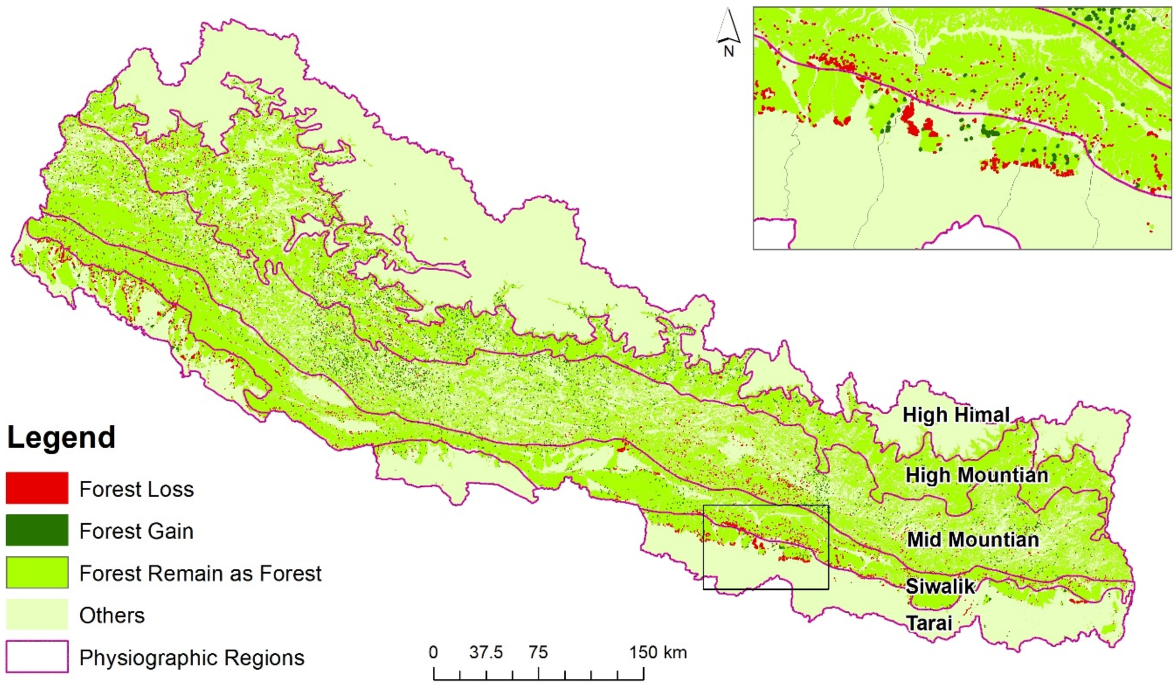


Figure 8: Distribution of Forest Change across physiographic regions of Nepal (Patch sizes above 2.25 hectare)

The result of the forest cover change assessment shows total forest loss of 26,970 ha, forest gain of 19,391.41 ha and stable forest (forest remaining as forest – FRF) of 5,918,250 ha within the reference period of 2000 - 2010. The results show that most of the forest loss (around 52%) has occurred in the Terai and Siwalik regions, which are relatively flat areas. As seen on the map, most of the deforestation has happened in the western/far western and eastern parts of these physiographic regions. This observation is relevant to the socio-political situation of the country in the past decade, as a lot of migration has occurred from hill and mountainous regions to the relatively flatter lands especially because of civil conflict. On the other hand, forest gain has occurred mainly in mountain regions. This could be due to the increase in community forestry and protected areas in hill and mountain regions during the reference period.

3.3.1 Accuracy Assessment

Stratified random sampling was chosen as it is a practical design that satisfies the basic accuracy assessment objectives for most of the desirable design criteria (Olofsson *et al*., 2014) and it helps the country to conform with the IPCC good practice principle of removing bias and reporting uncertainties transparently (GFOI 2016). Prior to the selection of sample plots, the availability of high resolution images within all parts of the country was assessed in Google Earth. In order to increase the confidence of verification for year 2000 classes, a "green window time period" between January 2000 and March 2003 was assumed as a baseline period to be considered for reference verification. This assumption provided a significant proportion of the country (25.78% of the total country area) having high resolution tiles available through Google Earth that can be used for reference verification of year 2000 and 2010 classes.

The following map shows the coverage of high resolution image tiles in Google Earth up to March 2003.

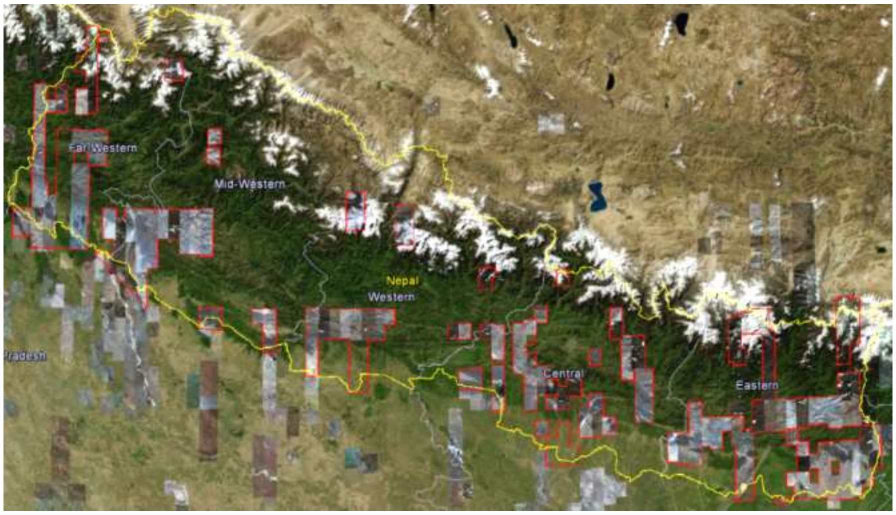


Figure 9: High resolution tiles coverage in Google Earth

The number of sample plots was determined based on a standard sampling design method suggested by Olofsson *et al*. A total of 632 sample plots (316 for forest change and 316 for no change) was identified, distributed across the country over 4 strata. The distribution of the 316 forest change plots was done based on the stratified random sampling method, under which at first 50% of plots were allocated within high resolution areas while the remaining 50% of the plots were located in other areas. Thus, Google Earth high resolution imagery is considered as the primary source of reference data for 50% of the plots. For change verification of plots outside Google Earth high resolution tiles, other reference data sources such as Landsat greenest pixel, NDVI and visual verification with Landsat imagery tiles were assessed. In case of the absence of any such reference sources (as in a few plots in high altitude regions), the same Landsat imagery used for land cover classification were used as the primary reference data.

For the second stage of sample distribution, the 5 physiographic regions were combined into 3 broader regions. Distributions of change plots across the 3 regions were done considering the proportion of forest loss and gain across them as follows:

Mountain – High Himal and High Mountain (10% of sample plots)

Hill – Middle Mountain and Siwalik (40% of sample plots)

Terai – Terai (50% of sample plots)

The remaining 316 'forest no change' plots (stable forest and stable non-forest) were distributed over the 3 broad regions equally. The following table shows the final distribution of samples:

	Mountain	Hill	Tarai	Total
Forest loss	16	63	79	158
Forest Gain	16	63	79	158
Stable Forest	52	52	54	158
Stable Non-forest	52	52	54	158
Total	**64**	**252**	**316**	**632**

Table 4: Distribution of samples in tile coverage region

The following map shows the final distribution of samples covering the entire country:

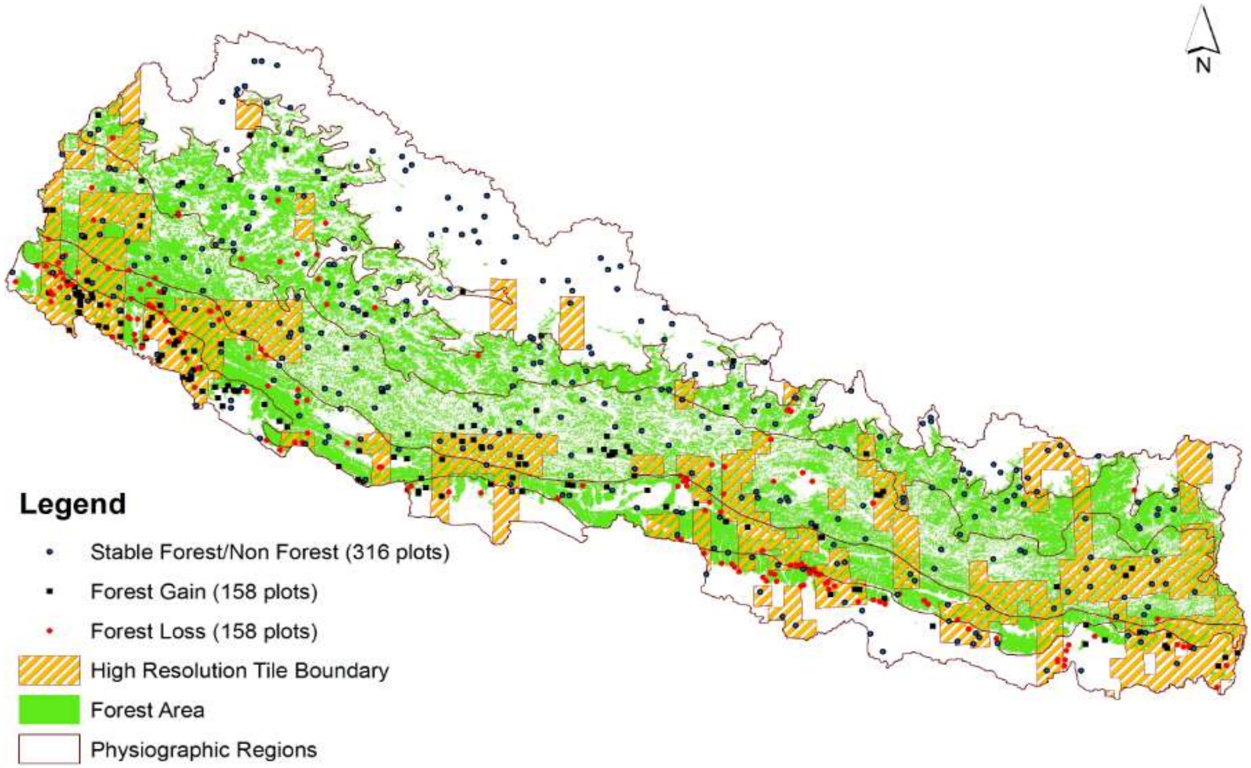


Figure 10: 632 random samples distributed over the country

Sample data collection was done using Open Foris Collect Earth, a tool developed by FAO with a data entry platform that runs on top of Google Earth used to collect sample-based reference data. All 632 plots were verified for change using this tool.

3.4 Results of Accuracy Assessment

The method produced an error matrix (confusion matrix) which is the cross tabulation of land cover classes identified from map data and reference data.

Error Matrix: Values are Number of Samples

	2000-2010	Reference data Forest loss	Forest gain	Stable Forest	Stable non-forest	Total samples in map class	User's accuracy
Map data	**Forest loss**	**130**	2	16	12	**158**	82%
	Forest gain	1	**108**	37	13	**158**	68%
	Stable Forest	0	0	**143**	15	**158**	91%
	Stable non-Forest	0	0	17	**141**	**158**	89%
	Total reference samples per class	**130**	**108**	**213**	**181**	**632**	
	Producer's accuracy	99%	98%	67%	78%	**Overall accuracy**	**83%**
	Coefficient of Agreement (Kappa) = 0.70						

Table 5: Error Matrix (Values are Number of Samples)

Error Matrix: Values are area proportions (samples in agreement/disagreement divided by total samples in map class)

	2000-2010	Reference data Forest loss	Forest gain	Stable Forest	Stable non-forest	Map area (ha)
Map data	**Forest loss**	0.81	0.01	0.10	0.08	**26,971**
	Forest gain	0.01	0.68	0.23	0.08	**19,394**
	Stable Forest	0.00	0.00	0.91	0.09	**5,913,190**
	Stable non-Forest	0.00	0.00	0.11	0.89	**8,766,433**

Table 6: Error Matrix in terms of area proportions

Weighted proportional area of land cover classes: Values are hectares (proportional agreement/disagreement weighted by area class)

	2000-2010	Reference data Forest loss	Forest gain	Stable Forest	Stable non-forest	Map area (ha)
Map data	**Forest loss**	21,914	337	2,697	2,023	**26,971**
	Forest gain	122	13,174	4,513	1,586	**19,394**
	Stable Forest	-	-	5,351,811	561,379	**5,913,190**
	Stable non-Forest	-	-	943,224	7,823,209	**8,766,433**
	Bias-correctedarea	**22,036**	**13,511**	**6,302,245**	**8,388,196**	

Table 7: Weighted proportional area

Error Matrix of Standard Error

2000-2010		Reference data			
		Forest loss	Forest gain	Stable Forest	Stable non-forest
Map data	**Forest loss**	3.21396E-09	2.60413E-10	1.89871E-09	1.46359E-09
	Forest gain	6.86104E-11	2.39181E-09	1.96017E-09	8.24193E-10
	Stable Forest	0	0	8.82446E-05	8.82446E-05
	Stable non-Forest	0	0	0.000216736	0.000216736
	Total	**3.28257E-09**	**2.65222E-09**	**0.000304985**	**0.000304983**
Standard error		844	758	257,172	257,171
95%Confidence Interval		1,654	1,486	504,057	504,055
95%Confidence Interval as percent of bias-corrected area		8%	11%	8%	6%

Table 8: Error Matrix of Standard Error

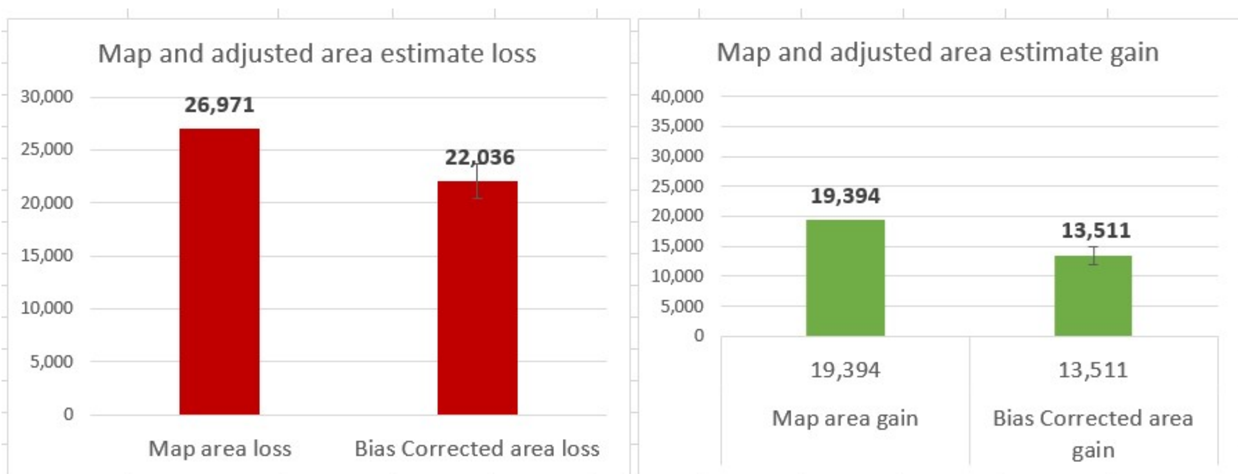


Figure 11: Map area and bias-corrected area of forest change

Summary:

- Observed overall accuracy of 83% and coefficient of agreement of 0.70.
- Observed loss and gain areas show a significant correspondence with global tree cover change data 2000-2014 according to Global Forest Watch: 35,504 ha of tree cover loss and 13,404 ha of tree cover gain.
- Bias-corrected area estimate shows that area correction would decrease the overall forest loss by 9% and forest gain by 17%.
- By using the Minimum Mapping Unit (MMU) of 2.25 ha, which is higher than the MMU in the national forest definition (1 ha), the resulting estimate may be an underestimate of the actual deforestation and afforestation happening in the country. However, with the ongoing constraints in available data (Landsat TM 30m), conditions of the country such as large terrain effects and shaded relief, the results are considered in accordance with IPCC guidance and guidelines, providing the best assessment of change using currently available data.

4 EMISSION FACTORS

4.1 Description and Analysis of NFI for Biomass Estimation

The Government of Nepal implemented the Forest Resource Assessment Nepal (FRA Nepal) project from 2010 to 2014 with support from the Government of Finland. It provides a wide range of information including forest cover, growing stock, biomass, emission factors and forest carbon stocks. A national report presents the results of the FRA of the entire country and separate physiographic region-wise detailed reports for Terai, Churia, and Middle Mountains, and a combined report for High Mountains and High Himal physiographic regions, giving region-specific details on methodology and results.

The Nepal FRL study used field plot level inventory information from the FRA Nepal study as one of the essential inputs for fuelwood and grazing-based assessments of forest degradation. A short summary of field sampling, emission factors and salient inventory results of NFI adopted for assessment of biomass are given below:

4.1.1 Field sampling design

A two-phased stratified systematic cluster sampling design was adopted. The five physiographic regions defined by the Department of Survey - High Himal, High Mountains, Middle Mountains, Churia and Terai were used as strata. A hybrid approach was adopted in the forest inventory through interpretation of satellite images at the first phase and measurement of forest characteristics in the field at the second phase. Detailed methodology is presented in the respective reports for the physiographic regions. Whilst a wide variety of biophysical forest parameters were assessed, for stem volume a target of 95% confidence limits was set, with plus or minus 10% accuracy. A total of 450 clusters (1,553 plots) were measured in forest areas. Altogether, 2,544 sample plots were measured, including 105 plots in Other Wooded Land (OWL) and 886 plots on other non-forest land (OL), in addition to the forest plots (Table 9). Details of the second phase sampling for each physiographic region can be found in the respective physiographic region reports.

Physiographic region	Permanent sample plots			No of forest
	Forest	OWL	OL	Clusters
Terai	175	5	160	56
Siwaliks (Churia)	477	11	219	109
Middle Mountain	433	63	377	146
High Mountain	421	21	115	139
High Himal	47	5	15	
Total	**1,553**	**105**	**886**	**450**

Table 9: Distribution of permanent sample plots and clusters (DFRS 2015)

Emission Factors: The different emission factors derived from DFRS National Forest Inventory on stem volume estimation, tree stem biomass estimation, tree branch and foliage biomass estimation and root: shoot ratio are explained below. Additional emission factors used specifically for the purpose of fuel wood and grazing related degradation are presented in the relevant sub-sections of this document.

4.1.2 Stem volume estimation

Stem volume was estimated using diameter at breast height (DBH) and total height of the tree. Height models were prepared for tree species and species groups by using the data collected from sample trees. A non-linear mixed-model approach was used to establish the relationships between the DBHs and total heights of trees using the 'Lmfor' package in R Software (Mehtatalo, 2012). A model for predicting tree DBH from stump diameter was also developed so that the volume and biomass of trees that had been felled could be estimated. Details on tree-height model of different species and their accuracy are given in individual reports for physiographic regions. The following allometric equation (Equation 1) developed by Sharma and Pukkala (1990) was used to estimate stem volume over bark:

Equation 1: Stem volume

$Ln(v) = a + b \ln(d) + c \ln(h)$ where,

ln = Natural logarithm to the base 2.71828.

V = Volume (dm^3) = $\exp[a + b \times \ln(DBH) + c \times \ln(h)]$

d = DBH in cm

h = Total tree height in m

a, b and c are coefficients depending on species

***Note**: Values were divided by 1,000 to convert them to m^3*

The volumes of individual broken trees were estimated by using a taper curve equation developed by Heinonen et al. (1996). Species specific coefficients were used (Sharma and Pukkala, 1990) for calculating the volume of individual trees. The coefficients used for different species across different physiographic regions were reported in individual reports for physiographic regions (DFRSNFI report -FRA 2015 (http://www.dfrs.gov.np/downloadfile/State%20of%20Nepals%20Forests%20 (DFRS)_1457599484).

4.1.3 Tree-stem biomass estimation

Tree-stem biomasses were calculated using Equation 2 and species-specific wood-density values (Sharma and Pukkala, 1990; MPFS, 1989) are presented in individual reports for physiographic regions. A carbon-ratio factor of 0.47 (IPCC, 2006a, b) was used for conversion into units of carbon stock.

Equation 2: Tree stems biomass

Stem biomass = Stem vol. × Density where,

Stem vol. = Stem volume in m^3

Density = Air-dried wood density in kg/m^3

4.1.4 Tree-branch and foliage biomass estimation

The separate branch-to-stem and foliage-to-stem biomass ratios prescribed by MPFS (1989) were used to estimate branch and foliage biomass from stem biomass. Dead trees were not taken into account for the estimation of branch and foliage biomass. The total biomass of individual trees was estimated by using Equation 3.The species specific biomass ratios were presented in individual reports of different physiographic regions.

Equation 3: Total biomass of each individual tree

Total biomass = Stem biomass + Branch biomass + Foliage biomass

4.1.5 Organic carbon in litter and woody debris

Organic carbon stock in litter and woody debris fractions was obtained on the basis of the total fresh mass collected from a known area as measured in the field. First, the dry mass of litter and woody debris sub-sample was obtained by oven-drying it to constant weight. Second, the total oven-dried weight of the litter and debris was estimated by multiplying the ratio of oven-dried to fresh weight of the litter and debris sub-samples. The total carbon content of litter and woody debris fractions was then obtained by summing the respective dry mass estimates per m^2, multiplied by0.50, a carbon content constant suggested by Pribyl (2010).

4.1.6 Below-ground biomass estimation

This estimation was calculated by using default value as recommended by IPCC (2006). The ratio 0.25 was used by taking an average of the five different forest types (primary tropical/sub-tropical moist forest = 0.24, primary tropical/sub-tropical dry forest = 0.27, conifer forest having more than 150 t/ha above-ground biomass = 0.23, other broadleaved forest having 75 t/ha to 150 t/ha above-ground biomass = 0.26, and other broadleaved forest having more than 150 t/ha aboveground biomass = 0.24). The biomass of seedlings and saplings having DBH less than 10 cm was not incorporated.

4.2 Above-ground Air-dried Tree Biomass

The national average above-ground air-dried biomass in Nepal's forests was 194.51 t/ha. The forests of High Mountains and High Himal contained the highest above-ground biomass per hectare (271.46 t), whilst Middle Mountains forests had the lowest (143.26 t). The average above-ground oven-dried biomass in Nepal's forests was 176.82 t/ha (Table 10).

Physiographic region	Stem biomass	Branch biomass	Foliage biomass	Total above-ground air-dried biomass	Total above-ground oven-dried biomass
Terai	134.49	47.55	7.98	190.02	172.74
Churia	122.24	42.59	7.38	172.21	156.55
Middle Mountains	89.21	44.37	9.68	143.26	130.24
High Mountains and High Himal	145.62	102.57	23.27	271.46	246.78
National average	118.14	62.95	13.42	194.51	176.82

Table 10: Above-ground air- and oven-dried biomass of tree component (t/ha) –Source: DFRS NFI Report 2015

4.3 Reliability of Inventory Results

Each sample cluster in forest areas was allocated systematically in all physiographic regions and strata. Reliability of the inventory results in terms of stem volume per hectare was first determined for each stratum, on the basis of which reliability of results for national level was determined. While designing this assessment, a 95% confidence limit was set for the inventory result with a range of plus or minus 10% of the stem volume or biomass (FRA Nepal, 2010). The standard error for forest plots at national level was found to be 6.17 and error of mean stem volume was 7.34% (Table 11). This is within the reliability limits set out in the project document.

Physiographic region	No. of cluster	No. of plot	Mean stem volume (m^3/ha)	Standard error of mean	Percentage of error of mean at 95% CL	95% Confidence limits of mean	
Terai	56	175	161.66	10.08	12.22	141.90	181.42
Churia	109	477	147.49	6.27	8.33	135.21	159.77
Middle Mountains	146	433	124.26	8.12	12.82	108.34	140.18
High Mountains and High Himal	139	468	225.24	15.84	13.78	194.20	256.29
National average/Total	450	1,553	164.76	6.17	7.34	152.67	176.86

Table 11: Standard errors and confidence limits in Forest for physiographic region –Source: DFRS NFI Report 2015

4.4 Stratification

The study adopted the five physiographic regions described above as stratification (LRMP, 1986) to analyze and report the results. These physiographic strata are widely used across the country for national and sub-national assessments. The details of these physiographic regions are given below.

The Terai physiographic region of Nepal occupies 13.7% of the total land area of the country. In terms of geomorphology, it consists of gently sloping recent and post-Pleistocene alluvial deposits, which form a piedmont plain south of the Himalayas. Its elevation varies from 63m to 330m above mean sea level (amsl) (LRMP, 1986).

The Churia region is the youngest mountain range in the Himalayas. Just north of the Terai, it runs the entire length of southern Nepal, from east to west, skirting the southern flanks of the Himalayas. The region occupies about 12.8 % of the total land area of the country, and covers parts of 36 Districts of Nepal (DoS, 2001). The elevation of Churia varies from 93m to 1,955m amsl.

The Middle Mountains region lies north of the Churia along the southern flanks of the Himalayas. The region occupies 29.2% of the total land area of the country and covers parts of 55 districts. The elevation of the Middle Mountains region varies from 110m in the lower river valleys to 3,300m amsl.

The High Mountains region occupies 20.4% of the total land area of the country and covers parts of 40 districts. The elevation of the High Mountains region varies from 543m in the river valley floors to 4,951m amsl. The region is characterized by rugged landscape and very steep slopes.

The High Himal region, which includes the highest Himalayan massifs, occupies about 23.9% of the total land area of the country, and covers parts of 25 districts. The region's elevation ranges from 1,960m to 8,848 m amsl.

5 DEFORESTATION AND AFFORESTATION – CARBON FLUXES DURING 2000—2010

The carbon fluxes due to afforestation and deforestation were estimated using activity data generated from Landsat TM based on the 2000-2010 forest cover change assessment and emission factors based on Nepal NFI data of 2010-14 and IPCC default values.

The activity data showing total areas under deforestation and afforestation in each physiographic region are presented in Tables12 and 13. The highest deforestation was found in the Terai region with an estimation of 26,791 ha area. The highest afforestation was estimated in the Middle Mountain region with a total area of 19,394 ha. Based on the commission and omission factors obtained from accuracy assessment of forest cover change, bias correction factors were applied on the map areas to generate bias-corrected annual loss and gain areas for each physiographic region. The bias-corrected areas were used for carbon flux estimations.

Physiographic Region	Loss >2.25ha, 2000-2010 (map area, ha)	Annual loss (map area, ha)	Bias-correction factor	Annual loss (bias-corrected, ha)
High Himal	382	38	0.82	31
High Mountain	3,366	337	0.82	275
Middle Mountain	1,721	172	0.82	141
Siwalik	7,601	760	0.82	621
Tarai	13,900	1,390	0.82	1,136
Total Loss	**26,971**	**2,697**		**2,204**

Table 12: Activity Data on Forest Loss Area - Emissions from deforestation

Physiographic Region	Gain >2.25ha, 2000-2010 (map area, ha)	Annual gain (map area, ha)	Bias-correction factor	Annual gain (bias-corrected, ha)
High Himal	495	49	0.70	34
High Mountain	4,064	406	0.70	283
Middle Mountain	7,924	792	0.70	552
Siwalik	2,740	274	0.70	191
Tarai	4,172	417	0.70	291
Total Gain	**19,394**	**1,939**		**1,351**

Table 13: Activity Data on Forest Gain Area - Removals from afforestation

Emission and removal factors applied for deforestation and afforestation respectively are presented in Tables 14 and 15. These factors were sourced from the NFI of 2010-14 (DFRS 2015) and IPCC (2006) guidelines and are appropriately cited in 14 and 15. Detected afforestation in Nepal concerns mainly assisted natural regeneration which on average takes 20 years to grow back to the average biomass stock of forest in the five different physiographic regions. The annual growth rate is therefore obtained by dividing the average biomass in the physiographic regions (Table 14) by 20. Accordingly to determine growth during the FRL period (the values in the first column of Table 15), the annual growth rate is multiplied by 5.5 which represents the average age of the afforested area detected during 2000-2010.The High Himal and High Mountain regions both had the highest emission factors and removal factors, with an average of 584.77 and 160.81 tCO_2/ha respectively (Table 14).

Physiographic Region	AGB (t DM/ha) (DFRS2015)	Root-shoot ratio (DFRS/NFI, 2014)	BGB (t DM/ha)	Carbon fraction (Table 4.3 IPCC 2006 - Tropical/all)	Total biomass (t C/ha)	Conversion factor (C > CO_2)	Emissions per ha (tCO_2/ha)
High Himal	271.460	0.250	67.865	0.470	159.483	3.667	584.770
High Mountain	271.460	0.250	67.865	0.470	159.483	3.667	584.770
Middle Mountain	143.260	0.250	35.815	0.470	84.165	3.667	308.606
Siwalik	172.210	0.250	43.053	0.470	101.173	3.667	370.969
Tarai	190.020	0.250	47.505	0.470	111.637	3.667	409.335

Table 14: Emission Factors – Deforestation

Region	Annual Growth 2000-2010 (tDM/ha/yr) (DFRS2015)	Root Shoot ratio	BGB (t DM/ha)	Carbon fraction (Table 4.3 IPCC 2006 - Tropical/all)	Total biomass (tC/ha)	Conversion factor (C > CO_2e)	Removals per ha (tCO_2e/ha)
High Himal	75	0.25	18.66	0.47	43.86	3.67	160.81
High Mountain	75	0.25	18.66	0.47	43.86	3.67	160.81
Middle Mountain	39	0.25	9.85	0.47	23.15	3.67	84.87
Siwalik	47	0.25	11.84	0.47	27.82	3.67	102.02
Tarai	52	0.25	13.06	0.47	30.70	3.67	112.57

Table 15: Removal Factors - Afforestation

The annual carbon dioxide emission and removals due to deforestation and afforestation are presented in Table 16. The table shows that total emissions due to deforestation was estimated at 91 7,743 tCO_2e and removals of 150,110 tCO_2e due to afforestation. The highest emissions were found in the Terai region (i.e. 464,870 tCO_2e) whilst the Middle Mountain contributed highest removals (i.e. 46,849 tCO_2e).

Physiographic Region	Annual emissions from deforestation (2000-2010)- tCO_2e	Annual removals from afforestation (2000-2010) - tCO_2e
High Himal	18,274	5,541
High Mountain	160,834	45,532
Middle Mountain	43,387	46,849
Siwalik	230,377	19,473
Tarai	464,870	32,715
Nepal	**917,743**	**150,110**

Table 16: Annual CO_2e (t) Emissions and Removals due to Deforestation and Afforestation

6 FOREST DEGRADATION:

6.1 Part 1: Estimating emissions from forest degradation due to fuelwood[1] harvesting

6.1.1 Introduction

The scope of this study was to estimate forest degradation due to excessive fueldwoodharvesting to be integrated in the construction of Nepal's FRL for REDD+. Several forest inventories were conducted in Nepal from the 1960's to the most recent in 2010-14, but each one followed an independent design and their results are not sufficiently detailed and consistent to allow a reliable estimation of changes in forest density and biomass stock over time.

In the absence of consistent multi-date observations of forest biomass stock for Nepal from which degradation rates could be measured, the degradation due to unsustainable fuelwood harvesting was estimated applying the Woodfuels Integrated Supply/Demand Overview Mapping (WISDOM) methodology.

It must be emphasized that WISDOM was here used in substitution of a direct measurement method (such as the multi-date observations of biomass stock) to produce an estimation of forest degradation, rather than to observe it. This represents an indirect method for the estimation of forest degradation, which may be applied when more direct measurement approaches are not feasible or not sufficiently reliable[2]. No doubt, the direct observation and measurement of forest degradation is of paramount importance for the accurate accounting of forest-related carbon fluxes and efforts for the development of sound methodologies must continue.

The data available for the WISDOM analysis was collected in or around 2010, which means that the resulting annual degradation rates are representative of the end of the reporting period, rather than being the average of the full reporting period. An attempt to use historical inventory data to estimate the situation at the beginning of the reporting period did not yield good usable results due to the poor consistency between historical inventories and the FRA inventory 2010-2014.

The present analysis, in addition to producing degradation estimates, will strongly contribute to future direct estimation efforts by providing survey stratification criteria (see map on degradation risk in Figure 13) that will make the direct observation of biomass stock changes more efficient and less expensive. It will also support the identification of remedial actions by providing essential quantitative and spatial elements linking cause (demand for fuelwood) and effect (rates of degradation) that are fundamental to the formulation of locally-tailored forestry and energy interventions and to the design of strategic and operational planning.

6.1.2 Methodology

Numerous studies affirm that fuelwood demand and supply patterns are very site specific and that the impact of fuelwood extraction cannot be estimated by simply comparing national or sub-national statistics of fuelwood consumption and supply potential[3]. Accordingly, in this study we assume that degradation

[1] woodfuel and fuelwood are interchangeably using throughout the report

[2] Wageningen University, GOFC-GOLD, World Bank FCPF, 2015. REDD+ training materials.

[3] Leach, M. & R. Mearns, 1988. "Beyond the Woodfuel Crisis: People, Land and Trees in Africa." Earthscan Publications. London. RWEDP, 1997."Regional study on wood energy today and tomorrow in Asia." Regional Wood Energy Development Programme

depends on the spatial relation between fuelwood consumption and accessible supply sources and, more specifically, on the harvesting of local and distant resources induced by fuelwood demand and on their sustainable supply potential. It should be noted that Nepal's second national communications report[4] to the UNFCCC did not account for the spatial dimension of fuelwood demand and supply and hence the results therein are not comparable with this study.

The WISDOM methodology was specifically developed to analyze this spatial relation and, through Woodshed Analysis, to model fuelwood harvesting on a gradient of demand pressure and accessibility of resources. The flowchart in Figure 11 provides an overview of the phases of analysis.

As summarized in Figure 11 there are two main phases of analysis:

Phase –I: WISDOM Base: This phase of analysis leads to the best possible estimation and mapping of fuelwood supply and demand and of the surplus/deficit estimated in a local harvesting context. This phase is based on the identification, procurement, elaboration and integration of numerous statistical and cartographic layers related to the annual fuelwood demand from all sectors and to the annual sustainable supply potential from forest and non-forest woody biomass sources.

Spatialized supply and demand data are then combined to estimate the "local" balance assuming a 3-km harvesting horizon of rural households that rely mainly on direct fuelwood collection. The local balance map is a key product of the WISDOM analysis that delineates and quantifies surplus and deficit conditions throughout the country, forming the basis for the following phase of analysis and, most commonly, for forestry and energy planning purposes.

Phase –II: Woodshed Analysis, The second phase of analysis focuses on modeling the fuelwood harvesting generated by the demand that cannot be satisfied by local resources (i.e. fuelwood deficit areas from local balance map). The location and intensity of fuelwood harvesting beyond the 3-km horizon, here termed "commercial harvesting", is then based on the pressure exerted by deficit areas (determined by level of demand and physical accessibility) and the availability of resources (i.e. surplus resources from the local balance map) that are suitable for commercial harvesting. Other driving factors are market mechanisms that determine the fraction of the local deficit that originates from commercial harvesting (the remaining fraction being therefore unsustainable harvesting of local resources) and transportation thresholds that represent the distance beyond which commercial harvesting becomes uneconomic.

In this phase several data variants are used and alternative assumptions are made to create different scenarios and to assess the sensitivity of the WISDOM analysis[5].

(RWEDP) in Asia GCP/RAS/154/NET. Field Document N 50. Food and Agriculture Organization of the United Nations / Kingdom of The Netherlands. Bangkok, Thailand.

Mahapatra A.K. & C.P. Mitchell, 1999. "Biofuel consumption, deforestation, and farm level tree growing in rural India." Biomass and Bioenergy 17:291-303.

Drigo R., O.R. Masera and M.A. Trossero.2002. Woodfuel Integrated Supply/Demand Overview Mapping – WISDOM: a geographical representation of woodfuel priority areas. Unasylva Vol. 53 2002/4, pp 36-40. FAO.(Available in English, Spanish and French).

Arnold M., G. Köhlin, R. Persson, G. Shepherd, 2003. "FuelwoodRevisited : What Has Changed in the Last Decade ?" Occasional Paper No. 39.Center for International Forestry Research (CIFOR).Bogor Barat, Indonesia.

See also numerous case studies of WISDOM applications by FAO and others at www.wisdomprojects.net

[4]Ministry of Science, Technology and Environment. 2014. Nepal Second National Communication to United Nations Framework Convention on Climate Change.

[5] See Table 17 further below for the full list of data variants and alternative assumptions considered. Table 17 presents also the specific set of variants and assumptions that form the Leading Scenario.

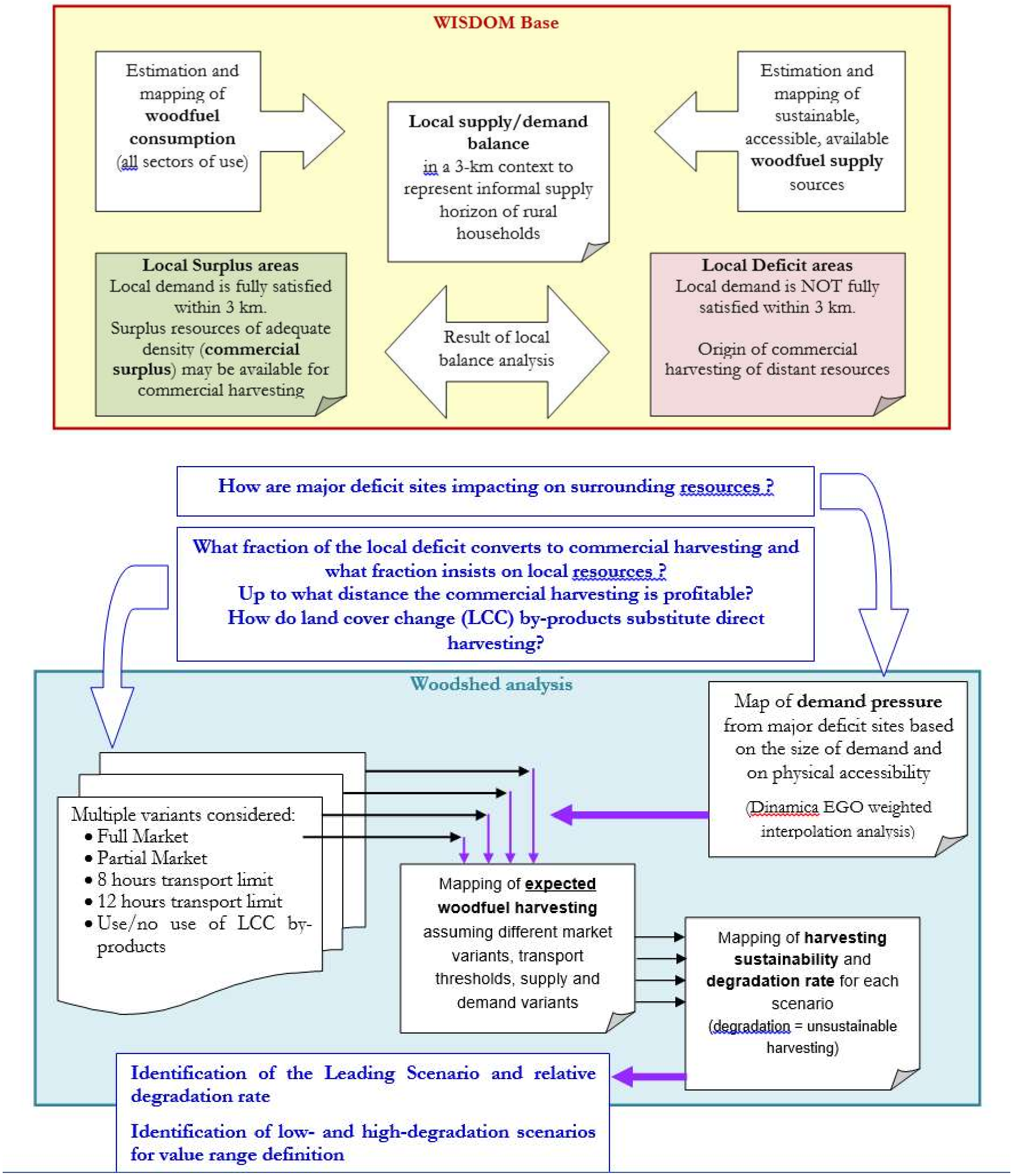


Figure 12: Overview of the phases of analysis in WISDOM

List of Definitions, data sources and assumptions

Main definitions

Woodfuel	Defined as in FAO /unified Bioenergy Terminology (UBET): In Nepal woodfuels are made almost exclusively by fuelwood (use of charcoal is negligible), hence in this context the terms can be used interchangeably
Fuelwood	Defined as in FAO /unified Bioenergy Terminology (UBET)
Conventional fuelwood	Fuelwood made of solid wood composed by split stemwood and branches, excluding marginal fuelwood
Marginal fuelwood	Fuelwood made of twigs and small branches produced by annual pruning of trees and shrubs
Total consumption	Fuelwood consumption in all sectors of use. It includes conventional and marginal fuelwood.
Conventional consumption	Consumption of conventional fuelwood, excluding marginal fuelwood.
Dendroenergy biomass (DEB):	Woody fraction of the aboveground biomass suitable to be used as conventional fuelwood. Equal to aboveground biomass less stump, twigs and foliage.
DEB stock	Standing dendroenergy biomass. Measured in kg or tons DM. Air-dry tons are also used. In this context, dry matter is 0.91*air dry mass (DFRS 2015).
DEB MAI	Mean annual increment (MAI) of the dendroenergy biomass (DEB). In this analysis it is taken as the sustainable production potential. It may correspond to the actual growth of secondary formations recovering from previous disturbance or the re-growth capacity of mature formations after harvesting
Physical accessibility	The physical accessibility is here based on the estimated transport time from the nearest accessible feature (road, settlement). It is a continuous value expressed as a percentage. Within 2 hours the accessibility is assumed as 100% and above 12 hours is assumed as 0%.
Legal accessibility	The legal accessibility is based on the limitations imposed inside Protected Areas (PA) to fuelwood harvesting. Different limitations are applied for local subsistence harvesting by local communities, depending on categories of PA. Commercial harvesting is considered off limits in all PA categories.
Accessible DEB MAI	Annual sustainable DEB production potential after application of physical and legal accessibility factors.
Available DEB MAI	Fraction of the accessible DEB MAI that can be considered available to energy uses after deduction of competing uses such as industrial round wood and timber production.
Supply/demand balance	Algebraic difference between the available Deb MAI and fuelwood consumption. Positive values represent surplus conditions and negative values represent deficit conditions.
Local balance	Difference between the available Deb MAI and fuelwood consumption in a 3km harvesting context, meant to represent rural (informal, non-commercial) harvesting horizon. The local balance reveals areas of local deficit and local surplus.
Commercial harvesting	With this term we refer to the harvesting of distant wood resources (beyond the local 3km horizon) that is done to satisfy local deficit areas, such as urban and dense rural areas.
Commercial surplus	Fraction of local surplus that is sufficiently stocked to be suitable for commercial harvesting. Areas where the local surplus is made of sparse wood resources are excluded.

Woodshed Supply zones of major deficit sites. These zones are termed "woodsheds" in analogy with the familiar geographical concept of watersheds (Drigo and Salbitano, 2008).

Sustainable woodshed The sustainable woodshed of a given consumption site is the minimum area around the site in which the cumulative balance between the deficit areas and commercial surplus areas is non-negative.

Commercial woodshed The commercial woodshed is the commercial harvesting area that supplies fuelwoodto major deficit sites (i.e. urban and rural fuelwood markets). Commercial woodsheds are determined by the level of demand, resource availability and transport costs, rather than by sustainability criteria.

Unsustainable harvesting The fraction of harvesting that exceeds the sustainable supply potential. Measured in tons DM of woody biomass, the unsustainable harvesting corresponds to the fuelwood-induced degradation.

Land Cover Change (LCC) by-products: Woody by-products of forest change processes. In this study the by-products that are used as fuelwood are assumed to range between 0 and 70% of the by-products released by LCC processes (deforestation, afforestation), the rest is either used as timber or left on site.

Forest-Remaining-Forest Fraction of forest that remained forest over the period 2000-2010.

<u>Data sources:</u>

Demand parameters:

Per capita household consumption: Census 2011, MPFS 1988, Central Bureau of Statistics, (CBS) Nepal. 2011. Nepal Living Standard Survey (NLSS) III -2010, Fox 1984, Rijal 2002.

Fuel saturation: CBS NLSS III 2010

Other sectors of fuelwood consumption: CBS, Census 2011, World Food Programme, WISDOM analyses, WECS 2013.

Supply parameters:

Land cover: DFRS, based on RapidEye 5m resolution 2010-201; Forest Type map (DFRS 2015)

DEB Stock and MAI: Georeferenced stock values from 2544 plots (FRA 2010-2014) (DFRS, 2015)

Physical accessibility analysis: Digital Elevation Model of 30m spatial resolution (source: ASTER); Road network and settlements from Topographic Maps of Nepal, ICIMOD land cover classes based on Landsat TM

Legal accessibility: Map of protected areas of Nepal from MoFSC database.

<u>Main assumptions</u>

As mentioned above, the sensitivity analysis was based on the adoption of data variants for demand and supply parameters and on alternative assumptions relative to market mechanisms, transportation thresholds and the use of land cover change by-products to substitute for direct fuelwood harvesting. The full range of data variants considered and assumptions made are presented in Table 21. This allowed the identification of the Leading Scenario representing mid-range conditions and relative degradation estimates.

6.1.3 Emissions- fuelwood demand

The annual consumption of fuelwood in the residential sector for cooking and heating was estimated using Central Bureau of Statistics (CBS) data from the National Living Standard Survey (NLSS) 2010 and from several sources that estimated per capita fuelwood consumption in rural and urban areas (MPFS

1984; Fox 1984; Rijal 2002; NLSS 2010). Other consumptions in the residential sector (cremations and construction material) were estimated based on available national sources (CBS, WFP) or, tentatively, based on other countries' estimates. The consumption in the commercial and industrial sectors were estimated based on the National Survey of Energy Consumption and Supply Situation conducted by the Water and Energy Commission Secretariat (WECS 2013).

The mapping of fuelwood consumption was based on the map of rural and urban populations in 2010-2011 that was produced specifically for this purpose using maps of Village Development Committees (VDCs) and statistics from Census 2011 and other spatial features (roads, settlements) derived from National Topographic Maps.

The national level consumption of fuelwood in the various sectors is summarized in Table 17 while the geographic distribution of fuelwood consumption in all sectors combined is shown in Table 18. The annual demand for fuelwood in 2010-2011 in all sectors of use is approximately 10.1 million tons DM, which may be subdivided into 9.3 million tons DM of conventional wood made of stemwood and branches and 0.82 million tons DM of "marginal" fuelwood made of twigs and small branches from pruning of farm trees and shrubs

Sector of use	Remarks/sources	Total annual fuelwood consumption 2010-2011
Household use for cooking and heating	Including conventional and marginal fuelwood	**8,996**
Other Household uses		
Cremation wood	Approximate, based on Hindu pop by District. (CBS, Census 2011; WFP)	**48**
Construction material	For fences and stables, house repairs, etc.; not for energy but same sources. Tentative, based on	**259**
Other sectors		
Industrial sector	(WECS 2013)	**385**
Commercial Sector	(WECS 2013)	**390**
		10,079

Table 17: Summary of annual fuelwood consumption in the various sectors in 2010-2011

Physiographic Zone	Total consumption (conventional + marginal) kt DM	Conventional consumption (excluding marginal) kt DM
High Himalaya	32	27
High Mountains	1,124	1,121
Mid Mountains	4,766	4,537
Siwaliks	1,076	1,050
Terai	3,080	2,526
Nepal	**10,079**	**9,260**

Table 18: Fuelwood consumption by Development Region and Physiographic zone. Distinction is made between conventional fuelwood and marginal fuelwood.

6.1.4 Removals - sustainable supply potential

The Dendroenergy Biomass[6] (DEB) stock in 2010 is estimated and mapped on the basis of the 2,544 field plots of the NFI carried out between 2010 and 2014. Field plots are grouped into 26 strata based on (i) land cover classes [including non-forest classes], (ii) vegetation types, (iii) physiographic zones and (iv) Development Regions. Mean DEB stock values per stratum ± 95% confidence intervals are used to define minimum, medium and maximum DEB stock variants.

In order to achieve a more discrete distribution of DEB stock than the mapping of simple strata means, MODIS Vegetation Continuous Field (VCF) data for year 2010[7] was used as a spatial proxy for the modulation of DEB stock within strata.

For the analysis of harvesting sustainability, however, what matters most is the annual sustainable supply potential, rather than the stock.

The annual sustainable supply potential is here intended as the Mean Annual Increment (MAI) of the DEB that is accessible and potentially available for energy uses. DEB MAI is calculated by dividing the DEB stock by the number of years necessary to produce it. In practice, the DEB MAI of a certain area represents the maximum quantity of DEB that can be annually extracted from the area by applying a sustainable rotation system[8].

In the absence of specific MAI data for Nepal's forests, the DEB MAI in 2010 is estimated by applying stock/MAI equations for coniferous and broadleaved formations that are based on published field observations of MAI and stock in similar ecological contexts (Puri et. al 2015).

The annual fuelwood harvesting in a given area is considered sustainable if it's less than, or equal to, the DEB MAI of such area, while the harvesting fraction that exceeds DEB MAI is considered unsustainable. The quantity of unsustainable harvesting corresponds to the annual forest biomass loss (or quantity of

[6] The DendroEnergy Biomass (DEB) is intended as the fraction of the aboveground biomass (AGB) that is suitable as fuelwood. DEB includes the total aboveground biomass, less foliage and stump.

[7]DiMiceli, C.M., M.L. Carroll, R.A. Sohlberg, C. Huang, M.C. Hansen, and J.R.G. Townshend (2011), Annual Global Automated MODIS Vegetation Continuous Fields (MOD44B) at 250 m Spatial Resolution for Data Years Beginning Day 65, 2000 - 2010, Collection 5 Percent Tree Cover, University of Maryland, College Park, MD, USA.

[8] In this analysis individual harvesting events are not considered. Rather than specific harvesting events that are extremely difficult to simulate, we consider the harvesting pressure in a local context of 3km for informal fuelwood harvesting and in a much wider context for commercial fuelwood harvesting.

biomass that cannot be regenerated by normal re-growth capacity) and represents the degradation due to excessive fuelwood harvesting.

As mentioned, not the whole DEB MAI is considered, but only the fraction that is physically and legally accessible and that may be considered available for energy use after deduction of competing uses such as industrial roundwood production. In order to assess the physical accessibility of woody resources, a detailed map of transport time to the nearest accessible feature was created combining topographic features (roads, tracks and footpaths; settlements), slope and altitude, and friction parameters associated to land use classes. Legal accessibility was mapped using protected areas and access rights for subsistence and commercial fuelwood harvesting.

The annual sustainable supply potential that is accessible and potentially available for energy uses is estimated to be 15.7 million tons DM [9], as shown in Table 15. Such supply potential is significantly greater than the annual fuelwood demand, exceeding it by 5.6 million tons DM. But this apparent surplus is purely <u>theoretical</u> since demand and supply potential are not evenly distributed and there are areas where fuelwood harvestings exceeds the sustainable increment and other areas where the supply potential remains untapped.

Box 1: Comparing applied MAI estimates and IPCC default MAI values

The forests of Nepal fall in 4 broad ecological zones, more or less equally represented (FAO global ecological zone map). Here are the zones and the IPCC growth values for Continental Asia in tons DM /ha/yr:

Tropical rainforest <20y= 7 (3 – 11); >20y= 2.2 (1.3 – 3).

Tropical moist deciduos forest <20y= 9; >20y= 2

Tropical mountain system <20y= 1 – 5 ;>20y= 0.5 – 1

Subtropical mountain system <20y= 1 – 5 ;>20y= 0.5 – 1

If we assume that these conditions are equally represented, the average of averages of IPCC values would be 3.46 tonnes DM /ha/yr. The average forest MAI of the WISDOM analysis is 2.64 tonnes DM /ha/yr. , which is 24% lower than IPCC values and could thus be considered a "conservative" value.

	DEB stock	**DEB MAI**	**Accessible & Available DEB MAI**
	Medium variant	**Medium variant**	**Medium variant**
Physiographic Zone	kt DM	kt DM yr^{-1}	kt DM yr^{-1}
High Himalaya	58,449	1,059	115
High Mountains	529,760	7,701	4,112
Mid Mountains	289,816	7,569	6,713
Siwaliks	209,977	4,170	2,872
Terai	83,901	2,451	1,879
Nepal	**1,171,904**	**22,949**	**15,692**

Table 19: Summary by Development Region and Physiographic zone of dendroenergy biomass (DEB) stock, Mean Annual Increment (DEB MAI), and DEB MAI legally and physically accessible and available for energy uses, according to Minimum, Medium and Maximum variants.

[9] The whole DEB MAI is estimated to be 25.2 million tons air dry (range 22.6 to 27.4), 23.7% of which is not accessible or not available for energy uses.

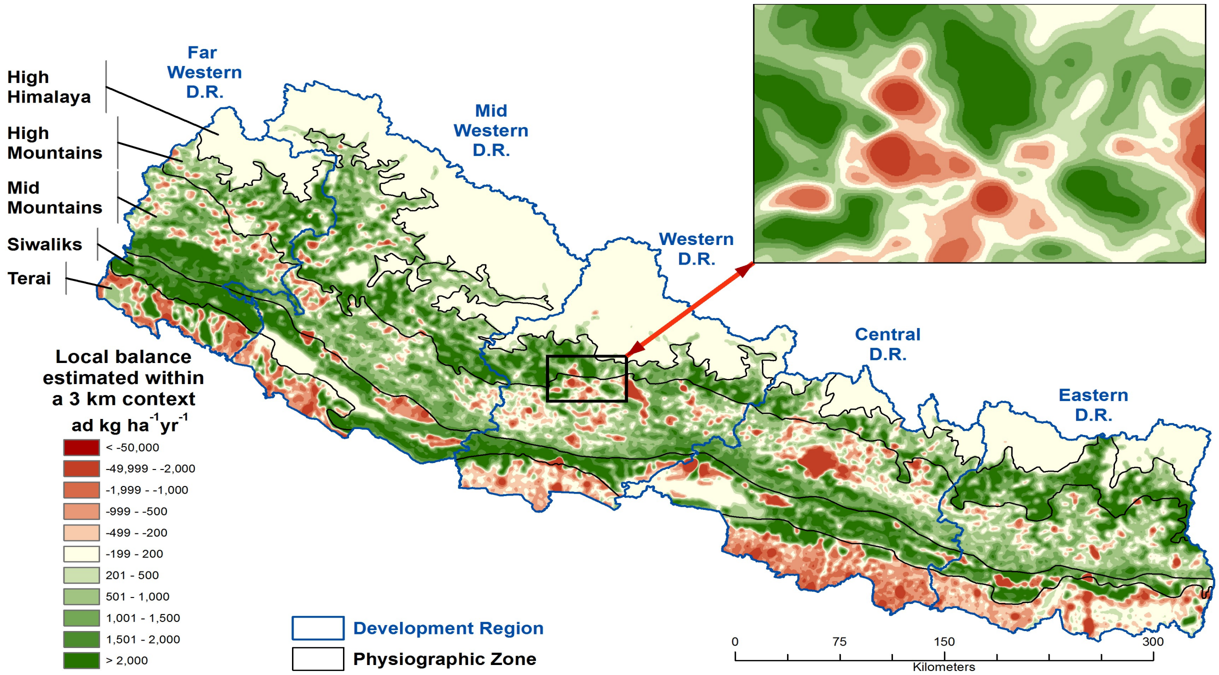
6.1.5 Net degradation estimate - local deficit and commercial harvesting sustainability

As mentioned in the Methodology section above, the spatial relation between consumption sites and available woody resources is more important than the respective total values. In this respect, we recognize two spatial contexts: the local context, with a harvesting horizon of 3km from consumption sites, and the commercial context, with a much wider harvesting horizon, limited primarily by transport time and cost considerations. In our analysis, we first estimate the balance in the local context and then estimate the commercial context in consideration of the demand that cannot be satisfied by local resources (local deficit).

In a large part of the country, the rural demand for fuelwood seems to be satisfied by the resources accessible within the typical harvesting horizon of 3km or within 10-15km for the larger settlements. However, this is not the case for the densely populated Terai, and in the Mid Mountains and Siwaliks of the Central and Western Development Regions, as shown in Figure 13. In these areas, the high concentration of the consumption that cannot be locally satisfied creates a strong commercial fuelwood demand, which poses a high pressure on the accessible resources with consequent risk of degradation. With reference to the conventional demand, 6.7 million tons DM (72%) is met from local resources, while 2.6 million tons DM (28%) is NOT met from local resources - representing the local deficit - as summarized by physiographic zone in Table 16.

The commercial harvesting necessary to satisfy the local deficit, and the consequent risk of degradation, was estimated through woodshed analysis, taking a range of assumptions concerning (i) the fraction of demand of local deficit areas (i.e. all cities and many densely populated rural areas) that gives origin to commercial harvesting and the fraction that insists on scarce local resources; (ii) the transport time threshold that makes distant harvesting unprofitable, and (iii) concerning the role of land cover change (LCC) by-products used. The full range of variants and assumptions considered, and those considered as most probably contributing to the Leading Scenario are presented in Table 18.

Figure 13: Map of Local Balance estimated within local harvesting context of 3 km. Medium supply and Conventional consumption variants.



Physiographic Zone	Conventional fuelwood consumption kt DM	Conventional consumption locally satisfied kt DM	Conventional consumption NOT satisfied by local resources (Local deficit) kt DM
High Himalaya	27	19	8
High Mountains	1,121	1,061	60
Mid Mountains	4,537	3,629	908
Siwaliks	1,050	706	344
Terai	2,526	1,273	1,253
Nepal	**9,260**	**6,688**	**2,572**

Table 20: Fuelwood demand satisfied by local resources (within a 3-km context) and demand that is NOT satisfied by local resources (local deficit) by Physiographic zones. The values refer to the Conventional fuelwood demand, excluding marginal fuelwood.

The range of alternative commercial harvesting assumptions, combined with demand and supply variants produced a large number of theoretical scenarios. Data variants and alternative assumptions were considered in order to improve the analysis and gain a sense of how each factor affects the final results. The degradation estimates relative to the theoretical scenarios provide a rich and comprehensive sensitivity analysis of the WISDOM model. The indirect assessment of degradation Nepal proposes for its FRL does not allow for a direct calculation of uncertainty of the estimate of net degradation from fuelwood extraction. The sensitivity analysis provides an approximation of the estimate's uncertainty by providing a range within which we expect the true value of net degradation from fuelwood extraction to be found.

6.1.6 Leading scenario

A thorough review of the scenarios considered, and the relative patterns and rate of degradation, allowed the identification of the most probable Leading Scenario, while low and high degradation scenarios were picked to represent the range of values.

The Leading Scenario is the one resulting from the application of the most probable variants and assumptions.

Variants considered	**Most probable variants (Leading Scenario)**	**Remarks on the selected variant/assumption**
Supply variants: • **Minimum** (mean minus 95% Conf. Interval) • **Medium** (mean strata values) • **Maximum** (mean plus 95% Conf. Interval)	**Medium** (based on mean strata values)	The supply potential based on mean strata values from the National Forest Inventory 2010-2014 is the obvious choice for national level estimates
Demand variants: • **Total demand** (including conventional and marginal fuelwood) • **Conventional demand** (excluding marginal fuelwood)	**Conventional demand** (excluding marginal fuelwood)	The productivity of twigs and pruning material is not included in the supply potential. Excluding the use of this marginal fuelwood in the deficit areas of the rural Terai, although only tentatively estimated, appears reasonable. Conventional demand is 95% of total demand.
Market variants: • **Full market** (all local deficit originates commercial harvesting) • **Partial Market** (the urban deficit and 50% of rural deficit is met from commercial harvesting, while the remaining 50% is met from overexploitation of local resources)	**Partial Market** (the urban deficit and 50% of rural deficit is met from commercial harvesting, while the remaining 50% is met from overexploitation of local resources)	The Full Market variant whereby rural users buy the fuelwood rather than overharvesting local resources seems unrealistic for economic reasons. Although the Partial Market mechanism is only tentative, it better represents economic factors and field experience.
Transport thresholds of commercial fuelwood: • **8 hours** • **12 hours**	**8 hours** transport threshold	Given the availability of resources, the 12-hours threshold seems unjustified. Although this parameter needs field verification, the 8-hours threshold seems more adequate. In many parts of the country, however, an even lower threshold may be justified.
Use of LCC by-products: • **No use (0%)** • **Full Use (70%)**	**Midpoint** between Use and No use, estimated as 35% of by-products released by LCCs.	The two variants represent the extremes (0% and 70%) rather than alternative scenarios. The midpoint between the two cases, i.e. 35% represents the moderate use of LCC by-products, which may best represent the most probable situation.

Table 21: Summary of all variants considered and selected variants forming the Leading Scenario

The results of the Leading Scenario are summarized in Table 22 by Physiographic zone. Results are presented for all FRA land cover classes, including Forests, Other Wooded Lands and Other Lands, as well as for the Forest-Remaining-Forest (FRF) area, that represents the area under forest cover for the whole reporting period 2000-2010.

It should be noted that by considering the use of deforestation by-products and the consequent reduction of direct fuelwood harvesting we avoid double counting.

The **expected annual degradation** rate due to excessive fuelwood harvesting **over all FRA land cover classes**, including Forests, Other Wooded Lands and Other Lands, according to the Leading Scenario is estimated to be 881,000 t DM, corresponding to net emissions of **1,518,000t CO_2e/year**[10].

Under the same Leading Scenario, the **expected annual degradation of the Forest-remaining-Forest (FRF)**, i.e. the area that remained under forest cover for the whole reporting period 2000-2010, is 198,0001 t DM, corresponding to net emissions of **341,000 t CO_2e/year**.

Physiographic Zone	Total Nepal			Within Forest-Remaining-Forest		
	Total area	Annual harvesting	Annual degradation	FRF area	Annual harvesting	Annual degradation
	'000 ha	kt DM yr^{-1}		'000 ha	kt DM yr^{-1}	
High Himalaya	3,538	29	**6**	162	4	**0.1**
high Mountains	3,012	1,175	**28**	1,803	554	**5.2**
Mid Mountains	4,309	4,633	**348**	2,213	2,197	**130.5**
Siwaliks	1,898	1,402	**72**	1,342	890	**25.2**
Terai	2,020	2,025 0.62/ha	**427**	398	460 1.15/ha	**36.8**
Total Nepal	**14,778**	**9,264**	**881**	**5,918**	**4,107**	**197.8**

Table 22: Summary of expected degradation induced by excessive fuelwood harvesting according to the Leading Scenario

The geographic distribution of the expected degradation is best represented by the map of the degradation risk shown in Figure 13, based on the quantity of woody biomass unsustainably harvested according to the Leading Scenario.

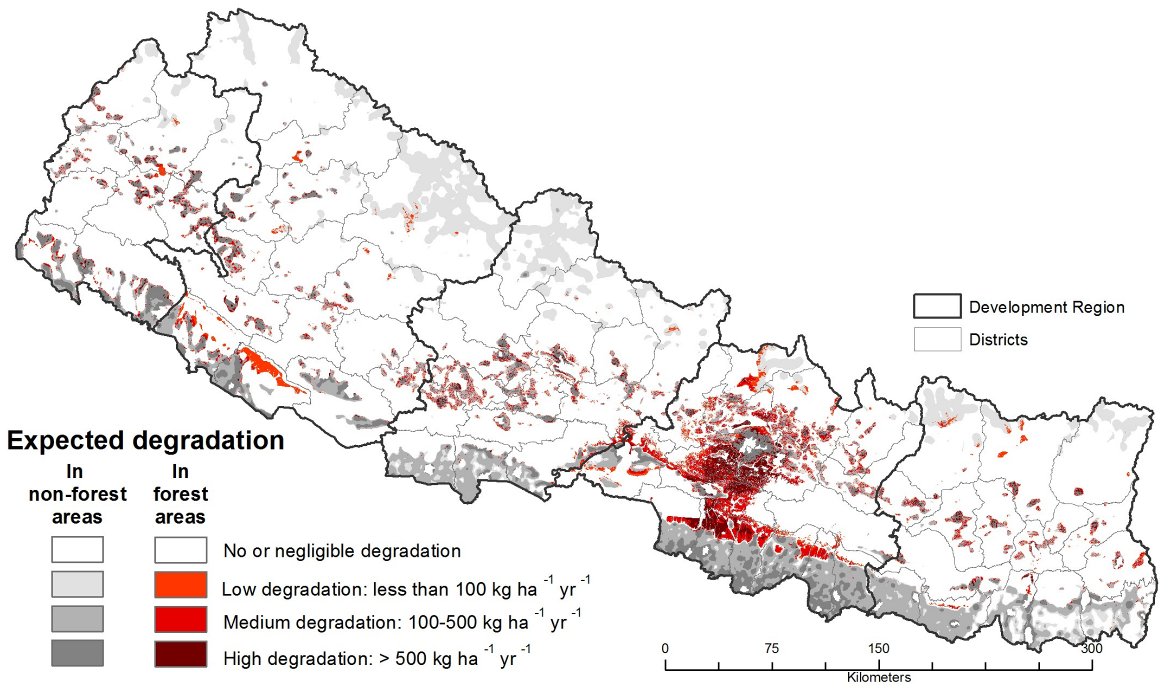
At country level, degradation of biomass stock is expected to take place over 25.7% of the entire territory, of which 10.4% may be classified as low degradation, 10.4% as moderate degradation and 4.9% as high degradation[11].

With reference to FRF, the degradation is expected to take place over 11.5% of the area, of which 3.5% may be classified as low degradation, 5.2% as moderate degradation and 2.7% as high degradation.

[10] Using a carbon fraction of 0.47 and a conversion factor from C to CO_2 of 44/12 (IPCC 2006)
[11]Ranking of degradation intensity: Classified as Low for degradation per hectare and per year below 100 ad kg; Moderate with degradation between 100 and 500 ad kg $ha^{-1}yr^{-1}$; High with degradation above 500 ad kg $ha^{-1}yr^{-1}$.

By physiographic zones, degradation is expected primarily in the Terai (with 58.2% of the area under moderate to high degradation) and Mid Mountains region (with 16.6% of the area under moderate to high degradation) followed by the Siwaliks (13.8% under moderate to high degradation).

Figure 14: Ranking of risk of degradation due to unsustainable fuelwood harvesting (Leading Scenario)



6.1.7 *Range of degradation estimates*

As mentioned above, each scenario produced different degradation estimates. Besides the understanding of how each assumption and data variant affected the results and helped to identify the Leading Scenario, these scenarios indicate the range of possible degradation estimates. The variants and assumptions leading to the highest and lowest degradation estimates are listed below.

Variants and assumptions leading to high degradation	Variants and assumptions leading to low degradation
Minimum Supply	Maximum Supply
Total Demand	Conventional Demand
Partial Market	Full Market
8 hours transport	12 hours transport
No use of LCC by-products	Full use of LCC by-products

Lowest estimates: According to the scenario based on **most favorable variants and assumptions**, the lowest degradation estimate for the whole Country is 54,000 t DM, or **93,060 t CO_2e/year**. When referred to the Forest-Remaining-Forest only, the lowest estimated degradation is 46,500t DM, or **80,135 t CO_2e/year**.

Highest estimates: According to the scenario based on **least favorable variants and assumptions**, the highest degradation estimate for the whole Country is 2,040,000t DM, or **3515,600 t CO_2e/year**. When referred to the Forest-Remaining-Forest only, the highest estimated degradation is 714,000t DM, or **123, 046 t CO_2e/year**.

6.1.8 Limitations and contributions of WISDOM analysis

Limitations

As discussed in the introduction, this study represents and indirect estimation of forest degradation, or estimation of the risk of degradation, which should be replaced by a direct estimation based on the measurement of changes of biomass stock over time, as soon as a sound and practical methodology is available.

A specific limitation of this study is that it estimates the annual degradation rate in 2010, which is at the end of the FRL 2000-2010 reporting period. Given the relatively low variability of the basic elements (fuelwood consumption; biomass resources, land cover, each of them expected to change less than 5% since 2005, which may be considered a mid-point representation of the 10-year period) the average annual degradation rate within the reporting period is not expected to change significantly from the one here estimated for 2010. Nonetheless, the rate here estimated cannot be taken as the average of the whole period but rather as representative of the last part of the reference period. An attempt to use historical inventory data to estimate the situation at the beginning of the reference period did not yield good usable results due to the poor consistency between historical inventories and the FRA inventory 2010-2014.)

The development of WISDOM Nepal implied several assumptions and some tentative value attributions to fill in for information gaps. In order to improve the analysis and consolidate the knowledge base these assumptions need validation and the tentative estimates should be replaced by solid reference data. The most relevant information gaps to be filled include the following:

Data weakness on supply

- There is little data on sustainable productivity in forests and nothing at all on productivity in farmlands and shrublands. These are important sources of fuelwood that must be well understood in order to assess with accuracy the true impact on forest resources.
- The industrial roundwood production appears very low. Beyond Forest Department records on timber production and sale, the estimation of the total use of industrial roundwood in Nepal should be based on industrial sector data in consultation with the Chamber of Commerce.
- The physical accessibility of wood resources is of paramount importance in a mountain country like Nepal. The data on roads and paths used in this analysis is extremely detailed but is probably out of date in some areas. Updated road network data, including non-motorable trails and footpaths, is essential for a correct estimation of accessible resources.

Data weakness on demand

- Fuelwood consumption surveys must adopt quantitative measurement techniques avoiding as much as possible people's estimates of consumption per month or per year. FAO produced practical guidelines on fuelwood consumption surveys (FAO, 2002) that offer possible solutions. In particular, the "average day consumption" approach could be effective as it allows measurement of a day's consumption with good accuracy with only one visit.
- Consumption surveys must differentiate between “conventional” fuelwood made of stem wood

and branches and "marginal" fuelwood made of twigs and smaller branches that are not considered among forest products and that are often produced through annual or periodic pruning of farm trees and shrubs, hedges, etc.

- The coping strategies put in place by rural households in scarcity or in absence of "conventional" fuelwood are little known. Annual or periodic pruning of farm trees, shrubs, hedges, etc. certainly produce more fuelwood than it is generally assumed

Assumptions made in the analysis of commercial woodshed

- How the shortage of resources in rural areas relates to commercial harvesting of distant resources or to the overexploitation of local ones remains uncertain, although this has important consequences on degradation estimates. In order to cover this aspect, separate assumptions were made in this study (Full Market and Partial Market variants) that need to be verified in the field for fine tuning of the WISDOM analysis.
- Similarly, assumptions were made concerning the efficiency, or rationality, of commercial fuelwood harvesting. A relatively high efficiency was assumed in this study (SIEF=0.8) based on previous studies but this was only tentative. Detailed knowledge on the official and customary management practices, on the areas under community management and un-managed public forests will allow fine tuning of this parameter for a more accurate estimation and mapping of actual forest degradation.

6.2 Estimating emissions from forest degradation due to grazing

6.2.1 Description of degradation by grazing in Nepal

The mountainous landscape of Nepal, largely covered with natural vegetation, serves as a source for meeting livestock dietary needs. The Master Plan for the Forestry Sector (1988) estimated the supply and demand balance of livestock feed and confirmed the critical importance of forest-based fodder resources in meeting this demand. The recent NFI (DFRS, 2010) reported grazing as the most frequent biotic disturbance reported across forests (Fig- 15). Several studies carried out across disturbed and undisturbed areas in different physiographic regions and forests of dominant species including *Shorea robusta*(Sapkota et al 2009, Singh, 2014,Giri and Katzensteiner, 2013),Quercus semicarpifolia (Vettas, 2000; Thakuri,2010),Rhdodendron (Gautam and Watnabe,2005), Pinus (Allard,2000) and *Betula utilis* (Sujaku et al 2013) have reported a significant impact of grazing intensity and practice on regeneration and biomass. In contrast, forests under management regimes such as community forestry (Dhakal *et al* 2005; Tachibana and Adhikari, 2005,), leasehold forestry (Thierry, 2015) and protected areas (Gurung *et al*, 2009; Brower and Dennis, 2002) have reported improvement in regeneration and growing stocks under regulated grazing regimes. Grazing and livestock management is expected to have a two-fold degrading impact on the forest structure and carbon stock. Firstly, through direct emissions from forest degradation as a result of biomass extraction from grazing and fodder/feed collection. Secondly, through a negative impact on forest regeneration as a result of browsing and trampling of tree saplings. The second impact does not directly result in emissions but rather in a reduction of removals due to delayed regrowth or restoration of forest stands.

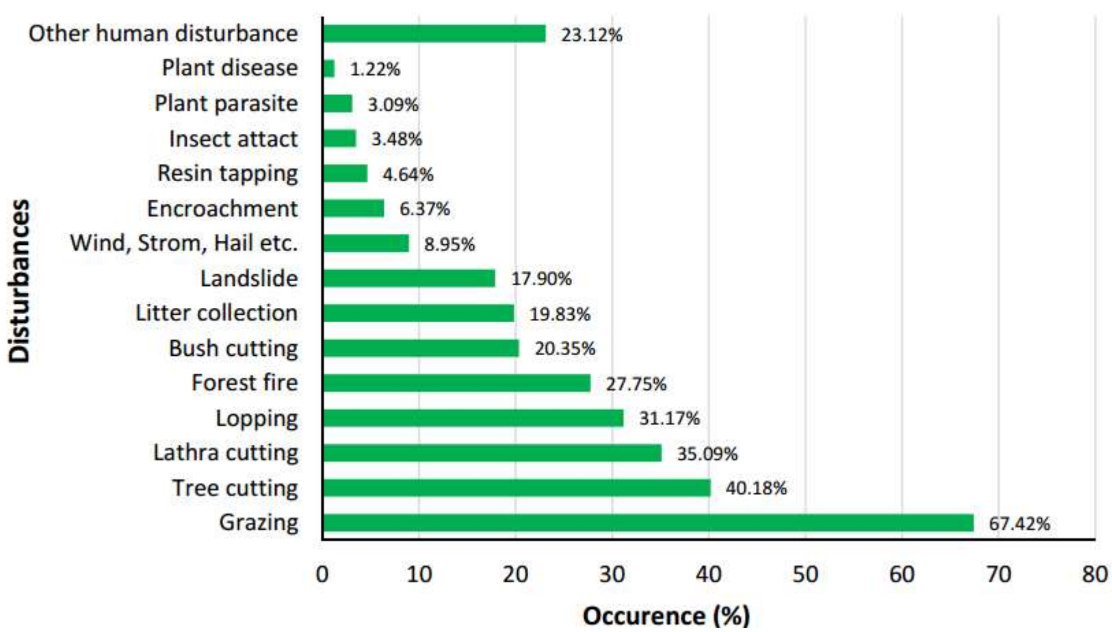


Figure 15: NFI data showing grazing as most occurring forest disturbance – Source NFI report, DFRS 2015

The above Figure (Figure 15) based on NFI (2015) data shows grazing as the most significant forest disturbance (occurrence of a disturbance does not translate directly into associated emissions, i.e. a less significant disturbance may still be more important in terms of emissions than a more frequently occurring disturbance)

As mentioned above, several studies report on the impact of grazing on forest biomass but do not provide direct temporal changes in carbon fluxes due to grazing. However, forest inventory databases, agriculture and livestock databases, which are periodically generated by different ministries, are found relevant and useful to assess forest degradation due to grazing. In view of this, the present study attempted to assess forest degradation and biomass losses due to grazing through the indirect method of assessing fodder supply and demand balance and associated impacts using nationally available information and statistics.

6.2.2 Importance of including grazing induced forest degradation in the FRL

Despite the challenges associated with quantifying emissions from forest degradation as a result of grazing and livestock management, this activity has been chosen for inclusion in the FRL because it is one of the activities strongly impacted by Nepal's REDD+ strategy. Over the past decades, Nepal has made significant progress in reducing degradation by grazing and livestock management activities in the forest through improved forest management as described by several authors (Dhakal *et al,* 2005; Tachibana and Adhikari, 2005; Thierry, 2015; Gurung *et al*, 2009; Brower and Dennis, 2002). Given that the FRL is a benchmark for assessing performance of a country in implementing REDD+ activities, it is therefore deemed important to include this activity in the FRL. Nepal would furthermore like to build its capacity to include this activity in its FRL and is therefore looking forward to the opportunity to exchange ideas with experts during the technical assessment and receive suggestions for improving the approach to assess net emissions from forest degradation by grazing.

6.2.3 Methodology for assessing net emissions from grazing induced forest degradation

It is hypothesized that fodder deficits due to a lack of sustainable supply from green fodder resources would lead to over-grazing of fodder resources in forests, resulting in degradation. Accordingly the study first estimated the fodder supply-demand balance and then assessed how this balance would impact forest biomass. While grazing impacts are very diverse in nature, in terms of fodder quality and type, species diversity, understory distribution, regeneration and woody biomass, the study was confined to the impaired regeneration effects of short-term and long-term grazing impact in terms of biomass losses. The schematic diagram showing the approach is given in Figure 16, the different supply and demand data are given in Tables 24 to 26.

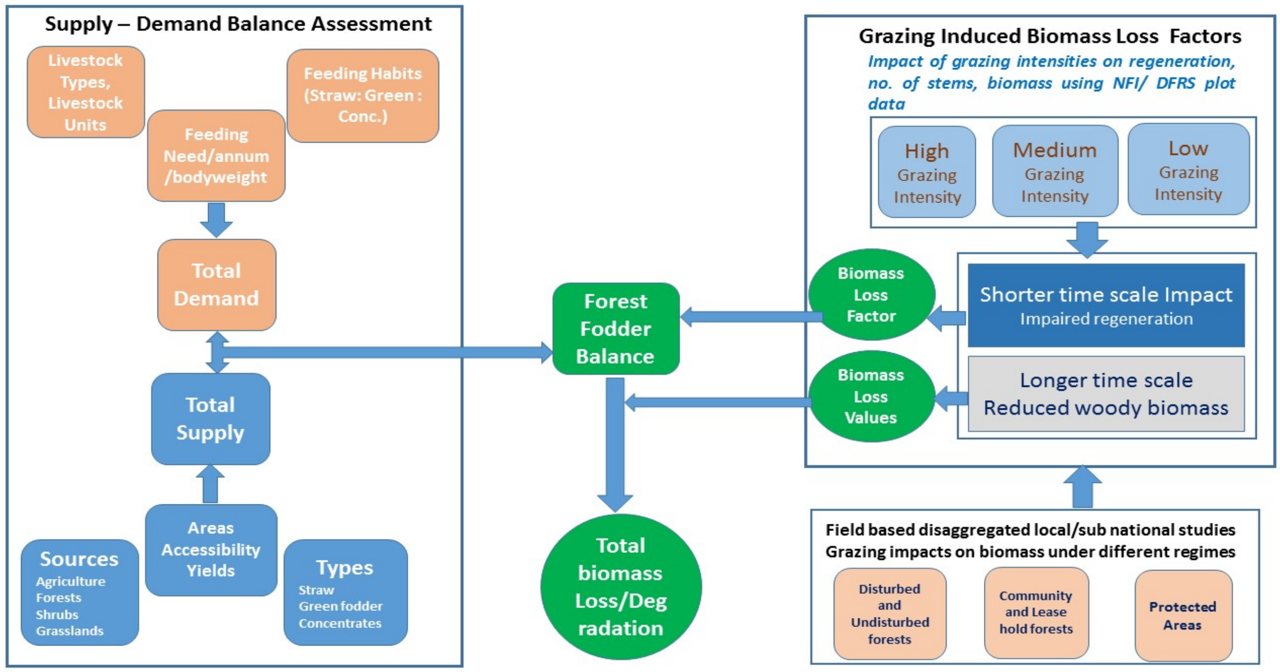


Figure 16: Schematic diagram showing methodology of estimating grazing induced forest degradation

6.2.4 Estimation of feed/fodder supplies from different sources

The total feed required/consumed by the livestock is grouped in three categories:

- Crop residue: Plant residues after removal of grains and or main products are considered as crop residue. The major sources of crop residue are paddy straw, wheat straw, maize stover, barley straw, millet stover, pulse residues, and sugarcane top. Crop residue is dry, low in feed value and high in volume. Protein and energy content is very low.
- Grain by-products/Concentrated feed: The residual parts of cereals, pulses and oil seeds, which are unsuitable for human consumption, are major sources of livestock feed. These grain by-products are high in nutritive value, rich in protein and energy and low in volume. The major types of grain by-products are rice/wheat bran, maize flour, oil cake and pulse husks.
- Green biomass: The green fodder and foliage collected and/or grazed by livestock are considered as green biomass. The major sources of green biomass are:
  a) Agricultural /farm fodder: Native grasses and weeds naturally grown in agricultural fields, fallow cropland grazing, cultivated fodder crops and foliage of fodder trees are considered as green biomass from agricultural lands,
  b) Forest and grassland biomass: Foliage from forests, shrubland and grassland: undergrowth herbaceous plants; tree foliage and grassland fodder either collected or grazed by livestock are considered as forest green biomass.

6.2.4.1 Methodology to calculate feed and fodder supply

The area sources used for different land cover types are given in Annex 1 and the detailed coefficients and factors are presented in Annex 2 and outlined below:

Crop residue: The area and production of the major crops with potential of livestock feeds such as paddy, wheat, maize, millet, pulses, oilseeds and sugarcane is documented based on MOAD, (2014). To estimate the quantity of crop residue for each category of food crops a grain to straw ratio is assigned. For example: paddy grain: straw is 1.62, wheat grain to straw is 2.17, maize grain: stover is 2.21, millet grain to straw is 1.95, pulses grain to plant residues is 1.5 and sugarcane stem to top is 0.1 (LRMP, 1986; Rajbhandary and Pradhan, 1991). A detailed table is presented in Table 3 of Annex 2.

Grain by-products /Concentrated feed: Grain by-products are considered as concentrated feed. The supply and production of grain is cited from MOAD, 2014. The calculation of grain by-products is based on the grain: grain by-product ration. The area and production of paddy, wheat, maize, millet, pulses, and mustard grain is calculated based on (MOAD, 2014) and the productivity of grain by-products based on LRMP (1986) and Rajbhandary and Pradhan (1991) as per the details given in Table 1 of Annex 2.

Green biomass: Green biomass includes all fodder, native grasses and forest tree foliage as explained below:

a) Forest and shrubland fodder: The total area of Forest Remaining Forest (FRF), including shrubland, between 2000-2010, is extracted from the Landsat TM data used for AD. The accessibility factors of forests and shrubland were obtained from a range of experts, given in Table 5 of Annex 2. The productivity of the forests of different physiographic regions are cited from LRMP (1986) and are presented in Table 2 of Annex 2.
b) Grassland fodder: The area of grassland is drawn from the Landsat TM land cover assessment of 2010 and the data on productivity of pastures is obtained from LRMP (1986). See Annex 1.
c) Green biomass from agricultural land: Data on green fodder from agricultural lands include the total area of land under agricultural use, cited from DFRS (2015); the area under cultivated fodder, cited from DLS (2016) and NARC (2016); the productivity of natural grasses and weeds and the grazing intensity of livestock on fallow land, cited from Rajbhandary and Pradhan (1991); the area under fodder trees, estimated based on CBS (2006); and the productivity of fodder trees, based on Pandey (1982). The details of these data sources are given in Annex 1.

6.2.4.2 Methodology to calculate feed and fodder demand

Calculation of Livestock Unit (LU)

The predominant livestock considered in this study were cattle, buffaloes, sheep, goats, yak/chauri and equines (excluding pigs and poultry). The livestock populations (MOAD, 2014) were converted into Livestock Units (LU) - a standard unit equivalent to 400 kg live body weight. The LU calculation is based on respective the herd composition and average live body weight of the individual herd members.

Herd Composition: Herd categories for each types of livestock population were grouped as:

- Cattle and buffalo: oxen/bull, milch, dry/old, heifer and calf;
- Sheep and goats: adult male, adult female and young;
- Yak/Chauri and Equines: adult and young

Live body weight: Each herd category of each livestock type was assigned a body weight, (see Table 2 of Annex 2) as recommended by LRMP (1986); and Rajbhandary and Pradhan (1991).

Estimation of Livestock Unit: 400 kg was considered as a standard body weight for a Livestock Unit (LU). Based on the composition and the respective live body weight of the cumulative livestock type, theLU for each livestock type was estimated (FAO, 2011). Table 2 of Annex 2 provides details of this calculation.

Dry matter intake (DMI) of feed and fodder by LU

Dry matter intake (DMI) was calculated based on a moisture-free basis @ 2.5% DM of body weight of LU (NARC, 2006) i.e. a LU with standard 400 kg body weight will consume 10 kg DM/day (3.65t DM/head/year). Annex 2 provides details of this calculation

Ratio of feed and fodder consumed by LU

Based on the patterns of grazing and foraging behavior of different types of livestock, the ratios of different types of feed (crop residue: green fodder: concentrated feed) for each type of livestock was determined as follows:

- Cattle and buffaloes: These livestock types are the main consumers of crop residue. Feeding ratios by physiographic region are given in Table 4 of Annex 2.
- Sheep and goats: These livestock types are predominantly grazers. Grasses, forbs and tree fodder dominates their diet. The ratio for the DMI of crop residue, green fodder and concentrated feed was estimated as 0:90:10.
- Yak/Chauri and equines (horses and asses): These animals are predominantly grazers, raised in free range systems. The ratio for the DMI of crop residue, green fodder and concentrated feed was estimated as: 20:70:10.

6.2.4.3 Assessing overgrazing impact on regeneration and woody biomass

It was assumed in the current study that overgrazing in forests is not significantly reduced either by supplies of green fodder from agricultural land, due to their limited resource potential, or from grasslands, due to their limited accessibility. The overgrazed biomass essentially consists of forest seedlings and saplings, and foliage from young and matured trees in forests. These components, even though over-extracted, inherently undergo recoupment via natural regeneration processes. However, under overgrazing conditions these processes are slowed compared to areas with sustainable grazing practices and this differential growth factor, particularly on longer time scales, leads to biomass loss and associated forest degradation.

These differential regeneration rates, and relative loss of biomass in overgrazed areas, can only be estimated through intensive field measurements on controlled and uncontrolled grazing sites across different physiographic regions. In view of the absence of such national level studies, data from the NFI was used, along with published research studies, to assess impaired regeneration on shorter time scales and woody biomass loss due to reduced growth on longer time scales. The NFI provided plot-level disturbance information at 1,600 locations from 2010-2014 in terms of grazing, lopping and bush cutting practices, according to qualitative categories of zero, low, medium and high. These disturbances have a direct correlation with the supply of green fodder resources from forests.The details of sampling design and disturbance levels are given in NFI report2015 (DFRS 2015).

The plot information also provided the number of seedlings and saplings, number of stems, and biomass estimated. Using the intensity score of disturbance reported due to grazing, lopping and bush cutting, mean disturbance intensity for plot is calculated due to these three factors and were categorized into 0,1,2,3 classes. An average biomass value of three intensity classes is generated. . The average biomass value of three intensity classes was taken to compare with zero intensity disturbance plots and calculate the difference in biomass value. The difference in biomass value is considered as degradation value and for converting into carbon emissions.

6.2.4.4 Estimation of biomass loss

The differential biomass between the normal (zero) and average values of three disturbance levels was used to estimate the biomass loss/annum. The differential biomass is multiplied with 0.7 and 0.3 considering the accessibility and likelihood differential impact over forests outside and inside of CF and PF areas to obtain separate values for forests inside and outside CF+PF areas. In addition 20% of the change in biomass was only attributed to grazing and fodder collection (grazing+lopping+bush cutting) with the remaining 80% attributable to fire, wood extraction, litter collection and other drivers.Accordingly the biomass change in each physiographic region was multiplied by 0.2 to estimate the impact of grazing and fodder collection. It is assumed that such biomass level change is spread over growth cycles of 20 years, indicated by 2006 IPCC guidelines as the average time for forests to reach maturity. The biomass change thus estimated through was therefore divided by 20 to obtain an estimate of annual change. The accessible forest areas outside and inside PF and CF are considered for grazing were multiplied with biomass change/ha/annum to obtain total biomass loss for each physiographic region.

6.2.5 Results of feed and fodder supply demand analysis

6.2.5.1 Supply of feed and fodder

Supply of feed and fodder from Agriculture Lands

The details of supply of crop residue, grain by-products and green biomass from agriculture lands are presented in Annex. The total production is estimated at 15,716,958 t DM, 1,521,758 t DM and 3,722,284 t DM/yr respectively. The paddy and maize-based residue and grain by-products are the most significant sources of livestock feed. The mid hills and Terai regions have the highest contributions to the national-level estimates. The total production of green biomass from agricultural land was 3,722,284 t DM out of which foliage of fodder trees, cultivated fodder, native grasses and weeds and fallow grazing constitute 69,532 t DM,114,429 t DM, 1,451,550 t DM and 685,454 t DM respectively.

Supply of green biomass from forests, shrublands and grasslands

The details of these estimates are presented in Table 23. Based on the accessibility function applied, the total areas of 3,929,255.26 ha, 275,060 ha and 555,778 ha of forests, shrubs and grasslands respectively is estimated as areas available/accessible area for grazing. Based on the biomass productivity reported by LRMP (1986), the total production of biomass from accessible forests is, 1034,996 t DM, from accessible shrublands 305,174 t DM (total biomass from forests and shrublands is 850,743 t DM) and from the accessible grassland is 275,245 t DM. The grand total of biomass from forests, shrublands and grassland is 1,125,989 t DM.

	Accessible area, ha				Accessible Biomass supply – Production of		
Region	**Accessible Forests area, ha – Outside Community Forest**	**Accessible Forests area, ha – Inside Community Forest**	**Accessible Shrubs area, ha**	**Accessible Grasslands, ha**	**Accessible Forests, (t DM/ha /yr**	**Accessible Shrubs (t DM/ha/yr)**	**Grass-lands(t DM/ha/yr)**
					LRMP, 1986		
Himal	212,774	62,562	136,383	20,640	0.17	1.0	0.44
High Mountain	838,018	93,323	862,75	251,315	0.22	1.16	0.65
Mountain	1,210,050	255,628	31,368	198,105	0.26	1.23	0.28
Siwaliks	475,798	152,407	11,909	37,995	0.3	1.35	0.53
Terai	558,974	69,721	9,125	47,724	0.34	1.54	0.57
Nepal	**3,295,614**	**633,642**	**275,060**	**555,778**			

Region	**Forest Biomass(t DM)– Outside Community Forest**	**Forest Biomass(t DM)– Inside Community Forest**	**Shrubs(t DM)**	**Grass- lands Biomass (t DM)**	**Total : ForestShrub & grass-lands**	**Total: Forest &Shrubs only**
Himal	36,172	10,636	136,383	9,081	192,272	183,190
High Mountain	184,364	20,531	100,079	163,355	468,329	304,974
Mountain	314,613	66,463	38,583	55,469	475,129	419,659
Siwaliks	142,739	45,722	16,077	20,137	224,675	204,538
Terai	190,051	23,705	14,052	27,203	255,011	227,808
Nepal	**867,939**	**167,057**	**305,174**	**275,245**	**1,615,415**	**1,340,170**

Table 23: Supply of green biomass (t DM) from forests, shrubs and grasslands for livestock feeds.

Total supply of feed and fodder

The total estimated supply of feed and fodder in terms of crop residue, grain by-products and green biomass is 22,576,415t DM (22 M t DM)in which the supply of crop residue is 15,716,958 t DM (15.7 M t DM), grain by-products is 1,521,758 t DM (15.2 M t DM)and the rest i.e. green biomass is 5,337,699t DM(5.3 M t DM) (Table 24). It should be emphasized that around 70% of the total supply and of the green fodder supply were from agriculture land. Furthermore, the analysis result reveals that the middle mountain contributes the highest amount of feed and fodder.

Region	**Straw, supply (t DM)**	**Grain By-products supply(t DM)**	**Agri.Biomass, supply (t DM)**	**Forest biomass supply(t DM)**	**Shrubs biomass supply(t DM)**	**Grassland biomass supply(t DM)**	**Supply of green Biomass**	**Total supply(t DM)**	**Total Supply per hectare (t DM)/ha**
Himal	842,365	79,287	243,163	46,807	136,383	9,081	435,435	1,357,087	0.45
High Mountai	1,778,553	159,973	680,019	204,895	100,079	163,355	1,148,348	3,086,873	0.85
Mountai	5,432,632	516,474	522,868	381,076	38,583	55,469	997,997	6,947,103	1.57
Siwalik	2,156,709	221,466	540,035	188,461	16,077	20,137	764,710	3,142,885	1.62
Terai	5,506,698	544,558	1,736,198	213,756	14,052	27,203	1,991,209	8,042,466	3.94
Nepal	**15,716,958**	**1,521,758**	**3,722,284**	**1,034,996**	**305,174**	**275,245**	**5,337,699**	**22,576,415**	**1.50**

Table 24: Total supply (t DM) of feeds and fodder

6.2.5.2 Demands of feeds and fodder by Livestock Unit (LU)

Livestock number equivalent to LU

This study estimated 23,519,440 head of livestock including cattle (7,250,916), buffalo (5,178,612), sheep (789,216), goats (10,177,531), yak/chauries (70,588) and equines (52,577). The respective numbers of LU were 3,988,000 cattle; 3,417,884 buffalo 55,245 sheep; 610,652goats; 35,294yak/chauries and 29,443 equines (total 8,136,522 LU). Further details of livestock distribution according to physiographic regions are presented in Annex 2.

Total demand of feeds and fodder ((t DM))

The total estimated fodder demand is 29,850,417**t DM**/annum of which crop residue is 12,797,763 **t DM** grain by-products is 5,652,153 **t DM** and green biomass is 11,400,501 **t DM** /year. The details are given in Table 25. On a national basis, the crop residue, green fodder and grain by-products constitutes demand by 54%, 35% and 11%. These figures will need to be updated regularly.

Region	Total LU	Straw (t DM)	Grain by Products (t DM)	Green biomass (t DM)	Total (t DM)	Total Demand (t DM/ha)
Himal	245,548	247,494	543,131	105,625	896,251	0.30
High Mountain	951,483	1,031,699	194,1345	499,870	3,472,914	0.99
Middle Mountains	3,249,762	5,272,670	431,3163	2,275,799	11,861,631	2.76
Siwalik	1,003,181	1,301,092	1,635,038	725,480	3,661,610	1.94
Terai	2,686,548	4,944,808	2,967,825	2,045,379	9,958,012	4.95
Nepal	**8,136,522**	**1,2797,763**	**11,400,501**	**5,652,153**	**2,9850,417**	2.03

Table 25: Total Demand (tDM/Yr) of feeds and fodder for the year 2010

Notes: a) LU Body Weight 400 kg, b) Feed Intake % of BW on DM basis =2.5,c) Daily DM intake 10 kg/DM/LU, d) Annual feed/fodder required 3650 kg DM/yr/LU)

Demand of feed and fodder (t DM) by LU types

In terms of LU types, out of the total feed demand, cattle requires 14,500t DM/annum, buffalo require 12,500t DM/annum, goats require 2,200t DM/annum, and the rest of fodder supplies are consumed by sheep (200 t DM/annum), Yak/Chauri (100 t DM/annum) and horses (100 t DM/annum) (Table 26).

SN	Type	Feed Required (t DM/yr)			Total (t DM/yr)
		Straw	Grain by-products	Green Biomass.	
1	Cattle	6,844,507	2,887,275	4,908,427	14,640,209
2	Buffalo	5,905,998	2,498,196	4,139,199	12,543,393
3	Sheep	0	20,164	181,480	201,644
4	Goat	0	2,005,993	222,888	2,228,879
6	Yak/Chauri	25,765	12,882	90,176	128,825
7	Equines	21,493	10,747	75,227	107,467
	Total	**12,797,763**	**7,435,257**	**9,617,397**	**29,850,417**

Table 26: Feeds and fodder demand (t DM/yr by LU types)

6.2.5.3 Feed and fodder balance situations

The overall deficits of livestock feed and fodder supply is estimated to be 7,200 t DM/year, constituting 32% of the total demand. The total supply of feed and fodder is 22,500 t DM/year and the demand is 29,850 t DM/year. The highest deficit is found in the Middle Mountains region which is over 71% compared to the lowest deficit of 13%, found in the High Mountain region. These results are presented in Table 27 and Figure 17.

Region	Total supply (t DM)	Total Demand (t DM)	Balance(t DM)	Balance in %
Himal	1,357,087	896,251	**460,837**	**34**
High Mountain	3,086,873	3,472,914	**-386,040**	**-13**
Middle mountains	6,947,103	11,861,631	**-4,914,528**	**-71**
Siwalik	3,142,885	3,661,610	**-518,725**	**-17**
Terai	8,042,466	9,958,012	**-1,915,546**	**-24**
Nepal	**22,576,415**	**29,850,417**	**-7,274,003**	**-32**

Table 27: Total Balance situation of feeds and fodder (t DM)

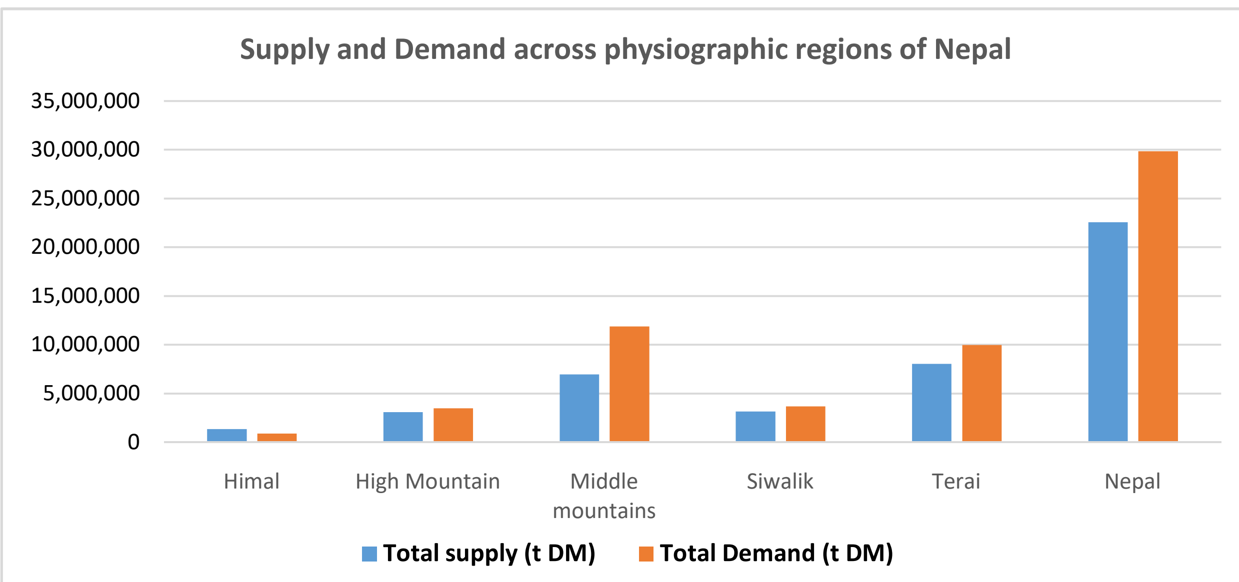


Figure 17: Supply and Demand per hectare across physiographic regions

Overall feed and fodder balance situations based on feed categories

- Crop residue: The total supply of crop residue is 15,716,958t DM/year and demand is 12,797,763t DM/year; thus the surplus is 2,919,194 t DM/year (Table 28).
- Grain by-products/concentrated feed: The total supply of grain by-products is 1,521,758 t DM/year and demand is 5,652,153t DM/year; thus the deficit is -4,130,395 t DM/year (Table 28).
- Green biomass: The total supply of green biomass is 5,337,699 t DM/year and the demand is 11,400,501t DM/year; thus the deficit is -6,062,802t DM/year
- Total balance: The total balance of feeds and fodder demand and supply is **-7,274,003** t DM/year.

Physiographic Region	Crop Residue(t DM)			Grain by-products(t DM)		
	Supply.	Demand	Balance	Supply.	Demand	Balance
Himal	842,365	247,494	594,871	79,287	105,625	-26,338
High Mountain	1,778,553	1,031,699	746,855	159,973	499,870	-339,898
Middle mountains	5,432,632	5,272,670	159,962	516,474	2,275,799	-175,9324
Siwalik	2,156,709	1,301,092	855,617	221,466	725,480	-504,014
Teria	5,506,698	4,944,808	561,890	544,558	2,045,379	-1,500,821
Nepal	**15,716,958**	**12,797,763**	**2,919,194**	**1,521,758**	**5,652,153**	**-4,130,395**
Physiographic Region	**Green Biomass(t DM)**			**Total Balance(t DM)**		
	Supply.	**Demand**	**Balance**	**Supply.**	**Demand**	**Balance**
Himal	435,435	543,131	-107,696	1,357,087	896,250	**460,837**
High Mountain	1,148,348	1,941,345	-792,997	3,086,873	3,472,914	**-386,040**
Middle mountains	997,997	4,313,163	-3,315,166	6,947,103	11,861,632	**-4,914,528**
Siwalik	764,710	1,635,038	-870,328	3,142,885	3,661,610	**-518,725**
Teria	1,991,209	2,967,825	-976,615	8,042,466	9,958,012	**-1,915,546**
Nepal	**5,337,699**	**11,400,501**	**-6,062,802**	**22,576,415**	**29,850,417**	**-7,274,003**

Table 28: Balance by feeds and fodder types

6.2.6 Grazing and Green fodder collection -impact on regeneration and forest biomass loss

The impact on regeneration in terms of change in seedlings and saplings under different grazing intensities over different physiographic regions is presented in Table 29. In all the physiographic regions except the Siwaliks, the mean number of seedlings and saplings were found to be less than in the zero grazing intensity plots. The mid-hills region, which has high demand for green fodder, was found to be most affected in terms of regeneration loss, by 24.75%. The higher regeneration levels in all grazing cagtegories in the Siwalik region and in the low to medium categories in other hill regions is accountable to the improved regeneration and forest growth capacity as reported in several independent studies of the impacts of community forestry regimes (Sapkota *et al*, 2009, Sujaku 2013, Connel,1978). The analysis at national level shows that overgrazing has impacted forest regeneration with a range of 6.21% - 24.75% leaving the Siwaliks with improved regeneration. As the biomass reported in NFI data considers stems of > 10 cm diameter class, this loss of regeneration or reduced number of stems (seedlings + saplings <10cm diameter class) is not reflected for estimation of biomass loss. However the impact of reduced regeneration leading to loss of biomass on a longer time scale is estimated.

Physiographic regions	Zero Intensity	1. Low	2. Medium	3. High	AVG	% difference (0 & AVG)
High Mount & Himal	7.20	8.21	9.11	2.93	6.75	6.21%
Middle Mountain	25.68	21.08	20.34	16.55	19.32	24.75%
Siwalik	42.23	61.47	48.66	42.83	50.98	-20.73%
Terai	78.71	61.61	82.90	67.83	70.78	10.07%

Table 29: Number of Seedling and Saplings/Plot across different grazing intensities

The NFI plot-based analysis on the impacts of different levels of grazing, lopping and bush cutting on the number of stems and above ground biomass over different physiographic regions and associated statistical analysis are given as online version. The average values of a number of stems/ha and above ground biomass/ha under different disturbance intensities is presented in Table- 30 and 31. The values here represent average of three disturbance types: grazing, lopping and bush cutting.

The difference in the number of stems/ha between zero and disturbance intensities is very low compared to the impact on above-ground biomass. It should be noted that biomass values are a manifestation of the structural changes in forests in terms of turnover and balance of number of stems over different diameter classes leading to a given biomass state. These two parameters are equally important in the context of sustainable forest management practices and biomass stands are more relevant in the context of carbon dynamics. Hence we are considering biomass differences to assess the impact of grazing and fodder collection. It should be noted that disturbance plots of Middle mountains and High Mountains/ High Himal regions were found with lower biomass estimates respectively compared to zero disturbance plots. The differences for Siwaliks and Terai are found very low.

These contrasting differences in biomass production under different grazing and fodder collection intensities depend on long-term structural and compositional dynamics of the forest ecosystem. It depends on the composition of palatable and non-palatable species, disturbance resistant species, age structure of the forests and how it finally leads to biomass change. These dynamics under different disturbance regimes may result in increased or decreased biomass, reduced or increased species diversity and unique age classes. Hence here we take the values as obtained from the analysis to assess biomass changes without probing into the reasons of such differential responses. Considerable further research work will be required in future in order to report on this part of Nepal's FRL accurately in the future.

Physiographic Regions	Zero Intensity - A Mean (SD)	Mean Disturbance Intensity - B Mean (SD)	Difference(A-B) Average biomass loss t/ha
High Mount &Himal	241.5 (197.5)	170.0 (145.9)	71.5
Middle Mountain	189.6 (157.6)	107.5 (96.2)	82.1
Siwalik	172.5 (113.2)	167.5 (113.4)	5
Terai	208.0 (121.4)	193.2 (104.7)	14.8

Table 30: Difference between biomass/ha levels of Zero and Mean Disturbance Intensity plots

Physiographic Regions	Zero Intensity - A Mean (SD)	Mean Disturbance Intensity - B Mean (SD)	Difference(A-B) Average biomass loss t/ha
High Mount & Himal	1000.4 (1053.3)	690.5 (629.6)	309.9
Middle Mountain	773.4 (872.2)	806.1(771.6)	-32.7
Siwalik	713.5 (625.2)	693.4 (756.9)	20.1
Terai	529.8 (595.9)	540.6 (494.27)	-10.8

Table 31: Difference between number of stems/ha of Zero and Mean Disturbance Intensity plots

Estimation of forest biomass loss due to grazing and fodder collection

The difference in biomass levels observed between zero and the average grazing disturbance gradient as given in Table-31 were used as basic input for estimation of biomass loss and carbon emissions The details of carbon emission estimation with sequence of steps as per the methodology given in Section 6.2.4.4 are presented in Annex 3 and 4. The consolidated results are presented in Table 32. The highest biomass loss was found in the High Mountain and Himal regions, followed by the Mid hill region. A total of **1,027,484 t DM/year of biomass** is estimated to be lost due to grazing and fodder collection from forests, which corresponds to an **emission estimate of 1,767,273 t CO_2e/year[12].**

Physiographic Regions	Total Biomass Loss (t DM/yr)	Total Carbon Loss (t CO_2e/year)
High Mount &Himal	224,647.5	386,393.7
Middle Mountain	741,666.7	1,275,666.6
Siwalik	10,104.1	17,379.0
Terai	51,066.3	87,834.1
Grand Total	**1,027,484.6**	**1,767,273.5**

Table 32: Total Carbon Emissions due to grazing based forest degradation - Includes all accessible forests both outside and inside CF and PF areas

Green fodder deficit and biomass loss

Out of the annual green fodder deficit of 6,062,802 t DM/year (6.06 M t DM), the study found that 15.6% **(1,027,484 t DM/year)** of biomass was lost for the long term, leading to forest degradation. The remaining area subject to overgrazing has suffered reduced regeneration (low undergrowth saplings and saplings), and reduced foliage which have led, in turn, to long-term impacts on biomass due to reduced photosynthetic activity (the level of which could not be reliably estimated). The study has limitations in terms of the information on the green fodder resources currently available. It should be also noted that the supply/demand balance and NFI data-based loss estimates mutually corroborate and complement each other. In the absence of NFI analysis we cannot quantify biomass and regeneration loss. On the other hand, the supply/demand based deficit signifies the biomass loss/degradation estimated and also provides parameters which regulate such deficits and lead to biomass loss. For effective development of a REDD+ strategy, it is important that these different processes should be understood, in order to identify appropriate policies and measures to minimize degradation. It should also be noted that overgrazing will also have led to diverse impacts in terms of forest physiognomy, species diversity and age structure, on which the current study did not focus.

6.2.6.1 Application of results and monitoring

The study has used databases from the NFI, and from the livestock and agriculture census which were periodically generated. The estimates on green fodder balance, regeneration loss and biomass loss resulting from long term impact thus generated should be periodically produced over coming years using national databases. The changes in these parameters could arise from changes in areas under land cover, improved productivity, changing livestock composition and number, altered accessibility and pressures on

[12] Using a carbon fraction of 0.47 (IPCC 2006) and a conversion factor of 44/12 to convert C into CO_2

forests for grazing, improved feeding habits of livestock such as shifting over to stall feeding under different management regimes. However Nepal could also plan in future to develop methodologies and measurements for direct assessment of grazing-induced forest degradation.

6.2.6.2 Limitations of the study

The current estimates are based on analysis of first order statistics of NFI plot data with low biomass differences between zero and different disturbance intensities especially in Siwalik and Terai region. These estimates could be further explored for more rigorous advances statistical analysis to assess the degradation contribution of grazing out of the multiple drivers impacting simultaneously. As of now we have assumed that major drivers impact with equal proportion. The study has limited temporal data at the national scale to assess the change during the reference period, both in terms of deficit analysis and impact of grazing on forest regeneration. Instead it has depended on gradients of qualitative grazing intensities to assess the impact of grazing as such data is generated on a national scale. The deficit analysis is controlled by feeding habits and accessibility. At this moment, these numbers are generated through assumptions of the national FRL team, with limited reference to published literature. In future, it is necessary to have nationally-relevant sub-national level ground monitoring designs and measurements, in conjunction with remote sensing, in order to bring more robustness to the assessment of grazing-induced forest degradation.

7 ADJUSTMENT BASED ON NATIONAL CIRCUMSTANCES

Paragraph 9 of Decision 12/CP.17 invites Parties to submit information and rationale on the development of their FRL/FRELs, including details of how the national circumstances were considered, and consequent adjustments made, in accordance with the guidelines contained in the annex to this decision.

Consideration of the need for adjustment was done on the premise that the most likely approach for the projection of Nepal's FRL is that emissions are either the same as those calculated based on analysis of historical data, or are expected to increase or decrease from this trajectory.

Historical emissions from deforestation and removals from afforestation and reforestation in Nepal were estimated applying a historic average approach (i.e. average between 2000 and 2010). In the absence of complete and consistent time series data in between these two dates, only data from the beginning and end of this period was considered. It was decided that this was the best available option in Nepal's circumstances, where required time-series inventory data (e.g. annual, biannual) were not available to establish a more statistically significant trend of historical GHG emissions and removals.

To estimate degradation resulting from unsustainable fuelwood harvesting and green fodder consumption by livestock, continuation of existing patterns of use was assumed. The only reliable data available for these purposes were theNFI data 2010 and onward (DFRS 2015). No corresponding national-level data is available for the year 2000. It was assumed that no significant changes to patterns of fuelwood consumption and livestock feeding practices were experienced in the preceding ten years.

In order for this approach to degradation estimates to have validity for this FRL, the assumption that no significant changes to these patterns will occur must also hold for the reporting period.

In order to apply a suitable adjustment for national circumstances based on factors such as projections of human population, Gross Domestic Product (GDP), and specific development plans(e.g. resettlement plans, infrastructure and urban development), it is not only necessary to have such policies and plans developed but also requires an assessment showing both that these plans are likely to be implemented as expected, and that there is a statistically significant relationship between the implementation of such plans and consequent patterns of GHG emissions and removals.

No such data currently exists in Nepal to enable this kind of analysis to take place.

- There are no migration policies that may either increase or decrease pressure on forest resources. There have been no resettlement plans since before 1990 (prior to the reference period). The occurrence of any migration since then has been unplanned.
- There are no plans for the development of a specific economic sector such as biofuels, tea, rubber etc. which may increase deforestation. The Forest Regulation of 1995 states that it is prohibited to clear any forest for agricultural purposes.
- There are no plans for the development of a particular region, which would be likely to cause rates of deforestation or afforestation/reforestation to deviate from those of the reference period.

No adjustment for national circumstances has therefore been made to Nepal's FRL .However, in keeping with the stepwise approach to FRL development, Nepal may undertake a more detailed study of the key socio-economic factors to improve future projections.

8 ESTIMATED FOREST REFERENCE LEVEL (FRL)

8.1 Result of the FRL estimation

Nepal's FRL is hereby submitted to take account of GHG emissions due to deforestation and forest degradation due to fuelwood extraction and grazing, and of GHG removals due to afforestation/reforestation between the years 2000 and 2010.This decision is consistent with the requirement for estimating FRL/FREL produced by the FCPF Methodological Framework suggesting a 10 year period prior to the REDD+ results reporting period. The definition and context of using these activities are detailed in sub section - 2.3. The physiographic region wise emission and removal estimates are presented in the respective sections. Brief details on emission and removals from each activity and net FRL at national level based on these four activities is given below. The corresponding values for each activity and net FRL are presented in the Figure-18.

Deforestation and Afforestation

The activity data (deforestation and afforestation areas) is derived at physiographic region level using bias corrected forest cover change area estimates prepared using Landsat TM satellite data of 2000-2010. The bias correction factor of 0.82 and 0.7 was used for deforestation and afforestation respectively based on the accuracy assessment of forest cover change assessment. At national level, the bias corrected annual deforestation and afforestation areas are estimated at 2,204 ha/year and 1,351 ha/year respectively and physiographic regions wise areas are used for emission and removal estimation.

The emission factors on above ground biomass/ha, annual growth/ha, root: shoot ratio used for this study are derived from DFRS/NFI 2014.The carbon fraction and CO_2econversion factor are based on IPCC,2006.The details on physiographic regions wise estimates along with tables on activity data and emission factors are given in Scetion-5. At national level the CO_2eemissions due to deforestation is estimated at 917,743 t CO_2e/year and removals are estimated at 150,110 t CO_2e/year. The emissions from deforestation are 6 times higher afforestation resulting both from higher deforestation area and also level of biomass/ha lost.

Forest Degradation – Fuel wood extraction

The study has used WISDOM model based spatial explicit approach for estimating carbon emission due to fuel wood extraction based forest degradation. Forest land remaining as forest, other wooded lands andnational census information on population are the critical activity data used. The above ground biomass, mean annual increment, physical and legal accessibility, fuel wood consumption/year/person and fuel type consumption pattern are a few critical emission factors used. The details of databases used are given in section – 6.1.2.

A range of alternative commercial harvesting assumptions, combined with demand and supply variants were used to assess different theoretical scenarios on the relative patterns and rate of degradation. Accordingly the most probable Leading Scenario (Medium degradation scenario) was chosen to report degradation, while low and high degradation scenarios were picked to represent the range of values. The leading scenario constitute mean supply, conventional demand (excluding marginal fuelwood), partial market conditions, 8hrs transport threshold,35% use of Land cover change products. Based on the leading scenario, the expected annual degradation of the Forest-remaining-Forest (FRF), i.e. the area that remained under forest cover for the whole reporting period 2000-2010, is 198,000 tons DM, corresponding to net emissions of 341,000 t CO_2/year.

Forest Degradation and Grazing

The grazing based degradation assessment has been done by estimating initially the fodder supply-demand balance and then assessing how balance impact the forest biomass levels. The area information on forests, shrub lands and grass lands developed using Landsat TM data of 2000-2010 and crop type areas of the Ministry of Agriculture Development were used as activity data to assess supply of grazing and fodder resources. Several coefficients on grain-straw ratio, forest accessibility for grazing, Livestock data and conversion into livestock units, feeding needs/body weight, feeding ratio (Straw: green fodder: Concentrated Feed) were used as emission factors in estimation of supply and demand. The details are given in Annex. National forest inventory data was used to assess the impact of grazing, lopping and bush cutting on regeneration and biomass over different grazing intensities. A total of **1027484** t DM/year of biomass is estimated to be lost due to grazing and fodder collection from a forest, which corresponds to an emission estimate of **1,767,273** t CO_2e/year. Out of the annual green fodder deficit of 6,062,802 t DM/year (6.06 M t DM), the study found that 15.6% (**1,027,484** t DM/year) of biomass was lost for the long term, leading to forest degradation.

Net Forest Reference Level

Based on the availability of reliable data and approach as described, the deforestation, afforestation, fuelwood and grazing are only considered in the current estimates (Fig-18). At national level, the country is found with net emission of 2,347, 636t CO_2e/year owing to these four activities. The national FRL scenario is bound to change due to emissions/removals from forest enhancement under community forestry, timber harvest and forest fire. The estimates are not compared with previous first and second national communication reports due to the fact that the activities, methodology and time periods considered for the assessment are different and hence are incomparable.

Net FRL = (Deforestation + Degradation fuelwood + Degradation grazing – Afforestation) tCO_2e/year
= (917,743 + 341,000 + 1,767, 273 - 150,110) t CO_2e/year **= 2,875,906tCO_2e/year**

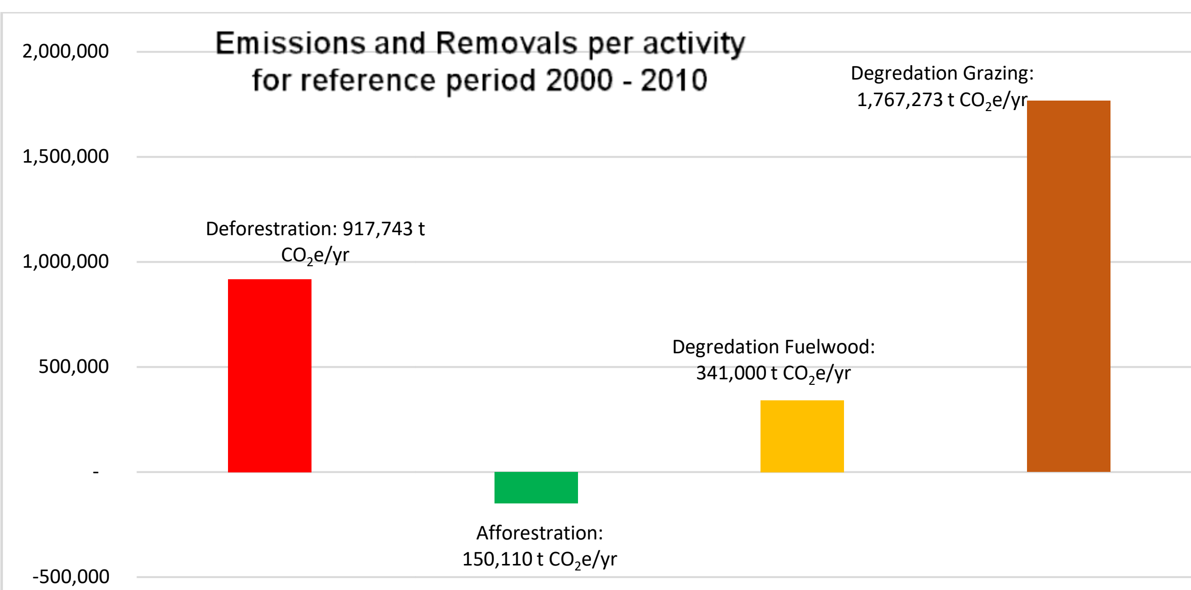


Figure 18: Annual Carbon emissions and removals (t CO_2e/year)

8.1 Historical period considered

Although UNFCCC decisions have not specified any specific time period to be considered for the estimation of historical FRL/FREL, the choice of historical points (i.e. years) and periods needs to be justified. On the one hand, taking average emissions/removals over a long time period may result in the inclusion of emissions/removals patterns that are not representative of expected future patterns. On the other hand, considering a very short time period (less than 7 years) may not be sufficientto represent the real historical trend of emissions/removals. Taking this into account, Nepal's FRL considered ten years as a suitable time frame to capture real historical trends, and the period between 2000 and 2010 as the historical reference period for which data is most readily available. This decision is consistent with the requirement for estimating FRL/FREL produced by the FCPF Methodological Framework suggesting a 10 year period prior to the REDD+ results reporting period. Further justifications include:

1. Availability of required data of the highest possible accuracy: NFI data, acquired using tools and approaches consistent with UNFCCC decisions on national forest monitoring systems for REDD+, were available for 2010.
2. Availability of livestock population data for the year 2010 and grazing intensity information from NFI plots.
3. Availability of NFI plot-level data to feed into WISDOM model and estimate degradation due to unsustainable fuelwood consumption.
4. Availability of land cover data for 2000 and 2010 prepared under the NASA-SERVIR/ICIMOD collaborative program.

8.2 Updating frequency

In line with UNFCCC decision 12/CP1713, Nepal's FRL estimation follows a stepwise approach, aiming to improve FRL accuracy overtime by incorporating better data, improved methodologies and, when appropriate, additional pools. Nepal will therefore follow a five-year periodic cycle in updating its FRL, ensuring consistency with the NFI, which will also follow a five-year cycle. In addition, Nepal will make efforts to enhance capacity to estimate emissions/removals from community-based forest management, natural growth, forest fire and unsustainable timber harvesting. These efforts will be applied particularly during the period 2017-2020 so that additional knowledge can be acquired for the modification of FRL scope and methodologies. Specific areas for future improvement are presented in the following section.

[13] UNFCCC, decision12/CP17,par10 and 12

9 FUTURE IMPROVEMENTS

Nepal has identified five specific areas for improvement of the FRL on which the country seeks to continue investigation, data collection and testing of methodologies, dependent on available resources. These are the following:

- Fully **include the activity forest carbon stock enhancement** on forest land remaining forest land. This would allow Nepal to report on the important results of improved forest management achieved in the country through the community forestry programme.
- Replace the indirect assessment of forest degradation from grazing and livestock management by **cost-effective direct measurements of forest degradation from grazing,** which allow for consistent and sufficiently accurate monitoring over time.
- Replace the indirect assessment of forest degradation from fuelwood extraction by **cost-effective direct measurements of forest degradation from fuelwood extraction,** which allow for consistent and sufficiently accurate monitoring over time.
- **Include small-scale deforestation and afforestation** in a cost-efficient manner with sufficient accuracy
- **Include estimates of degradation by drivers other than fuelwood collection and grazing**

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11 ANNEX

Annex 1: Data and sources of Area based information

Annex 2: Coefficients and factors used for supply demand assessment

Annex Table 2.1: Herd composition and respective body weight of each group

Annex table 2.2: Conversion of livestock number into LU

Annex Table 2.3: Ratio used for calculation of plant residues and grain by- products

Annex Table 2.4: Feeding ratio for cattle & buffaloes, sheep & goats, and Yak and equines

Annex Table 2.5: Coefficient used for calculation of accessibility factors and biomass supply from accessible forests, shrubs and grasslands

Annex 3: Mean and standard deviation of total biomass across physiographic regions

Annex Table 3.1: Mean total Biomass across physiographic regions for Major 3 disturbances

Annex Table 3.2: Standard deviation of total Biomass across physiographic regions for Major 3 disturbances

Annex 4: Biomass loss estimation due to grazing and fodder collection on Accessible forests outside PF and CF areas

Annex 5: Biomass loss estimation due to grazing and fodder collection on Accessible forests inside PF and CF areas

Annex 1: Data and sources of Area based information

SN	Data	Sources	References
1	Forest Area	ICIMOD 2010	ICIMOD 2010: Wall to wall landcover mapping done based on **Landsat TM 30m data.**
2	Grassland area	ICIMOD 2010	ICIMOD 2010: Wall to wall landcover mapping done based on **Landsat TM 30m data.**
3	Shrubs (OWL) Include crop type area: source MOAD	DFRS, 2015	**DFRS, 2015:** State of Nepal's Forests. GON, Ministry of Forests and Soil Conservation, Department of Forest Research and Survey, Forest Resource Assessment Nepal, 2015
4	Agricultural farm Fodder supply		
4.1	Fodder trees	Area under fodder tress CBS, 2006	CBS, 2006: Agricultural Statistics Nepal 2006. Government of Nepal National Planning Commission Secretariat Central Bureau of Statistics Kathmandu, Nepal
4.2	Fodder tree biomass production	KK Pande, 1982	Panday, Kk. 1982. , Fodder trees and tree fodder in Nepal. Swiss Federal Institute of Forestry Research Birmensdorf, Switzerland. B509
4.3	Productivity of native grasses and weess	Rajbhandary, H.B. and Pradhan, S.L. 1991	Rajbhandary, H.B. and Pradhan, S.L. 1991. Livestock Development and Pasture Management. Background Papers to the National Conservation Strategy for Nepal, Vol. 1, Nepal National Conservation strategy Implementation Programme, National Planning Commission, HMG Nepal in collaboration with the World Conservation Union (IUCN),Nepal pp 259-331.
5	Livestock data Crop production for each districts (paddy, maize, wheat, millet, barley, mustard, sugarcane, pulses)	MOAD, 2014	**MOAD, 2014**: Statistical Information on Nepalese Agriculture 2013/14 (2070/71), GoN, MOAD, Agri-Businee Promotion and Statistical Division, Agri Statistics Section, Singh Durbar, Kathmandu, 2014

Annex 2 : Coefficients and factors used for supply demand assessment

Annex Table 2.1: Herd composition and respective body weight of each group

SN	Animals/ Herd type	Herd Comp %	BW, kg
1	**Cattle**		
1.1	Oxen/Bull	41	300
1.2	Milch	12	220
1.3	Dry/old	20	220
1.4	Heifer	13	150
1.5	Calf	14	50
2.0	**Buffalo**		
2.1	Oxen/Bull	7	420
2.2	Milch	24	320
2.3	Dry/old	30	320
2.4	Heifer	16	250
2.5	Calf	23	100
3.0	**Sheep**		
3.1	Adult male	25	35
3.2	Adult female	50	30
3.3	Young	25	18
4.0	**Goat**		
4.1	Adult male	25	30
4.2	Adult female	50	25
4.3	Young	25	17
5.0	**Pigs**		
5.1	Adult	50	45
5.2	Young	50	25
6.0	**Yak/Chauri**		
6.1	Yak/Jhopkyo	41	250
6.2	Nak/Chauri	12	200
6.3	Dry/old	20	200
6.4	Heifer	13	150
6.5	Calf	14	100
7.0	**Horse/ass**		
7.1	Adult	50	300
7.2	Young	50	150

Sources: a) Herd composition % is based on ASD, (1996); ASD. 1996. Statistical Information on Nepalese Agriculture. Agriculture Statistical Division, Ministry of Agriculture, HMGN, Kathmandu, Nepal.

b) Body weight- Rajbhandary and Pradhan (1991); Rajbhandary, H.B. and Pradhan, S.L. 1991. Livestock Development and Pasture Management. Background Papers to the National Conservation Strategy for Nepal, Vol. 1, Nepal National Conservation strategy Implementation Programme, National Planning Commission, HMG Nepal in collaboration with the World Conservation Union (IUCN),Nepal pp 259-331.

Annex table 2.2: Conversion of livestock number into LU

Animals/Herd composition	Herd Comp %	Body Wt. (KG)	Total Pop	Cumulative BW, kg	LU Equivalent=400 kg/each
CATTLE					
Oxen/Bull	41	300	2,972,876	891,862,668	2,229,657
Milch	12	220	870,110	191,424,182	478,560
Dry/old	20	220	1,450,183	319,040,304	797,601
Heifer	13	150	942,619	141,392,862	353,482
Calf	14	50	1,015,128	50,756,412	126,891
Sub-total			**7,250,916**		**3,986,191**
BUFFALO					
Oxen/Bull	7	420	362,503	152,251,193	380,628
Milch	24	320	1,242,867	397,717,402	994,294
Dry/old	30	320	1,553,584	497,146,752	1,242,867
Heifer	16	250	828,578	207,144,480	517,861
Calf	23	100	1,191,081	119,108,076	297,770
Sub-total			**5,178,612**		**3,433,420**
SHEEP					
Adult male	25	35	197,304	6,905,640	17,264
Adult female	50	30	394,608	11,838,240	29,596
Young	25	18	197,304	3,551,472	8,879
Sub-total			**789,216**		**55,738**
GOAT					
Adult male	25	30	746,792	22,403,745	56,009
Adult female	50	25	1,493,583	37,339,575	93,349
Young	25	17	746,792	12,695,456	31,739
Sub-total			**2,987,166**		**181,097**
PIGS					
Adult	50	45	595,069	26,778,105	66,945
Young	50	25	595,069	14,876,725	37,192
Sub-total			**1,190,138**		**104,137**
YAK/CHAURI					
Yak/Jhopkyo	41	250	28,941	7,235,270	18,088
Nak/Chauri	12	200	8,471	1,694,112	4,235
Dry/old	20	200	14,118	2,823,520	7,059
Heifer	13	150	9,176	1,376,466	3,441
Calf	14	100	9,882	988,232	2,471
Sub-total			70,588		35,294
HORSES/ASS					
Adult	50	300	26,289	7,886,550	19,716
Young	50	150	26,289	3,943,275	9,858
Sub-total			**52,577**		**29,575**

Annex Table 2.3: Ratio used for calculation of plant residues and grain by- products

SN	Crops	By-products	Ratio	Factor
1	Paddy			
1.1		Paddy Straw	Paddy grain to straw	1.62
1.2		Rice Bran	Paddy grain to bran	0.13
2	Maize			
2.1		Maize Stover	Maize grain to stover	2.21
2.2		Maize flour	20% as cattle feed	
3.0	Millet			
3.1		Millet Straw	Millet grain to straw	1.95
4	Wheat			
4.1		Wheat straw	Wheat grain to straw	2.17
4.2		Wheat bran	Wheat grain to bran	0.34
5	Pulses			
5.1		Pulses residues	Pulses grain to plant residues	1.5
5.2		Pulses husk	Pulses grain to bran	0.4
6.0	Sugarcane			
6.1		Sugarcane top	Sugarcane stem to top	0.1
6.2		Molasses	Sugarcane stem to molasses	0.4
7	Mustard	Oil cake	Mustard grain to oil cake	0.4

Sources: Rajbhandary&Pradhan (1991);

Rajbhandary, H.B. and Pradhan, S.L. 1991. Livestock Development and Pasture Management. Background Papers to the National Conservation Strategy for Nepal, Vol. 1, Nepal National Conservation strategy Implementation Programme, National Planning Commission, HMG Nepal in collaboration with the World Conservation Union (IUCN),Nepal pp 259-331.

DMI calculation

Dry matter intake (DMI) for a LU =2.5% DM of body weight a LU with standard 400 kg body weight

Daily consumption- 10 kg DM/day (400*2.5%). Annual consumption - 3.65 mt DM/head/year.

Source: Adapted from NARC, 2006: Nutrient Contents of Feeds and Fodder in Nepal. (ed C R Upreti, BK Shrestha), Nepal Agricultural Research Council , Kathmandu, Nepal

Annex Table 2.4: Feeding ratio for cattle & buffaloes, sheep & goats, and Yak and equines

Physiographic Region	Feeding Habit	Cattle and Buffalo	Sheep	Goat	Yak	Equine	Total feed Demand by LU,
Tarai	Straw	54%	0%	0%	20%	20%	4,944,808
	Green	26%	90%	90%	70%	70%	2,967,825
	Concentrated	22%	10%	10%	10%	10%	2,045,379
Siwalik	Straw	39%	0%	0%	20%	20%	1,301,092
	Green	40%	90%	90%	70%	70%	1,635,038
	Concentrated	21%	10%	10%	10%	10%	725,480
Mid Hill	Straw	48%	0%	0%	20%	20%	5,272,670
	Green	32%	90%	90%	70%	70%	4,313,163
	Concentrated	20%	10%	10%	10%	10%	2,275,799
High Hill	Straw	33%	0%	0%	20%	20%	1,031,699
	Green	52%	90%	90%	70%	70%	1,941,345
	Concentrated	15%	10%	10%	10%	10%	499,870
High Himal	Straw	35%	0%	0%	20%	20%	247,494
	Green	53%	90%	90%	70%	70%	543,131
	Concentrated	13%	10%	10%	10%	10%	105,625
Total							**29,850,417**

Notes: a) LU Body Weight 400 kg, b) Feed Intake %/day =2.5, c) Daily intake 10 kg/DM/LU, d) Annual feed required 3650 kg DM/yr/LU) e) Details in Annex-2

(Sources: Consultants estimation with consultation NARC and DLS 2016)

Annex Table 2.5: Coefficient used for calculation of accessibility factors and biomass supply from accessible forests, shrubs and grasslands

Regions	Accessibility Factors				Biomass Supply(t/ha/anum)		
Types	Forest Land (Outside CF)	Forest land (Inside CF)	Shrub land	Grassland	Forests	Shrubs	Grassland
High Himal	80	61	61	5	0.17	1.0	0.44
High Mountains	80	38	38	53	0.22	1.16	0.65
Mid Mountains	80	31	31	96	0.26	1.23	0.28
Siwaliks	80	38	38	60	0.3	1.35	0.53
Terai	80	31	31	83	0.34	1.54	0.57
Nepal	80	61	61	5	0.17	1.0	0.44

Source: Accessibility Factors : Forests and Shrub lands: Source - REDD IC expert consultation 2016
Accessibility Factors of Grassland and biomass supply: Master Plan for Forestry Sector Nepal, Main Report Part 1.

Annex 3 : Mean and standard deviation of total biomass across physiographic regions

Annex Table 3.1: Mean total Biomass across physiographic regions for Major 3 disturbances

Biomass (ADT Ha)	**Grazing intensity**				
Region	**0**	**1**	**2**	**3**	**Average**
High Mount & Himal	263	244	276	279	266
Middle Mountain	150	137	136	111	134
Siwalik	165	175	178	170	172
Terai	178	190	175	201	186
Total	**193**	**182**	**198**	**183**	189

Biomass (ADT Ha)	**Lopping intensity**				
Region	**0**	**1**	**2**	**3**	**Average**
High Mount & Himal	289	202	174	288	238
Middle Mountain	152	155	112	70	122
Siwalik	177	167	180	129	163
Terai	185	189	189	178	186
Total	**205**	**175**	**155**	**140**	169

Biomass (ADT Ha)	**Bush catting**				
Region	**0**	**1**	**2**	**3**	**Average**
High Mount & Himal	281	189	233	83	196
Middle Mountain	146	127	115	70	115
Siwalik	178	144	198	117	159
Terai	189	112	237	181	180
Total	**202**	**149**	**174**	**98**	156

Source: DFRS NFI plot data, Forest Resource Assessment Nepal 2014

Annex Table 3.2: Standard deviation of total Biomass across physiographic regions for Major 3 disturbances

Total Biomass (ADT Ha)	**Grazing intensity**				
Region	**0**	**1**	**2**	**3**	**Average**
High Mount & Himal	224	256	301	351	283
Middle Mountain	138	167	133	118	139
Siwalik	107	97	109	128	110
Terai	123	118	112	142	124
Total	**167**	**170**	**203**	**213**	189

Total Biomass (ADT Ha)	**Lopping intensity**				
Region	**0**	**1**	**2**	**3**	**Average**
High Mount & Himal	301	152	186	283	231
Middle Mountain	165	135	92	58	112
Siwalik	104	106	104	130	111
Terai	122	130	134	121	127
Total	**204**	**131**	**135**	**169**	160

Total Biomass (ADT Ha)	**Bush catting**				
Region	**0**	**1**	**2**	**3**	**Average**
High Mount & Himal	290	152	275	105	205
Middle Mountain	154	117	112	72	114
Siwalik	104	96	122	92	104
Terai	120	77	189	62	112
Total	**198**	**120**	**163**	**88**	142

Annex 4: Biomass loss estimation due to grazing and fodder collection on Accessible forests outside PF and CF areas

Region	A- Biomass loss t/ha (0.7*Average biomass loss)	(B) - (Weightage Factor of 0.2*(A))	(C - (B/20 Yrs)	Accessible Area outside PF+CF(ha)	Total Biomass loss t/Yr	Total Carbon Loss (t CO2e/year)
High Himal,High Mountian	50.05	10.01	0.5005	257,679.8	128,968.7	221,826.2
Middle Mountian	57.47	11.494	0.5747	1,176,518.6	676,145.2	1,162,969.8
Siwaliks	3.5	0.7	0.035	174,263.6	6,099.2	10,490.7
Terai	10.36	2.072	0.1036	448,339.4	46,448.0	79,890.5
	Total			**2,056,801.4**	**857,661.2**	**1,475,177.2**

Annex 5: Biomass loss estimation due to grazing and fodder collection on Accessible forests inside PF and CF areas

Region	A- Biomass loss t/ha (0.3*Average biomass loss)	(B) - (Weightage Factor of 0.2*(A))	(C - (B/20 Yrs)	Accessible Area outside PF+CF(ha)	Total Biomass loss t/Yr	Total Carbon Loss (t CO2e/year)
High Himal,High Mountian	21.45	4.29	0.2145	446,055.0	95,678.8	164,567.5
Middle Mountian	24.63	4.926	0.2463	266,022.8	65,521.4	112,696.8
Siwaliks	1.5	0.3	0.015	266,989.9	4,004.8	6,888.3
Terai	4.44	0.888	0.0444	104,017.7	4,618.4	7,943.6
	Total			1,083,085.3	169,823.4	292,096.3