National Forest Reference Level of Nepal (2000 – 2010)

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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 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 a visually interpreted sample data (reference data) often of higher resolution and GPS tagged field information was used to develop activity data on deforestation and afforestation. A total of 22,314 hectare and 13,598hectare 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 due to fuelwood extraction. 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).

Forest degradation due to other drivers such as grazing, timber extraction and fire; and enhancement due to community forestry, are all believed to be of significance. However due to the lack of reliable data, these activities have not been included in this submission.

The annual emissions and removals due to deforestation and afforestation are estimated at 929,325 t CO2e /year and -151,077 tCO2e/year respectively. It is estimated that the annual degradation due to unsustainable fuelwood extraction in Forest-remaining-Forest (FRF) resulted in emissions of 408,500 t CO2e/year. The FRL as per the three currently considered activities therefore contains emissions of 929,325 t CO2e/year for deforestation, emissions of 408,500 t CO2e/year for degradation and removals of -151,077 tCO2e/year for enhancement.

1 INTRODUCTION

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.

UNFCCC has used two terms "Forest Reference Emissions Level (FREL)" and "Forest Reference Level (FRL)" without explicit definition of these terms and their differences. However, Nepal's interpretation is that FREL refers only to the activities that reduce emissions while FRL refers to both activities that reduce emissions (reduction function) and enhance carbon stocks (uptake function) in the forests.

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 Program under the World Bank's Forest Carbon Partnership Facility (FCPF), population growth, 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 (Figure-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.

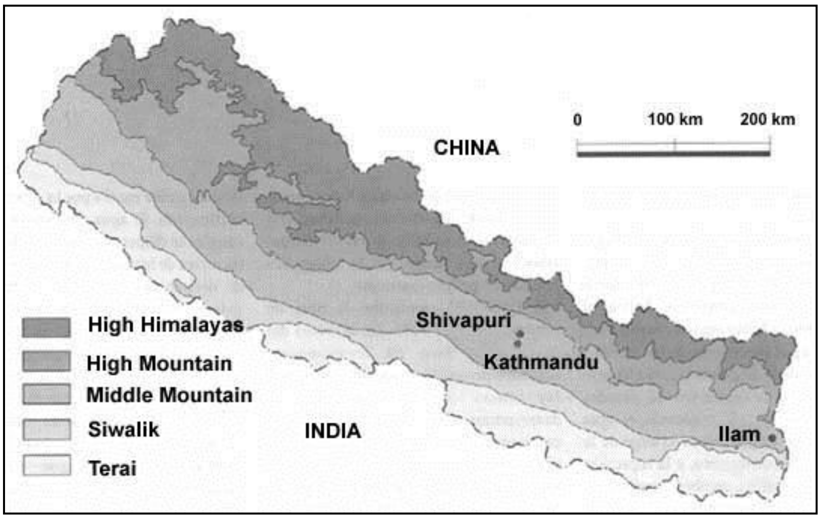


Figure 1: FRL national coverage

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 and fuelwood extraction.

Besides emissions from deforestation, the FRL includes an estimate of 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. 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, Siwalik (Churia), and Middle Mountains, and a combined report for High Mountains and High Himal physiographic regions. (Web Link: http://www.dfrs.gov.np/downloadfile/state%20of %20forest_1470140234.pdf).

The FRA Nepal study has provided basic plot-level information for calculating biomass and different emission factors, which were used for the degradation assessment. The emission factor information related to cropland, grassland and forest which are not available through the FRA study were collected from other relevant published literature or government reports and are detailed in relevant subsections.

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, methodology and tools of forest cover change analysis, 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 inventories are 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).

This FRL is prepared maintaining consistency with the second national communication report (NCR) to the greatest possible extent. Both GHG inventory and FRL estimation considered CO_2as the major gas, and above ground and below ground biomass as the major carbon pools. Both have considered unsustainable harvesting of fuelwood in forests as the major variable while estimating emissions and removals due to forest degradation. Further, both the studies are consistent in considering degradation/enhancement under forest land remaining as forest, deforestation/afforestation as the main activities for assessing carbon gain/loss. Both studies have estimated total annual biomass loss due to forest clearing. The second NCR estimated off site, onsite and decay-based release of $CO_2$from biomass released through forest clearing. The FRL study has directly converted total annual biomass loss for estimating CO_2loss due to forest clearing. Degradation by forest fires which have not been included (unless they resulted in deforestation), including through controlled on-site burning, due to a lack of reliable data suitable for monitoring.

However, there are also some differences between the two studies, mainly because of different components and datasets used for the estimation. This FRL has used new data (Section 1.5) developed recently and estimated emissions and removals more rigorously while the GHG inventory for national communication reports relied mostly on older data (i.e. MPFS 1989). Both the previous national communication reports were developed in the absence of a FRL (Base year for 2nd NCR was 2000/2001 and adopted 1994 forest cover estimates). This FRL is estimated using more robust and recent data and methodologies. With reference to forest land remaining as forest, the second NCR estimated net carbon loss/gain as a net function of total annual increment of carbon stocks and total carbon loss due to biomass consumption from forest stocks. The FRL is designed to assess degradation and enhancement explicitly to arrive at carbon loss/gains for each activity considering the several drivers related to each activity, in the absence of reliable and representative overall direct measurements of degradation. At the moment, it has considered only fuelwood as a driver of degradation and estimated impact on carbon loss/gain as a function of consumption through spatial explicit analysis using WISDOM model. Due to a lack of data, degradation due to grazing, fire and timber harvesting and carbon enhancement due to restoration are not assessed.

The next GHG Inventory for the third communication report will use the FRL data as the basis for estimation of forestry-related emissions and removals, so consistency between FRL and national communication reports will be maintained in accordance with decision 12/CP,17, para 8. In fact, this

FRL will be a part of the next communication report. The third communication report is being prepared considering year 2010, consistent with this FRL.

The FRL is estimated taking the national REDD+ strategy into account. One of the five objectives of the REDD+ strategy is to establish and maintain a National Forest Monitoring System (NFMS) with robust measurement, monitoring, reporting and verification mechanisms. The strategy suggests a stepwise approach to estimate FRL including (i) estimation with simple projections, based on historical data, (ii) progressively updating the FRL based on more robust national datasets for country-appropriate extrapolations and adjustments and (iii) ultimately basing the FRL on more spatially explicit activity data and driver-specific information support (Step 3). In line with the Strategy, FRL estimation follows stepwise approach and this report is the first step of FRL estimation. The REDD+ strategy includes 12 strategies and 70 actions to meet its objectives. One of the strategies is related to the FRL and NFMS with six strategic actions including (i) Enhance national capability with investment, technology and human resources for conducting forest resource survey and inventory periodically, (ii) Develop appropriate capacity of government agencies and local communities for the collection, analysis, storage, management and dissemination of carbon and non-carbon related data and information for planning and MRV, (iii) establish a well-functioning Forest Management Information System under the NFMS, (iv) develop and functionalize cost-effective mechanisms for monitoring, measurement, reporting and verification of REDD+ programs, (v) strengthen community-based monitoring systems with identified monitoring indicators in community-based forest management, and (vi) Establish spatially explicit information systems on land use potential, allocations and potential conflicts/complementarity with REDD+ strategies. Further, this FRL complies with environmental provisions of newly promulgated constitution of Nepal and other related policies and measures. Highlights of related such policies and measures are presented at the end of this document (i.e. Annex 9).

Nepal has submitted an Emission Reduction Program Document (ERPD) at sub-national level covering Terai Arc Landscape to World Bank's Forest Carbon Partnership Facility (FCPF). The document has estimated sub-national/jurisdictional Forest Reference Level in line with similar methodology of this National FRL to the best possible extent. However, Sub-national FRL has taken more sample plots at various time intervals than the NFRL. The sub-national FRL is being revised in order to address the comments made by the Technical Advisory Panel (TAP) assigned by the FCPF. The TAP has advised REDD IC to make both the RLs consistent with each other in terms of applied tools and techniques for the estimation. Therefore, REDD IC has planned to make both the national and sub-national FRL consistent with each other in the future.

1.5.2.3 Accurate Information

According to IPCC, accurate estimates refer to estimates that are systematically neither over nor under estimates true emissions or removals, as far as can be judged. Systematic 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 to create “bias-corrected” area estimates using a combination of map and reference data (Section 5).

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 to support national level FRL assessment. Nepal carried out a National Forest Inventory (NFI) between2010 and 2014, temporal land cover maps generated with national coverage and also 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, 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.

Department of Forest Survey and Research (DFRS),the central authority for Forest Resources Assessment (i.e.) in Nepal has prepared a forest cover database for the year 2010 in accordance with the national definition of forests using Rapid Eye 5 m resolution data and National Forest Inventory (NFI) field information. In view of non-availability of similar data for the year 2000, the study has adopted Landsat TM 30 m resolution data for the years 2000 and 2010 to make the forest cover change assessment. Considering the resolution of satellite data used the mosaic forest landscape and highly rugged terrain and to ensure reliability and accuracy, the study has made forest cover change assessment at the size of 2.25 ha and reported accordingly. In view of this, the FRL submission will not be reporting changes at 0.5 ha size, adhering to the national definition of forests, due to data limitations (details are given in section -3.5). Using Rapid Eye 5 m resolution data based forest cover of 2010 as a baseline, the preparation of future change assessments using satellite data of the same or comparable resolution would help to ensure that these assessments are consistent with the national definition of forest.

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

e) Enhancement of forest carbon stocks from afforestation/reforestation

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

2.3.1 **Deforestation:**

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

2.3.2 **Degradation:**

Degradation is the long term or permanent reduction of biomass in forest land remaining forest land. The expression "long-term" is used in opposition to short-term/temporary degradation, which may be induced by individual disturbance and from which we can assume that the forest will be able to recover thus over time resulting in no net change to CO_2 in the atmosphere. Long-term degradation is understood as the result of recurrent disturbance with an impact above the recovery capacity of the forest thus resulting in emissions of CO_2 to the atmosphere which is not compensated by subsequent removals through post-harvest regrowth.

For instance, disturbances adequately spaced over time, such as fuelwood harvesting or livestock grazing do not induce long-term or permanent degradation, while recurrent/continued harvesting and/or grazing above the regrowth capacity of the forest cause the progressive reduction of the forest biomass and other negative impacts that will worsen until the excessive harvesting and/or grazing is reduced or stopped. Degradation may be considered permanent when the recovery capacity of the forest to return to the original status is impeded, as in case of a critical loss of soil and nutrients. We could refer to the actual emissions associated at the time of the degrading event (e.g. fuelwood extraction) as gross degradation. Net degradation deducts removals associated with the forest recovery processes following the degradation event (e.g. post-harvest regrowth). As such, gross degradation emissions can be much higher than net degradation emissions. Nepal reports in this FRL on net degradation from fuelwood extraction to avoid potential over-estimation of emissions from degradation.

With reference to fuelwood harvest based degradation, biomass extraction (fuelwood) in each location is compared against the re-growth capacity of the harvested area (re-growth capacity is estimated as a function of the empirical relation between biomass stock and mean annual increment) to determine whether the regeneration capacity was exceeded or not. Hence the use of the word 'net' suggests that regrowth is deducted from the degradation estimate.

2.3.3 **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 long term or permanent 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.

Community Based Forest Management (CBFM) practices, especially Community Forestry and pro-poor Leasehold Forestry programs, are considered to significantly contribute to forest restoration. Post-harvest or post-disturbance regrowth is not included under restoration since this is included in the degradation estimate when converting gross degradation into net degradation.

2.3.4 **Rationale for inclusion of the above activities:**

The proposed FRL is estimated using national level data. Deforestation and forest degradation are the main sources of emissions from the forestry sector in Nepal, hence REDD+ intervention must focus on addressing them. Afforestation/reforestation and participatory management of forest resources have contributed to the restoration of the forest landscape in Nepal.

Measurement of the outcomes of these three activities (i) reducing deforestation, (ii) reducing forest degradation and (iii) promoting afforestation, reforestation (enhancement of forest carbon stocks) will enable Nepal to assess the contribution of the forest sector to emissions reduction and enhancement of carbon stock. While Community forestry contributes to positive outcomes of these three activities, it is also believed to contribute substantially to enhancement of forest carbon stock in forest land remaining forest land.

Enhancement of carbon stocks in forest land remaining forest land may constitute a significant share of removals, especially thanks to Nepal's efforts on promoting community forestry (see "restoration" paragraph below). However, due to data constraints Nepal is not yet able to include enhancement in forest land remaining forest land. The non-inclusion of enhancement of carbon stocks in forest land remaining forest land is likely to result in an underestimation of removals and an underestimation of results on this activity.

Deforestation and afforestation/reforestation

It is generally not possible to say if an individual forest loss event observed through remote sensing is permanent or temporary. However, Nepal observed loss over an extended period of time (i.e. 10-years) to correct for events of temporary loss followed by regrowth of the forest. Within a certain number of years the temporary forest cover loss grows back to forest, therefore net loss over this period represents the deforestation component of the detected loss. In a spatial context, as per the minimum mapping unit adopted for change assessment, each location which was forest at $time_1$ is assessed to see if it has changed to non-forest at $time_{2.}$ This essentially involves identifying the change as deforestation at the end of change assessment period as an outcome of all temporary deforestation and recovery process undergone during the period. All the locations will be assessed for such change to report the total deforestation or loss for the entire area.

Deforestation and afforestation/reforestation can be readily detected through comparison of digital data on land cover available for the years 2000 and 2010 The FRL study did not attempt to identify and attribute causes for deforestation. Hence forest fire induced deforestation and associated emissions are not attempted but in case forest fire resulted in the long-term loss of forest (land use conversion) it is implicitly included in the current deforestation estimate in terms of CO_2 emissions. Non-CO_2 emissions from fire induced deforestation have not been included but an IPCC default calculation shows that these emissions can be considered not significant (see section 2.5).

Forest degradation

Degradation and enhancement in forest land 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 program) 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 program of decentralized forest management which has resulted in significant long-term permanent enhancement of forest biomass in many forests under this program, 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), only harvesting of fuelwood has been considered for assessing forest degradation in the current submission and this assessment is based on estimated average historical fuelwood consumption rates.

The methodologies used to measure the impact of fuelwood extraction 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.

The fact that only fuelwood collection is considered as a driver of forest degradation in this submission does not mean that other important drivers like grazing, 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, the remaining drivers of forest degradation will also be assessed for their emissions contribution and incorporated in the FRL.

The recent NFI (DFRS, 2010) reported grazing as the most frequent biotic disturbance reported across forests. However, to date at country level there is no well-defined consistent field measurements to compare and assess the impact of different grazing intensities and management regimes on forest carbon fluxes. Several studies reported (Annex 1) on the impact of grazing on forest biomass and the role of different management regimes in reducing grazing-based degradation but they do not provide a basis to make national-level estimates. However, an attempt has been made to assess the supply/demand scenario of grazing resources, and its associated impact on forest degradation using available national data on different fodder and grazing resources, livestock data, accessibility functions, feeding habits and 1,500 NFI plot level databases on qualitative grazing disturbances and biomass.

Due to lack of reliable field measurements, the analysis was relied on several assumptions made to assess grazing impact on degradation. Different spatial statistical approaches were also applied to assess the relationship between qualitative grazing intensities and biomass changes. However the results were not found sufficiently reliable to draw scientifically robust conclusions on grazing induced degradation. In view of this, this activity is not included in the current submission. In the coming years, Nepal will develop scientifically robust field designs and undertake measurements to asses grazing induced forest degradation and the impacts of different management regimes on restoration of forests through controlled grazing.

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 undertaken to estimate timber harvest 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.

Community Based Forest Management (CBFM) practices are believed to contribute to the reduction of forest degradation especially through reducing the pressures from fuelwood collection, grazing and fire (Annex2).

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 Annex 2). CBFM practices (Community Forestry and pro poor Leasehold Forestry program in particular) are been considered to contribute significantly to forest restoration. However, Nepal does not yet possess data which allows estimation of GHG removals from restoration in a sufficiently robust and reliable manner. Nepal intends to consider CBFM's contribution to enhancement of forest carbon stocks in the future, with appropriate field and remote sensing measurements. Nepal is currently investigating what data it needs to collect to estimate removals in the community forests in a robust and reliable manner (details of CBFM contribution to carbon enhancement is discussed in Annex 2).

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 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 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 subsequent estimations 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 forest are considered as the significant pools hence included in the FRL

The other three pools (i.e. dead wood, litter and soil organic matter) did not seem to contribute significantly to GHG emissions from forestry. As described, FRA 2014 (state of the forests report) shows that litter and debris (dead wood) 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. Soil Organic Carbon (SOC) is omitted because no credible data was available whilst the cost of data collection was likely to exceed the benefit of including SOC. It is Nepal's understanding that for a default calculation of SOC emissions/removals associated with a conversion of one land use category to another, at a minimum the land use category replacing forest land should be known as well as the management regime (see section 2.3.3.1 of IPCC 2006), Nepal does not have this information and can therefore not provide a reliable estimate of potential emissions/removals from SOC.

For SOC, expert judgment suggests that it consists of a small proportion of the total emissions since there is no drainage of peat lands in Nepal. Based on the FRA data it is confirmed that DOM (litter and deadwoods) accounts for less than 5%. Nepal follows IPCC guidelines i.e. 25-30% to be significant. Nepal interprets that any pools below 25% of the total carbon can be considered as not significant and DOM in Nepal accounted for less than 5%.

2.5 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). The reliable estimates on forest fire effected areas and the degree of biomass lost from such areas is lacking in the country. However the Global Forest Resources Assessment 2015 (FAO 2015) provides a burned forest area estimate for Nepal which is on average 9,738 ha/yr for the period 2003-2010. This number concerns mainly fire events in forest land remaining forest land, a sub-category which is currently not fully covered by the FRL. In the remote sensing analysis these areas are included in the stable forest class. Afforestation/reforestation only happens on non-forest land use categories and is not preceded by burning of the land.. In its first FRL submission, Nepal did an IPCC default calculation for non-CO_2 emissions associated with fire using FAO 2015 burned forest area and the average above ground biomass (mass of fuel for combustion) as obtained from Nepal's National Forest Inventory (2010). The estimates found non-CO_2 emissions associated with forest fires to constitute 22% of total annual emissions included in Nepal's FRL.

However, we now believe this estimate largely overestimated non-CO_2 emissions from forest fires for two reasons. First, fires in forest in Nepal tend to be scattered. The areas reported in FAO 2015 are based on the MODIS Collection 5 Burned Area Product which has a pixel size of 250 m therefore capturing a much larger area in case the fire affected area is much smaller than 250 by 250 m (see Van Lierop et al, 2015). Second, forest fires would affect open forest structures representing degraded and secondary forests whereas the average above ground biomass value used in the non-CO_2 emission calculation concerns more primary or dense forest. Using the IPCC secondary forest default fuel biomass consumption value (IPCC 2006, Vol 4, Chapter 2, Table 2.4) would result in 40% lower non-CO_2 emission estimate than the estimate suggested in the first submission. This results in lowering the non-CO_2 emission estimate to 13% of total emissions in the FRL. Due to the likely over-estimation of the area by MODIS, though it is likely the estimate would be even less by<10% 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 (ICIMOD 2010) and forest cover database of year 2010 from DFRS(2015) prepared using Rapid Eye 5 m resolution were also used as supplementary information. 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 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 Program. 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 four steps as shown in Figure-2 best describe the overall methodology adopted for accurate 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

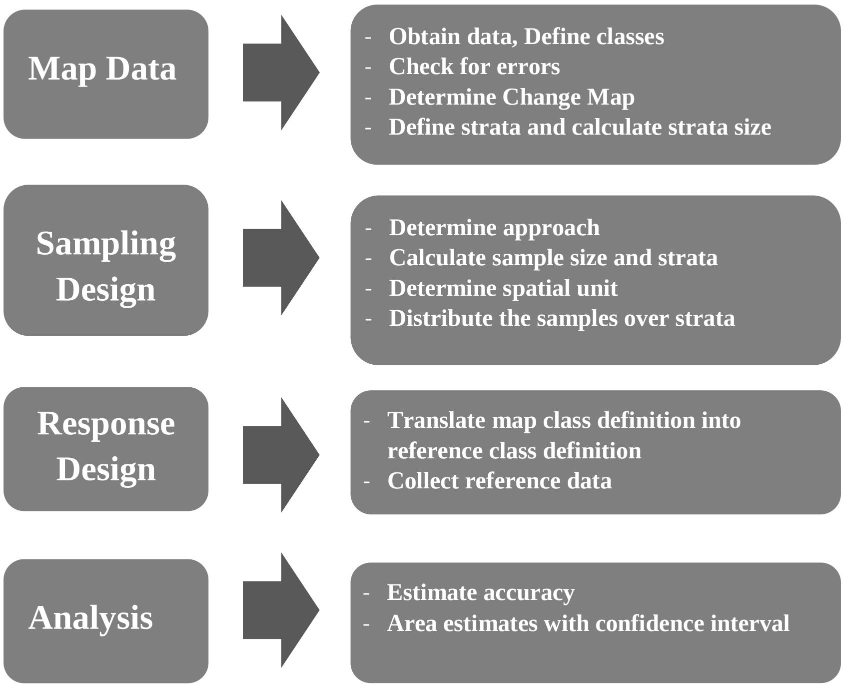


Figure 2: Methodology for forest change accuracy assessment

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 considering the consistency, completeness and accuracy.

3.2.2 Preparation of Land Cover database of 2000 and 2010

The Landsat TM satellite path-wise data sets used for the classification of years 2000 and 2010 landcover are given in Annex3. Apart from these, additional seasonal datasets were also consulted whenever required for improvement of classification. For image classification, the object-based image analysis technique was adopted using e-Cognition developer software and standard methodology as explained in *Kabiret. al* (2015). Multi-resolution segmentation was used for delineating image objects, and mean indices were calculated within each segment for better classification. During the data preparation phase of land cover databases, several national consultation workshops were also held to capture ground experiences to support individual product accuracy and change assessment.

For quality control of land cover data preparation, 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 to the extent possible.

Subsequently individual 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. The overall classification accuracy of 2000 and 2010 was found to be 86.7% and 85.7% respectively and the details of accuracy assessment are presented in Annex4.

3.2.3 Forest Cover Statistics and Change reporting:

Land cover classification was done at individual pixel resolution in order to retain and leverage the advantage of pixel level spectral purity. The land cover images thus developed at original pixel level for 2000 and 2010 were used as inputs to generate change areas during 2000-2010. 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 converting to Non forest

Forest Gain (FG): Non forest converting to forest

Stable Forest: Forest Remaining as Forest

Stable Non Forest: Non forest remaining as Non forest

The pixel wise change image was converted into vector database and change areas were grouped into three size classes below 1 ha, 1 to 2.25 ha and above 2.25 ha. The below one ha size change areas were not considered for change assessment owing to the minimum size of one ha (3x3 pixels) to be considered for change reporting based on the input LANDSAT TM resolution of 30 m. The assessment of accuracy of change areas of 1 to 2.25 ha size was not found satisfactory owing to inherent hilly terrain induced registration errors, hilly shadows, highly fragmented and intermixed land cover mosaic. The change areas of above 2.25 ha size was found with better accuracy. The 2.25 ha size (equivalent to 5x5 pixel window) is the next higher window size compared to minimum size of pixel window to be used for change monitoring as per the input pixel resolution of 30 m. Accordingly, the change areas of above 2.25 ha size were only considered for the FRL assessment and all the change areas below 2.25 ha were added back to stable non forest to make more conservative forest estimate. In addition, the stable forest was also improved using DFRS forest cover of 2010 prepared using Rapid Eye satellite data of 5 m resolution. Accordingly, the land cover statistics of 2000, 2010 at minimum mapping unit of change at 2.25 ha are presented in the table 1 and physiographic region wise statistics are presented in Table 3.

Classes	2000		2010		2010-2000
	Area(Ha)	**%**	**Area(Ha)**	**%**	**Area difference (ha)**
Forest	5,945,220.60	40.39	5,937,644.41	40.34	- 7,576.19
Shrubland	353,216.87	2.40	338,499.50	2.30	- 14,717.37
Other Landcover[1]	8,419,662.44	57.21	8,441,956.00	57.36	+ 22,293.56
Total	**14,718,100**	**100**	**14,718,100**	**100.00**	

1 – Other Land Cover-: Land Cover other than forest and shrub land

Table 1: Land cover statistics for year 2000 and 2010 based on Landsat TM data with minimum mapping unit of 2.25 ha

It can be observed from table 1 that the forest area changed from 40.39% to 40.34% during 2000 to 2010 withdecrease in forest area by 7,576.19 ha.

3.2.4 Spatial Forest Cover change analysis – Change Matrix

The forest change matrix prepared using spatial comparison of 2000 and 2010 forest cover products is presented in table 2. Here, total forest loss across the country was observed to be 26,970.6 hectares and total forest gain of 19,349.4 hectare resulting in net decrease of forest area by 7,576.19 hectare. The forest land remaining as forest during 2000-2010 is estimated as 5,918,250.0 hectare.

2000/2010	Forest	Non Forest	Total 2000
Forest	5,918,250.00	26,970.60	**5,945,220.60**
Non Forest	19,394.40	8,753,484.90	**8,772,879.30**
Total 2010	**5,937,644.40**	**8,780,455.50**	**14,718,099.90**

Table 2: Forest change matrix showing forest loss and forest gain between 2000 and 2010

The highest level of deforestation was found in Tarai region with 51.5% of country forest loss and highest level of afforestation was found in Middle mountain region with 40.9% of country forest gain (as presented in Table 3).

The following figures 3 and 4 show an example of the change assessment work conducted between landcover maps of 2000 and 2010 followed by verification of the change areas in Google Earth high resolution imagery.

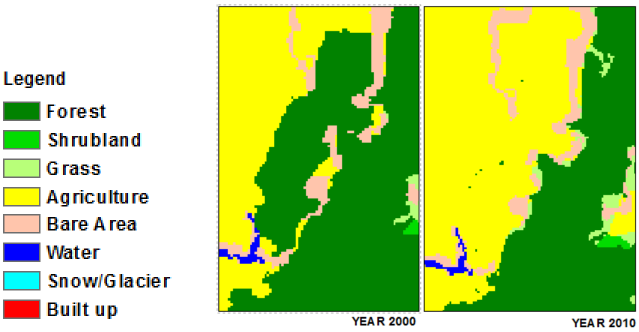


Figure 3: land cover map of year 2000 and 2010 showing forest loss

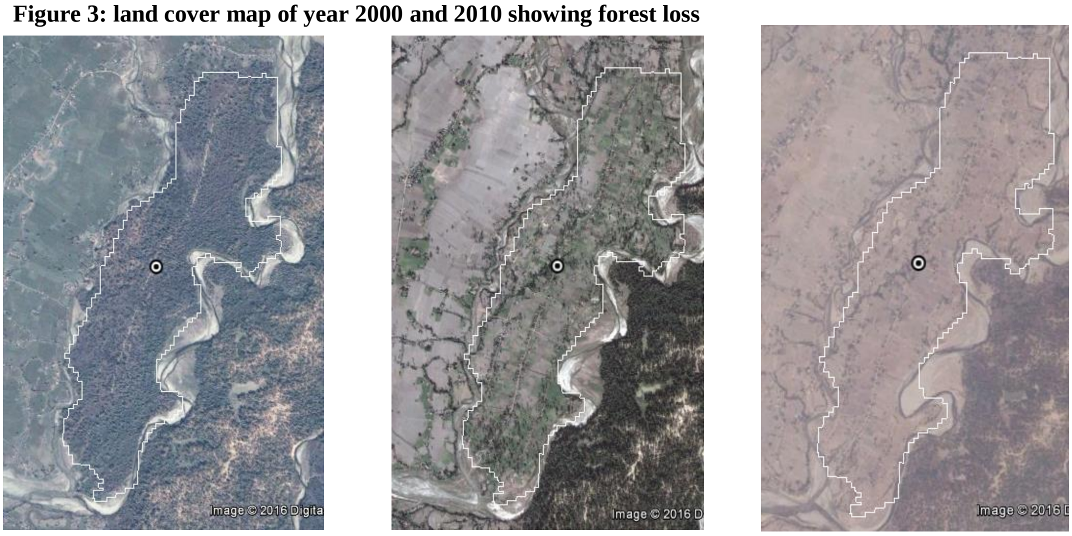


Figure 4: Google imagery for verification of forest loss for year 2000 and year 2010
Source: Google Earth, Location: Jhalari-Pipladi, Kanchanpur District, Far-Western Nepal.
Area: 185 hectare, Coordinate: 28°55'39" N, 80°22'46" N

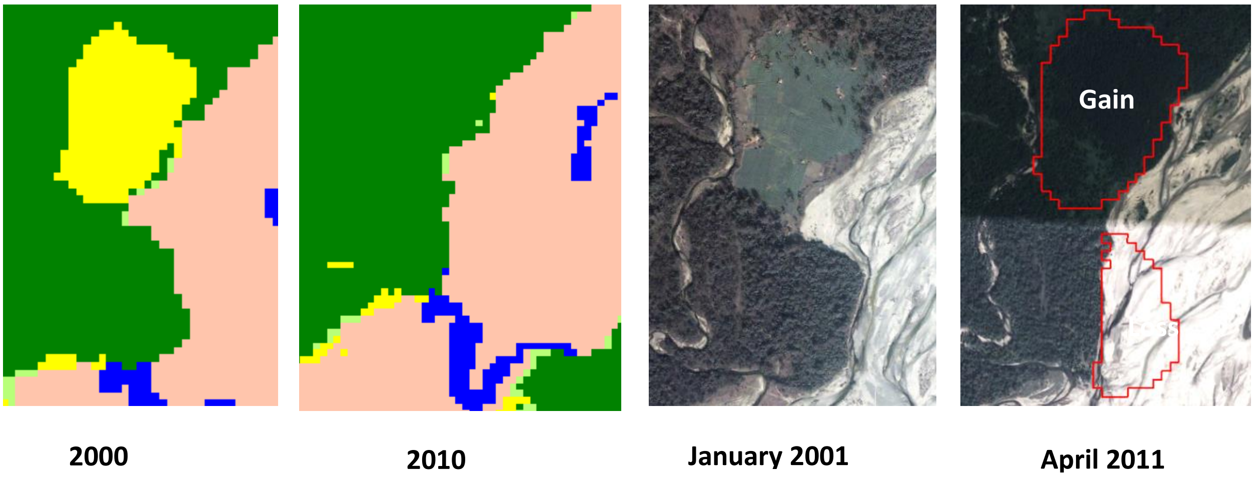


Figure 5: Forest loss and gain areas identified in Landcover of year 2000 and 2010 and verified in Google Earth
Source: Google Earth, Location: Krishnapur, Kanchanpur District, Far-Western Nepal.
Gain Area: 26 hectare Loss area: 12 hectare, Coordinate: 28°53'23" N, 80°27'33" N

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%	368,528.00	6.2%	3,344,190.08	38.2%
High Mountain	3,366.34	12.5%	4,064.22	21.0%	7,430.56	16.0%	1,293,111.00	21.8%	1,190,772.87	13.6%
Middle Mountain	1,720.77	6.4%	7,923.92	40.9%	9,644.69	20.8%	2,337,169.00	39.5%	2,067,715.96	23.6%
Siwalik	7,600.91	28.2%	2,739.93	14.1%	10,340.84	22.3%	995,818.00	16.8%	545,563.33	6.2%
Tarai	13,900.08	51.5%	4,171.74	21.5%	18,071.82	39.0%	923,624.00	15.6%	1,605,242.66	18.3%
Grand Total	**26,970.60**		**19,394.41**		**46,365.01**		**59,18,250.00**		**87,53,484.90**	

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

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

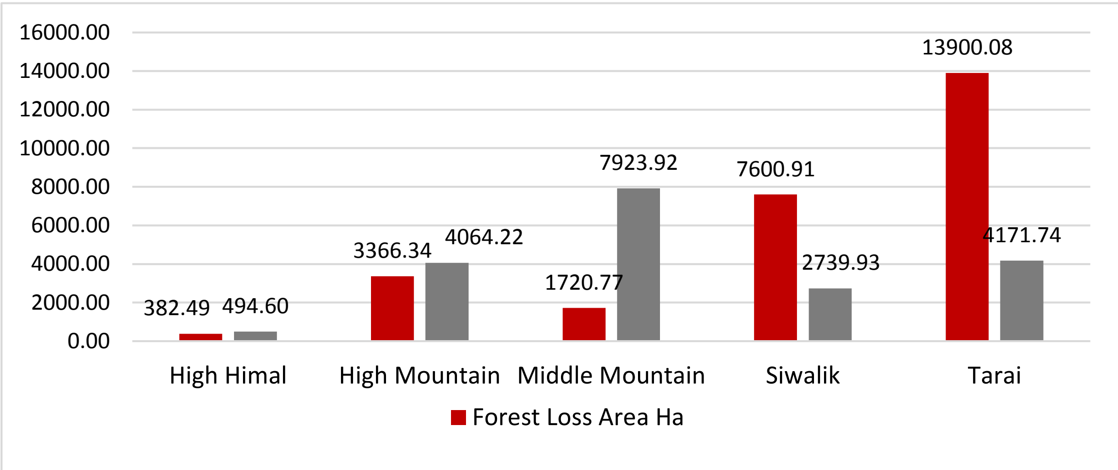


Figure 6: Forest Change over reference period 2000 -2010 across physiographic regions of Nepal

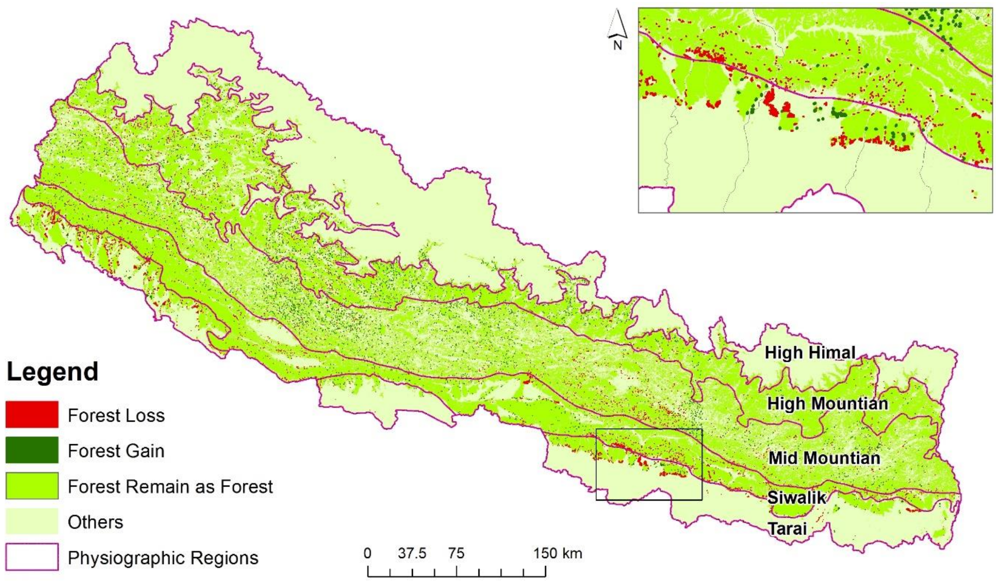


Figure 7: Distribution of Forest Change across physiographic regions of Nepal (Patch sizes above 2.25 hectare)

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. On the other hand, forest gain has occurred mainly in mountain regions.

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.

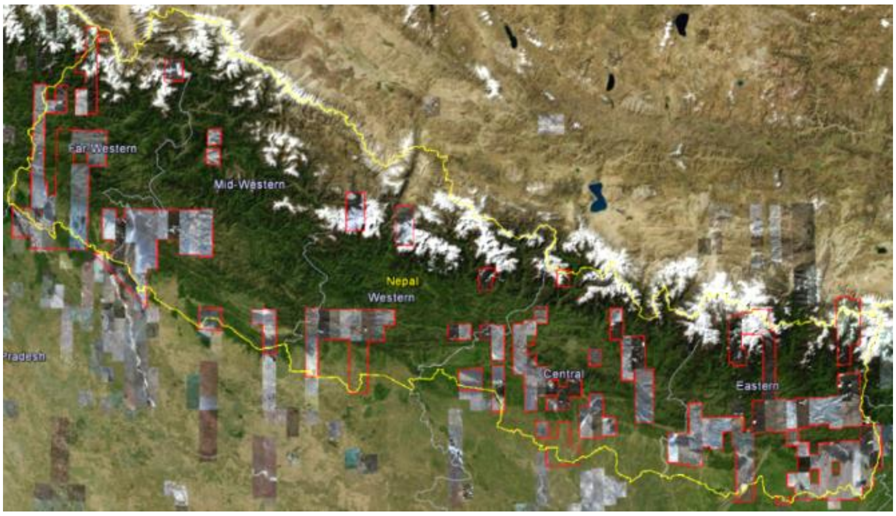


Figure 8: High resolution tiles coverage in Google Earth

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 the sample plots)

The remaining 316 ‘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	**136**	**230**	**266**	**632**

Table 4: Distribution of samples in tile coverage region

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

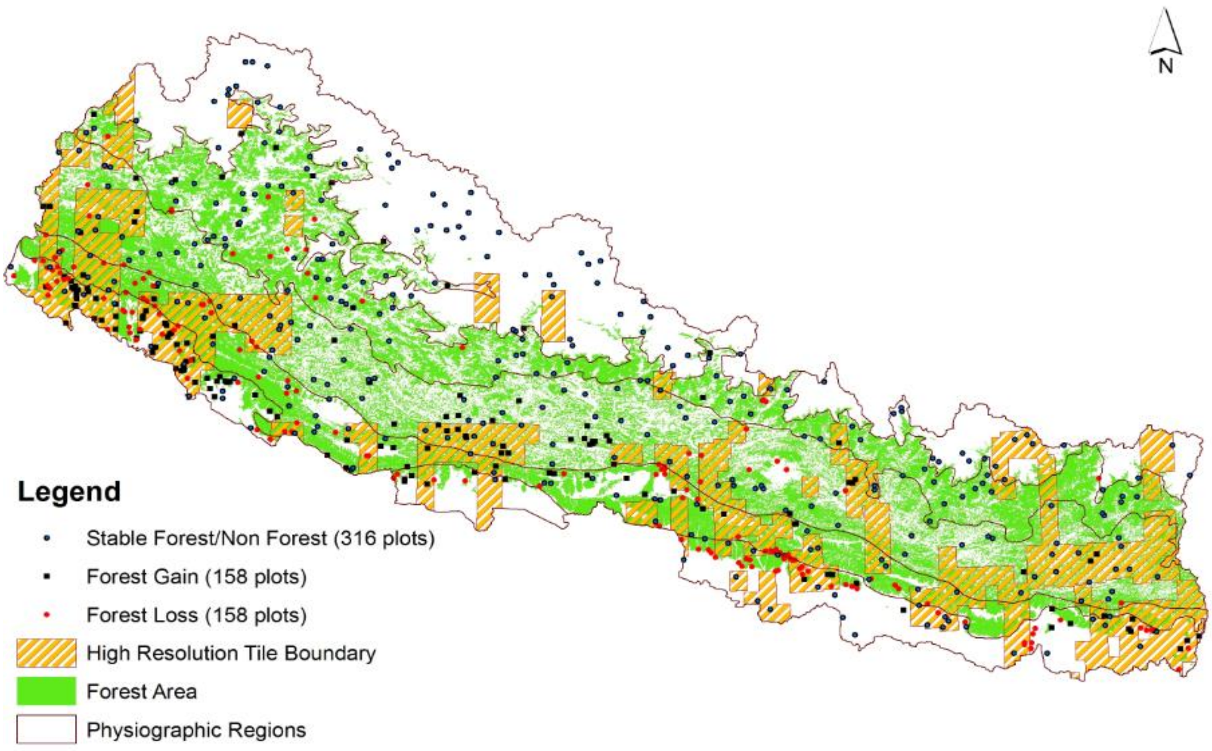


Figure 9: 632 random samples distributed over the country

Further 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 as per the details given in Annex-5

3.3 Results of Accuracy Assessment

Our stratified random sampling design covering optimal distribution and number of sample points, the google earth high resolution images; and use of Collect Earth Tool for comparative evaluation of map and reference data forms global followed good practice to assess accuracy of both deforestation and afforestation. The methodology adopted produced an error matrix (confusion matrix) which is the cross tabulation of land cover classes identified from map data and reference data. The individual land cover products compatible at minimum mapping unit of 2.25 ha, accuracy assessment locations and associated datasets are uploaded as supporting documents to FRL at the following web page link of REDD implementation center Nepal: http://mofsc-redd.gov.np/?page_id=948. The following tables 5- 8 and Figure – 10 provides results of accuracy assessment and bias corrected area statistics.

	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	15	11	**158**	82.28%
	Forest gain	1	**108**	36	13	**158**	68.35%
	Stable Forest	0	0	**143**	15	**158**	90.51%
	Stable non-Forest	0	0	17	**141**	**158**	89.24%
	Total reference samples per class	**131**	**110**	**211**	**180**	**632**	
	Producer's accuracy	99.24%	98.18%	67.77%	78.33%	**Overall accuracy**	**82.59%**
	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**	0.82	0.01	0.09	0.08	**26,970.60**
	Forest gain	0.01	0.68	0.23	0.08	**19,394.41**
	Stable Forest	0.00	0.00	0.91	0.09	**5,918,250.00**
	Stable non-Forest	0.00	0.00	0.11	0.89	**8,753,484.90**

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**	22,191.00	341.40	2,560.50	1,877.70	**26,970.60**
	Forest gain	122.75	13,256.94	4,418.98	1,595.74	**19,394.41**
	Stable Forest	-	-	5,356,390.82	561,859.18	**5,918,250.00**
	Stable non-Forest	-	-	941,830.65	7,811,654.25	**8,753,484.90**
	Bias-correctedarea	**22,313.75**	**13,598.34**	**6,305,200.96**	**8,376,986.87**	

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**	3.11864E-09	2.67312E-10	1.83777E-09	1.3854E-09
	Forest gain	6.95561E-11	2.39238E-09	1.9458E-09	8.35117E-10
	Stable Forest	0	0	8.84905E-05	8.84905E-05
	Stable non-Forest	0	0	0.000216328	0.000216328
	Total	3.1882E-09	2.65969E-09	0.000304822	0.000304821
Standard error		831.04	759.04	256,965.65	256,964.99
95%Confidence Interval		1,628.85	1,487.73	503,652.68	503,651.39
95%Confidence Interval as percent of bias-corrected area		7%	11%	8%	6%

Table 8: Error Matrix of Standard Error

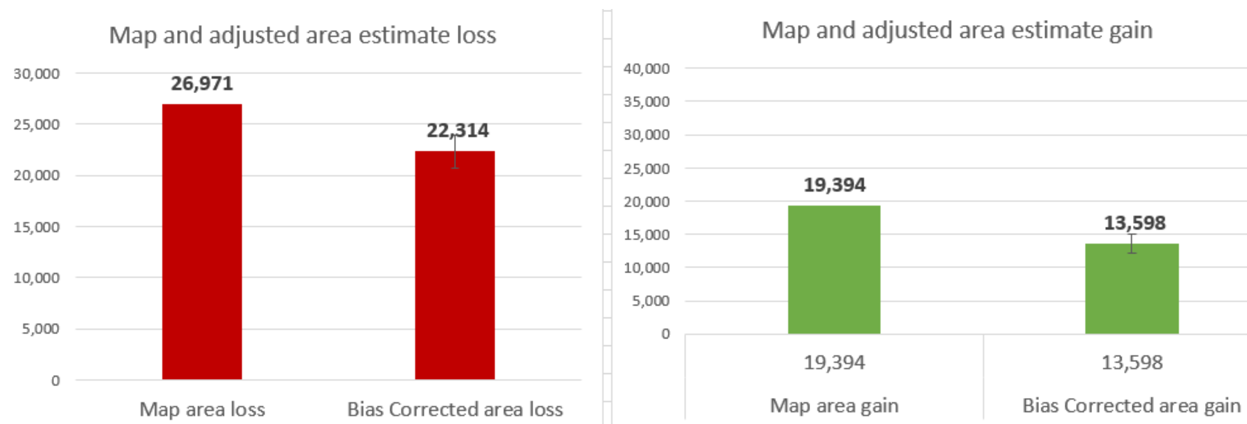


Figure 10: Map area and bias-corrected area of forest change

3.4 Comparison with Previous National Estimates

All national forest cover estimates along with Landsat TM based forest cover change assessment at 2.25 ha size area are given in Table 9.

Study	Year	Forest and Shrub %	Forest + Shrub %
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: Aerial Photo,LandsatTM,Field data	1994	Forest: 29% Shrub: 10%	39.0%
Forest Resource Assessment (FRA): Rapideye 5m	2010	Forest: 40.36% Shrub: 4.38%	44.7%
land cover 2000 : Landsat TM 30m	**2000**	**Forest: 40.4% Shrub: 2.4%**	**42.8%**
land cover 2010 : Landsat TM 30m	**2010**	**Forest: 40.3% Shrub: 2.3%**	**42.7%**

Table 9: Comparison of previous studies with Landsat TM land cover

Out of the series of national estimates of forest cover as presented above, the current estimates were discussed in relation to the 1994 and latest 2010 national assessments. The 1994 national estimatewhich were used for second national communication refer to data sets of 1987 - 1998 period. A part from this, various datasets such as aerial photography, Landsat TM, and field estimates were used separately for different physiographic regions with varying minimum mapping units ranging from 1 to 25 hectare. It is expected that the estimates prepared with such inconsistent datasets across the country and representing longer time periods would be spatially inconsistent. It may also be noted that the 1994 forest cover estimates (Table-9) deviates largely from all other national estimates regarding the over estimation of shrubland.

All the national estimates are of similar ranges based on the combined total of forest and shrub, with differences attributable either to the inherent forest cover of the data period or to data/methodological differences.

Since the current estimates are prepared using spatially and temporally consistent Landsat TM 30 m resolution data of 2000 and 2010 with minimum mapping unit of 2.25 ha, it is not technically possible to make a direct comparison between these figures and the 1994 estimate. For the 2015 FRA of FAO, Nepal could not provide updated data to the FAO on time because the national forest inventory project was underway. Instead, a formula was used (total area of 1999 multiplied by deforestation rate 1.7%) to estimate forest cover. This estimate will be updated with NFI data in due course.

The current study estimates are found to be very close to the FRA 2010 assessment, using Rapid Eye satellite data of 5m resolution. The wall to wall comparison of both the data products found correlation of 86% and the remaining differences are attributed to coarse resolution data used in the current estimates. In view of this, Landsat land cover 2000 and 2010 data products were selected as the primary map data for FRL development of Nepal.

3.5 Summary and Conclusions - Current Change Reporting

- Observed overall accuracy of change assessment at 2.25 ha Minimum Mapping Unit (MMU) size is 83% with coefficient of agreement of 0.70.
- Observed loss (26,971 ha) and gain (19,394 ha) areas are approximately 70% of the values according to of Global Forest Watch, which shows tree cover change data from 2000-2014 as 35,504 ha loss and 13,404 ha gain. Data from Global Forest Watch, however, are not ground verified.
- Bias-corrected area estimate shows that area correction would decrease the overall forest loss by 9% and forest gain by 17%.
- The forest cover change process in Nepal Himalayas is a complex spatial and temporal function due to large terrain effects, shaded relief, fragmented land cover mosaic, gradual change process over time. These complexities need to be addressed using optimal time window for change assessment along with optimal spatial resolution. The 10 year time period considered in the study is good enough to capture greenness change on temporal scale due to both deforestation and afforestation/reforestation. On the other hand, the forest cover changes controlled at spatial scale due to small land holdings and fragmented land cover should be addressed through higher spatial resolution satellite data to address both deforestation and afforestation/reforestation
- In view of the above, despite addressing temporal change function, using the MMU of 2.25 ha, which is higher than the MMU in the national forest definition (0.5 ha), the resulting estimate under reports both deforestation and afforestation/reforestation actually happening in the country. Our relatively lower accuracies of afforestation compared to deforestation is also on similar line where globally several studies reported complexities involved in monitoring afforestation than deforestation (Kennedy et al,2007 and Kurz 2010,Hansen et al 2011). Accordingly to overcome the classification errors, bias corrected areas were used for carbon flux estimates where bias factors were estimated using globally followed best practices (Section – 3.2.4).
- The under reporting of deforestation/afforestation could be best addressed using high resolution satellite data of 5m resolution adhering to minimum mapping unit (0.5 ha) as per national definition of forest with a minimum of 5 year time period to account change. It is worth mentioning that Nepal has already prepared forest cover data base of 2010 using Rapid Eye satellite data of 5 m resolution with 0.5 ha minimum size of forests. The future assessments with the same satellite data or of comparable resolution would be able to capture the changes of less than 2.25 ha to provide better national forest cover change assessment. However, it may be noted that with the ongoing constraints of available data (Landsat TM), conditions of the country such as large terrain effects, shaded relief ,mosaic and fragmented land cover, the results are considered in accordance with IPCC guidelines providing the best assessment of change.

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 10). 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 10: 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 fuelwood 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.

4.1.7 Forest Type Mapping

An approach based on machine learning and classification was developed for national level wallto-wall forest type classification and mapping. The approach used Classification and Regression Tree (CART) with threefold cross-validation algorithm. In the CART process, Landsat 8 (acquired during October/November 2013) imagery variables (6 MSS bands, 8-Grey Level Co-occurrence Matrix) along with DEM parameters (elevation range, slope, aspect) were used as predictor variables. The machine learning CART process was trained by using FRA field inventoried forest type data from the Permanent Sample Plots (PSPs) (n = 907) selected randomly (80% intensity with forest types as strata) within individual Landsat 8 scene coverage areas. The CART process uses binary regression algorithm to classify each image segment into designated forest types. The classified forest type was cross-validated by using the remaining 20% PSP forest type plots (n = 597).According to forest cover mapping, the Terai Mixed Hardwood (TMH) forest type has the highest coverage (24.61%) followed by the Upper Mixed Hardwood (UMH) (18.23%). Similarly, the share of Shorea Robusta and Pinus Roxburghii forest types are 15.27% and 8.45%, respectively. Nearly 60% of the total forest area is composed of mixed forest types (Figure 11). The spatial distribution of forest type is presented in Annex-6.

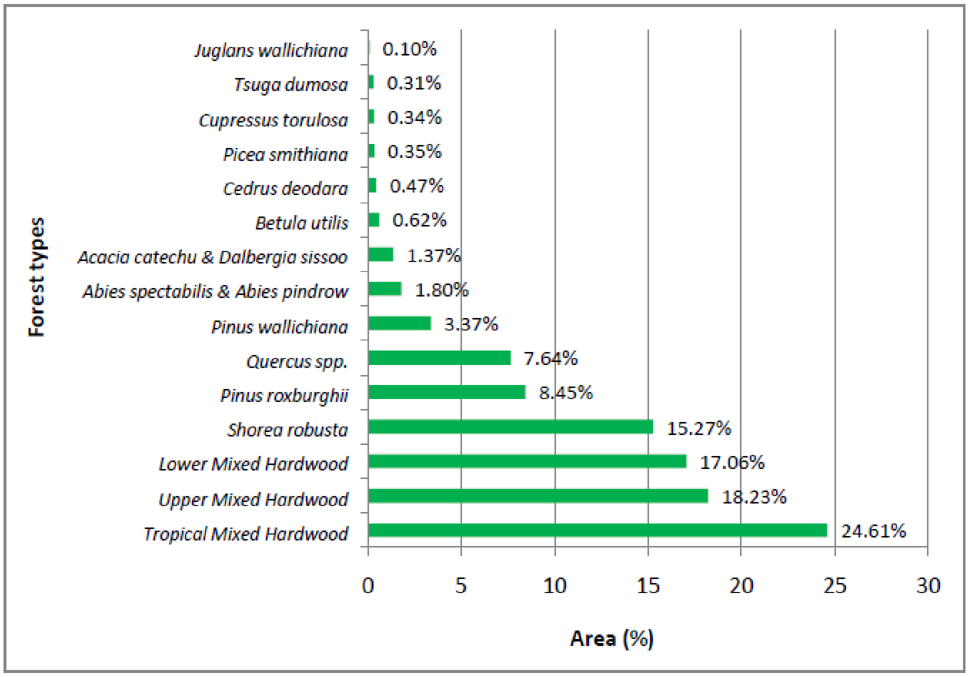


Figure 11: Coverage of Forest Types based on NFI plots

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 11).

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
Siwalik	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 11: 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%

ofthe 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 12). 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
Siwalik	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 12: 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 Tables13 and 14. Based on the commission and omission errors 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 national level bias corrected forest loss and gain areas were estimated at 22,313.75 ha and 13,598.34 ha respectively (Table – 7). The national level bias-corrected areas were used to estimate physiographic regions wise bias corrected forest loss and gain areas as a function of percentage loss/gain mapped area under each region (Table-13 and 14).These areas were then used for carbon flux estimations. The highest deforestation was found in the Terai region with an estimation of 11,500 ha area over the period 2000-2010, or 52% of the total deforestation in the country. The highest afforestation was estimated in the Middle Mountain region with a total area of 5,556haover the period 2000-2010, or 41% of the total afforestation in the country.

Physiographic Region	**Loss area >2.25ha, 2000-2010 (map area, ha)**	**% of Total loss** *(Physio Region loss / Total loss)*	**Bias Corrected Area** *(% Total loss * Total bias corrected area)*	**Annual loss in ha – bias corrected** *(Bias Corrected Area / 10)*
High Himal	382.49	1.42%	316.45	31.64
High Mountain	3,366.34	12.48%	2,785.10	278.51
Middle Mountain	1,720.77	6.38%	1,423.66	142.37
Siwalik	7,600.91	28.18%	6,288.51	628.85
Tarai	13,900.08	51.54%	11,500.04	1,150.00
Total Loss	**26,970.59**	**100.00%**	**22,313.75**	**2,231.38**

Table 13: Activity Data on Forest Loss Area - Emissions from deforestation

Physiographic Region	**Gain area >2.25ha, 2000-2010 (map area, ha)**	**% of Total gain** *(Physio Region loss / Total loss)*	**Bias Corrected Area** *(% Total gain * Total bias corrected area)*	**Annual Gain in ha – bias corrected** *(Bias Corrected Area / 10)*
High Himal	494.60	2.55%	346.79	34.68
High Mountain	4,064.22	20.96%	2,849.62	284.96
Middle Mountain	7,923.92	40.86%	5,555.84	555.58
Siwalik	2,739.93	14.13%	1,921.09	192.11
Tarai	4,171.74	21.51%	2,925.00	292.50
Total Gain	**19,394.41**	**100.00%**	**13,598.34**	**1,359.83**

Table 14: Activity Data on Forest Gain Area - Removals from afforestation

Emission and removal factors applied for deforestation and afforestation respectively are presented in Tables 15 and 16. 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 15) by 20. Accordingly to determine growth during the FRL period (the values in the first column of Table 16), 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 15).

Physiographic Region	AGB (t DM/ha) (DFRS2015)	Root-shoot ratio (DFRS/NFI,2014)	BGB (tDM/ha)	Carbon fraction (Table 4.3 IPCC 2006 - Tropical/all)	Total biomass (tC/ha)	Conversion factor (C > CO_2)	Emissions per ha (tCO_2e/ha)
High Himal	271.46	0.25	67.87	0.47	159.48	3.67	584.77
High Mountain	271.46	0.25	67.87	0.47	159.48	3.67	584.77
Middle Mountain	143.26	0.25	35.82	0.47	84.17	3.67	308.61
Siwalik	172.21	0.25	43.05	0.47	101.17	3.67	370.97
Tarai	190.02	0.25	47.51	0.47	111.64	3.67	409.33

Table 15: Emission Factors – Deforestation

Region	AGB (t DM/ha) (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	74.65	0.25	18.66	0.47	43.86	3.67	160.81
High Mountain	74.65	0.25	18.66	0.47	43.86	3.67	160.81
Middle Mountain	39.40	0.25	9.85	0.47	23.15	3.67	84.87
Siwalik	47.36	0.25	11.84	0.47	27.82	3.67	102.02
Tarai	52.26	0.25	13.06	0.47	30.70	3.67	112.57

Table 16: Removal Factors - Afforestation

The annual carbon dioxide emission and removals due to deforestation and afforestation are presented in Table 17. The table shows that total emissions due to deforestation was estimated at 929,325 tCO_2e and removals of 151,077 tCO_2e due to afforestation. The highest emissions were found in the Terai region (i.e. 470,737 tCO_2e) whilst the Middle Mountain contributed highest removals (i.e. 47,151 tCO_2e).

Physiographic Region	Annual emissions from deforestation (2000-2010)- tCO_2e	Annual removals from afforestation (2000-2010) - tCO_2e
High Himal	18,504.93	5,576.75
High Mountain	162,864.05	45,825.20
Middle Mountain	43,934.85	47,150.50
Siwalik	233,284.23	19,598.33
Tarai	470,736.67	32,925.92
Nepal	**929,324.73**	**151,076.71**

Table 17: Annual CO_2e (t) Emissions and Removals due to Deforestation and Afforestation

6 FOREST DEGRADATION

6.1 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 fuelwood harvesting 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 specifically 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 14) 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 used 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.

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 12 provides an overview of thetwo main phases of analysis of the WISDOM methodology:

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 of the local deficit being satisfied through the 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[4].

For each scenario, the level of woody biomass extraction in each location is compared against the re-growth capacity of the harvested area (approximated with a function of the empirical relation between biomass stock and mean annual increment) to determine whether the regeneration capacity was exceeded

(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] See Table 22 further below for the full list of data variants and alternative assumptions considered. Table 22 presents also the specific set of variants and assumptions that form the Leading Scenario.

or not. In the analysis of woodfuel harvesting sustainability, the recovery is assumed to happen where the harvesting is less than the estimated re-growth capacity. The degradation is generated where harvesting exceeds the re-growth capacity, and the quantity of degradation is estimated as the harvesting portion in excess of the re-growth capacity

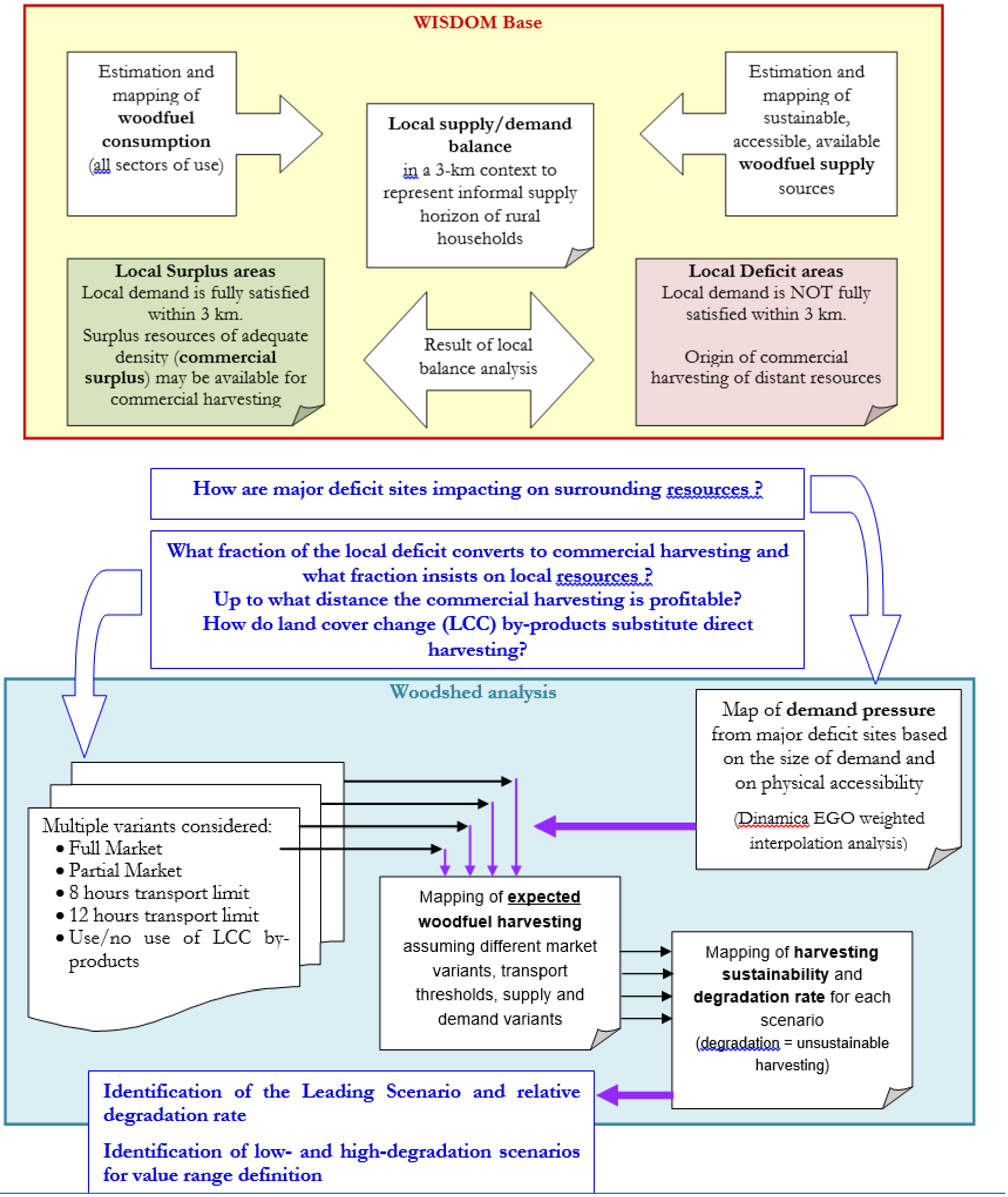


Figure 12: Overview of the phases of analysis in WISDOM

Uncertainty assessment

The WISDOM model provides an indirect estimation of degradation due to unsustainable woodfuel harvesting. This indirect approach is chosen because a direct estimation of forest degradation is at present not feasible.

Given the large number of data sources used in the analysis (most of which are without statistical parameters) a conventional calculation of the confidence interval of the final degradation value is not possible. However, a sensitivity analysis of the model was done by use of numerous data variants and alternative assumptions. This allowed for estimation of the annual degradation of forests according to three main scenarios:

- the Leading Scenario, based on most probable/realistic variants and assumptions, which forms the basis of the FRL (i.e. 227kt DM yr^{-1});
- the low-degradation scenario, based on most favorable variants and assumptions (i.e. 46.5 kt DM yr^{-1});
- the high-degradation scenario, based on the least favorable variants and assumptions (i.e. 714 kt DM yr^{-1}).

The range of values between the low-degradation and the high-degradation scenarios may be considered as a sort of confidence interval around the estimate of the Leading Scenario

The analysis is fully documented in the Annex "Update and upgrade of WISDOM Nepal", to which we refer for all details concerning sources and analytical steps and has been uploaded as online document. To be noted that in the original analysis woody biomass was measured in air-dry (ad) weight, while in this report we use dry matter (DM). The conversion from air-dry to dry matter was done applying a factor of 0.91, as indicated in the documentation of the National Forest Inventory of Nepal (DFRS 2015).

List of Definitions, data sources and assumptions

<u>Main definitions</u>

Woodfuel	Defined as in FAO /Unified Bioenergy Terminology (UBET, FAO, 2004): 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, FAO, 2004)
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 metric tons DM. Air-dry (ad) metric 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 fuelwood to 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 by products (LCC bp) : Woody by-products of forest change processes. In case of forest loss (i.e. deforestation) the by-product corresponds to the stock of the forest while in case of forest gain (afforestation) the by-product corresponds to the mean annual increment. 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. The FRF area here considered in the presentation of results is the bias-corrected area of Stable Forest reported in Table 7, Section 3.3.

Note: For other important terms, such as *forest, deforestation, degradation, afforestation / reforestation*, etc., see the definitions provided in Section 2.2 and 2.3.

Data sources:

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; Forest Type map (DFRS 2015).Forest remaining as Forest (2000-2010)

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.

Industrial roundwood production: Nepal Foresters' Association for REDD Nepal, 2012

Main assumptions

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 Relation with previous estimates:

It should be noted that Nepal's Second National Communication report[5] to the UNFCCC, which included preliminary estimates of fuelwood demand and supply potential, used previous references (primarily, NFI 1994 for supply; MPFS 1989 projections and WECS 2001-2011for demand, as reported in the Second Nat. Comm. report, pg. 40-42). All data and references used for this analysis are more recent, as listed above, and in general more detailed and reliable than those used for the Second National Communication. A comparative evaluation with previous studies in terms of data sets, methodology used and estimates of supply and demand are given in Annex - 7.

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

In addition, this analysis included the spatial dimension of fuelwood demand and supply. In assessing and mapping woodfuel consumption, for instance, the WISDOM analysis considered the regional variations as reported by Census 2011 and by CBS NLSS 2010. WECS statistics were reviewed and discussed with responsible WECS Officers and many other references concerning per capita consumption and sectors of use were integrated. The new consumption estimates are spatially explicit, and are considered more up-to-date and accurate than previous national level WECS statistics.

All these factors mean that the estimates produced in this study are not directly comparable with those of the Second National Communication.

6.1.4 **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 was 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 18 while the geographic distribution of fuelwood consumption in all sectors combined is shown in Table 19. 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 stem wood 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 previous WISDOM	**259**
Other sectors:		
Industrial sector	(WECS 2013)	**385**
Commercial Sector	(WECS 2013)	**390**
Total consumption		**10,078**

Table 18: Summary of annual fuelwood consumption in the various sectors in 2010-2011

	Total consumption (conventional + marginal)	Conventional consumption (excluding marginal)
Physiographic Zone	kt DM	kt DM
High Himalaya	32.43	26.60
High Mountains	1,123.51	1,121.30
Mid Mountains	4,765.88	4,537.01
Siwaliks	1,076.29	1,049.75
Terai	3,080.43	2,525.77
Nepal	**10,078.55**	**9,260.43**

Table 19: Fuelwood consumption by Physiographic zone. (Distinction is made between conventional fuelwood and marginal fuelwood.)

6.1.5 **Removals - sustainable supply potential**

The stock of Dendroenergy Biomass[6] (DEB) 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.

[6] The Dendro Energy 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.

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 (Drigo et al. 2014; Bailis et al., 2015). See Box 1 for a comparison of the MAI applied in this study and IPCC default MAI values.

The annual fuelwood harvesting in a given area is considered <u>sustainable</u> if it's less than, or equal to, the DEB MAI of such area, while the harvesting fraction that exceeds DEB MAI is considered <u>unsustainable</u>. The quantity of unsustainable harvesting corresponds to the annual forest biomass loss (or quantity of biomass that cannot be regenerated by normal re-growth capacity) and represents the degradation due to excessive fuelwood harvesting.

As mentioned, the total DEB MAI is not considered accessible and available for fuelwood extraction. Hence, physical and legal accessibility factors were used to estimate the accessible DEB MAI and competing uses of industrial roundwood production were deducted to estimate the available DEB MAI as described below:

Accessible DEB MAI: In order to assess the physical accessibility of woody resources, a detailed map of transport time to the nearest accessible feature(roads, track and footpath; settlement) was created combining topographic features (roads, tracks and footpaths; settlements), slope and altitude, and friction parameters associated to land use classes. The legal accessibility was estimated and mapped using protected areas and access rights for subsistence and commercial fuelwood harvesting. As summarized in Table 20, the physically and legally accessible DEB MAI amounts to 17.5 million tons DM, representing 76.3% of the total DEB MAI. Of the 23.7% inaccessible DEB MAI, 17.2% is due to physical conditions and 6.5% to legal conditions.

Available DEB MAI: The industrial roundwood production represents the main competing use of woody biomass. Its annual production is estimated to be 2,086 kt DM, including timber, poles, posts and construction material (Nepal Foresters' Association for REDD Nepal, 2012). Since part of the construction material used for rural fences and small house repairs is already included as a component of the rural household demand (see Table 18) the corresponding amount is subtracted from the total

[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.

roundwood production in order to avoid double counting. Hence, the competing uses are estimated to be 1,827 kt DM. This quantity was then deducted from the total accessible supply potential in order to estimate the annual sustainable supply potential that is accessible and potentially available as fuelwood or construction material for rural households. The accessible and available resources are estimated to be 15.7 million tons DM, as shown in Table 20.

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 theoretical 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	Total DEB MAI	DEB MAI Physically and Legally Accessible	DEB MAI Accessible & Available
Physiographic Zone	kt DM	kt DM yr^{-1}	kt DM yr^{-1}	kt DM yr^{-1}
High Himalaya	58,449.39	1,059.42	121.49	114.89
High Mountains	529,760.05	7,700.59	4,420.67	4,112.17
Mid Mountains	289,816.25	7,569.21	7,456.61	6,713.24
Siwaliks	209,976.95	4,169.56	3,301.21	2,872.49
Terai	83,901.36	2,450.69	2,219.24	1,879.45
Nepal	**1,171,904.01**	**22,949.48**	**17,519.22**	**15,692.24**

Table 20: Summary by Physiographic zone of dendroenergy biomass (DEB) stock, total Mean Annual Increment (DEB MAI), DEB MAI legally and physically accessible and DEB MAI accessible and available for energy uses, according to the Medium supply variant.

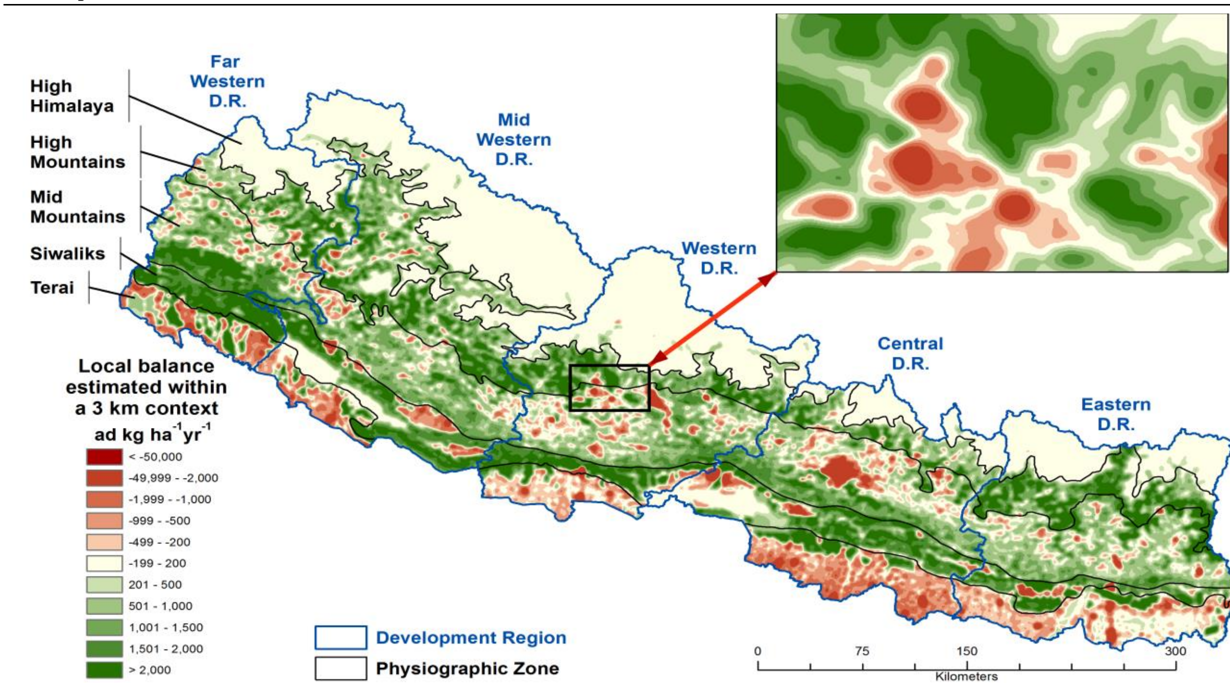
6.1.6 **Net degradation estimate - local deficit and commercial harvesting sustainability**

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 21.

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. Table 22 shows the full range of variants and assumptions considered, as well as those considered as most likely, which form the Leading Scenario.

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	Conventional consumption locally satisfied	Conventional consumption NOT satisfied by local resources (Local deficit)
	kt DM	kt DM	kt DM
High Himalaya	26.60	19.34	7.25
High Mountains	1,121.30	1,060.93	60.37
Mid Mountains	4,537.01	3,628.75	908.25
Siwaliks	1,049.75	706.36	343.39
Terai	2,525.77	1,272.82	1,252.96
Nepal	**9,260.43**	**6,688.20**	**2,572.23**

Table 21: 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. While the indirect assessment of degradation from fuelwood extraction as Nepal proposes for its FRL does not allow for a direct calculation of uncertainty of the estimate. The sensitivity analysis provides an approximation of the estimate's uncertainty by producing a range of values within which we expect the true value of net degradation from fuelwood extraction to be found.

6.1.7 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. With reference to the reconstruction of the emissions from forest degradation, the specific steps of analysis and resulting national-level estimates are summarized in a separate table in order to facilitate the understanding of the analytical process (Annex -8). However, given the spatial approach of analysis, it is not possible to reconstruct the reference level in an excel table through application of simple formulae.

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 land cover change by-products (LCCbp): • **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-bp, which may best represent the most probable situation.

Table 22: Summary of all variants considered and selected variants forming the Leading Scenario

The results of the Leading Scenario are summarized in Table 23 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.

The degradation estimated through this analysis is relative solely to the direct harvesting of woody biomass for fuelwood production, excluding the use of woody biomass available as result of deforestation and afforestation processes since the emissions relative to forest loss and gain are already accounted for (See Chapter 5). Thus, by limiting the degradation only to the amount of fuelwood directly harvested from the forest or from other wooded areas and excluding land cover change by-products (LCC-bp), we specifically avoid double counting.

In order to estimate the quantity of LCC-bp potentially available and to account for their spatial distribution we have derived the average annual area of forest loss and gain from the spatially explicit Land Cover Change Assessment, for 25 sub regions created by intersecting 5 development regions and 5 physiographic zones. As part of Leading Scenario of fuelwood supply-demand, we have estimated that 35% of LCC-bp is used as fuelwood (i.e. half of the potentially available by-products, which is estimated as 70% of the all by-products) and we have excluded such amount from the demand to be met through direct harvesting from forests, other wooded lands and other lands.

The analysis of unsustainable direct harvesting leading to the degradation of forests and other land cover types was hence limited to the fuelwood harvested directly, excluding biomass from LCC-bp. The degradation of Forests (excluding Other Wooded Lands and Other Lands) was then extracted by masking the total unsustainable harvesting with the area of "forest-remaining-forest".

The estimated annual degradation of forests and other land cover, presented in Table 23 is entirely additional to the emissions due to deforestation and afforestation.

	Total Nepal (Including Forest and Non Forest)			**Within Forest-Remaining-Forest area**		
Physiographic	Total area	Total direct harvesting after use of LCC-bp	Total degradation from unsustainable direct harvesting after use of LCC-bp	Bias Correct ed FRF area	Direct harvesting in FRF after use of LCC-bp	Forest degradation from unsustainable direct harvesting after use of LCC-bp
Zone	'000 ha	kt DM yr^{-1}		'000 ha	kt DM yr^{-1}	
High Himalaya	3,538.46	26.93	8.96	172.65	4.41	0.28
High Mountains	3,011.88	1,150.75	54.09	1,919.41	578.59	10.86
Mid Mountains	4,309.35	4,627.71	379.49	2,356.63	2,336.95	148.53
Siwaliks	1,898.24	1,367.95	109.08	1,429.07	924.19	29.81
Terai	2,020.38	1,959.38	456.12	427.25	471.15	37.89
Total Nepal	**14,778.31**	**9,132.72**	**1,007.74**	**6,305.00**	**4,315.28**	**227.37**

Note: According to the Leading scenario, 35% of land cover change by-products (LCCbp) are used as fuelwood.

Table 23: Summary of expected degradation induced by excessive fuelwood harvesting according to the Leading Scenario

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 1,008 kt DM, corresponding to net emissions of **1,811 kt CO_2e/year**[9].

[9] Using a carbon fraction of 0.49 and a conversion factor from C to CO_2 of 44/12 (IPCC 2006)

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 227 kt DM, corresponding to net emissions of **408.5kt CO2e/year**. In order to present estimates in terms of bias corrected FRF area, the final estimates generated using spatial process were normalized with a factor of 1.065 (Bias corrected FRF area [6,302 k ha] / Map Area [5,918 k ha]).

The geographic distribution of the expected degradation is best represented by the map of the degradation risk shown in Figure 14, 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[10].

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.

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).

6.1.8 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 kt DM, or **93 kt CO_2e/year**. When referred to the Forest-Remaining-Forest only, the lowest estimated degradation is 46.5 kt DM, or **80.1 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 kt DM, or **3,516 kt CO_2e/year**. When referred to the Forest-Remaining-Forest only, the highest estimated degradation is 714 kt DM, or **1,230 kt CO_2e/year**.

6.2 Limitations and contributions of WISDOM analysis

Limitations

As discussed in the introduction, this study represents and <u>indirect</u> estimation of forest degradation, or estimation of the risk of degradation, which should be replaced by a <u>direct</u> estimation based on the

[10]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 $ha^{-1}yr^{-1}$.

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 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 (Drigo et al. 2014) 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.

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, continuation of existing patterns of use was assumed. The only reliable data available for these purposes were the NFI 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 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.
- Despite the fact that the country is being restructured into Federal system based on the new constitution passed on 2015, and several development plans for metropolitan and industrial areas, airports, dams etc are under preparation in different states, details of such development plans are not yet finalized and approved, so cannot be considered for the purposes of FRL adjustment.

Therefore, no adjustment for national circumstances has been made in this FRL submission. However, considering the national restructuring process and 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 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. Brief details on emissions and removals from each activity and on the FRL at national level, based on these three activities, are given below. The corresponding values for each activity and the final FRL are presented in Figure-15.

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 factors were used for deforestation and afforestation respectively based on the accuracy assessment of the forest cover change assessment. At national level, the bias-corrected annual deforestation and afforestation areas are estimated at 2,231 ha/year and 1,359 ha/year respectively and physiographic regions are used for emission and removal estimation.

The emission factors on above ground biomass/ha, annual growth/ha, and 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 estimates for physiographic regions, along with tables on activity data and emission factors, are given in Scetion-5. At national level the CO_2eemissions due to deforestation are estimated at 929,325 t CO_2e/year and removals are estimated at 151,077 t CO_2e/year. The emissions from deforestation are 6 times higher than afforestation resulting both from higher deforestation area and also level of biomass/ha lost.

Forest Degradation – Fuelwood extraction

The study has used a spatially explicit approach based on the WISDOM model for estimating carbon emissions due to forest degradation from fuelwood extraction. Information on forest land remaining as forest, other wooded lands and national census information on population are the critical activity data used. Information on above ground biomass, mean annual increment, physical and legal accessibility, fuelwood consumption/year/person and fuel type consumption pattern are considered in the development of emission factors. 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 constitutes mean supply, conventional demand (excluding marginal fuelwood), partial market conditions, 8hrs transport threshold and 35% of demand satisfied through products derived from deforestation or other land use change. Based on the leading scenario, the expected annual degradation of Forest-Remaining-Forest (FRF), i.e. the area that remained under forest cover for the whole reporting period 2000-2010, is 227 kt DM, corresponding to net emissions of 408.5kt CO_2e/year.

Forest Reference Level

Based on the availability of reliable data and approach as described, deforestation, afforestation, and degradation due to fuelwood are considered in the current estimates (Fig-15).The annual emissions and removals due to deforestation and afforestation are estimated at 929,325 t Co_2e and -151,077 tCO2e respectively. It is estimated that the annual degradation due to unsustainable fuelwood extraction in Forest-remaining-Forest (FRF) resulted in emissions of 408,500 t CO2e. **The FRL therefore contains emissions of 929,325 t CO_2e/year for deforestation, emissions of 408,500 t CO_2e/year for degradation and removals of -151,077 tCO_2e/year for enhancement**. The national FRL scenario is bound to change due to emissions/removals from forest enhancement under community forestry, grazing, timber harvest and forest fire based forest degradation. 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.

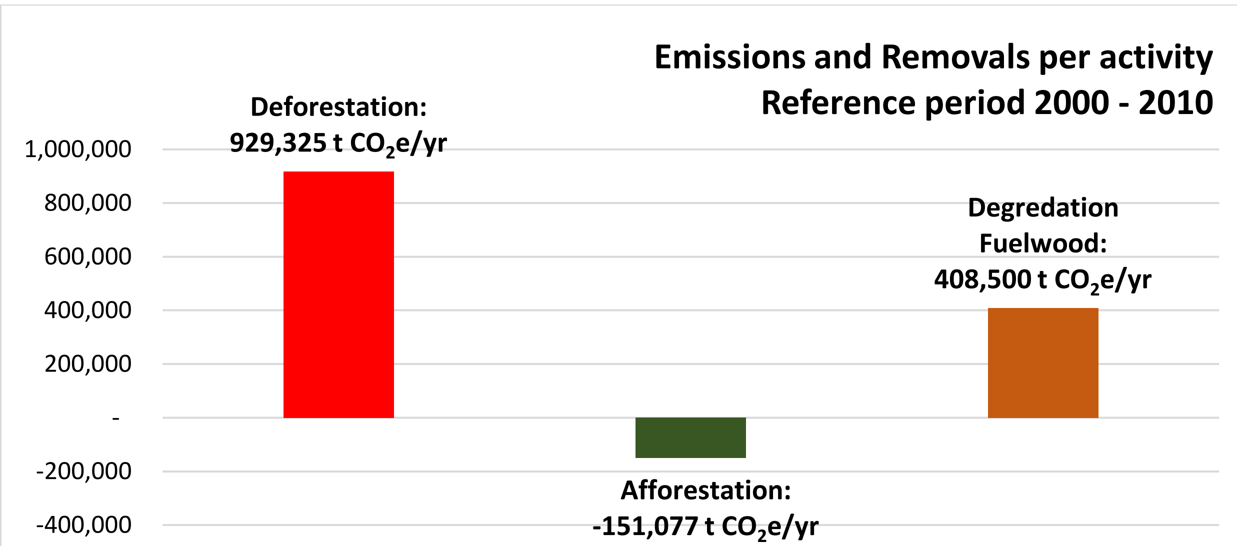


Figure 14: Annual Greenhouse Gas emissions and removals of Nepal (t CO_2e/year)

8.2 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 sufficient to represent the real historical trend of emissions/removals. Taking this into account, Nepal's FRL considered ten years (2000 -2010) as a suitable time frame to capture real historical trends, and as the historical 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 land cover data for 2000 and 2010 prepared under the NASA-SERVIR/ICIMOD collaborative program.
3. Availability of NFI plot-level data to feed into WISDOM model and estimate degradation due to unsustainable fuelwood consumption.

8.3 Updating frequency

In line with UNFCCC decision 12/CP17[11], 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, grazing, 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.

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

9 FUTURE IMPROVEMENTS

Nepal has identified four 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 on 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 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**

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11 ANNEXURES

ANNEX 1: Forest degradation due to grazing

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- 1). Several studies carried out across disturbed and undisturbed areas in different physiographic regions and forests of dominant species including *Shorearobusta*(Sapkota et al 2009, Singh, 2014,Giri and Katzensteiner, 2013),Quercussemicarpifolia (Vettas, 2000; Thakuri,2010),Rhdodendron (Gautam and Watnabe,2005), Pinus (Allard,2000) and *Betulautilis* (Sujaku et al 2013) have reported a significant impact of grazing intensity and practices on regeneration and biomass. 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).

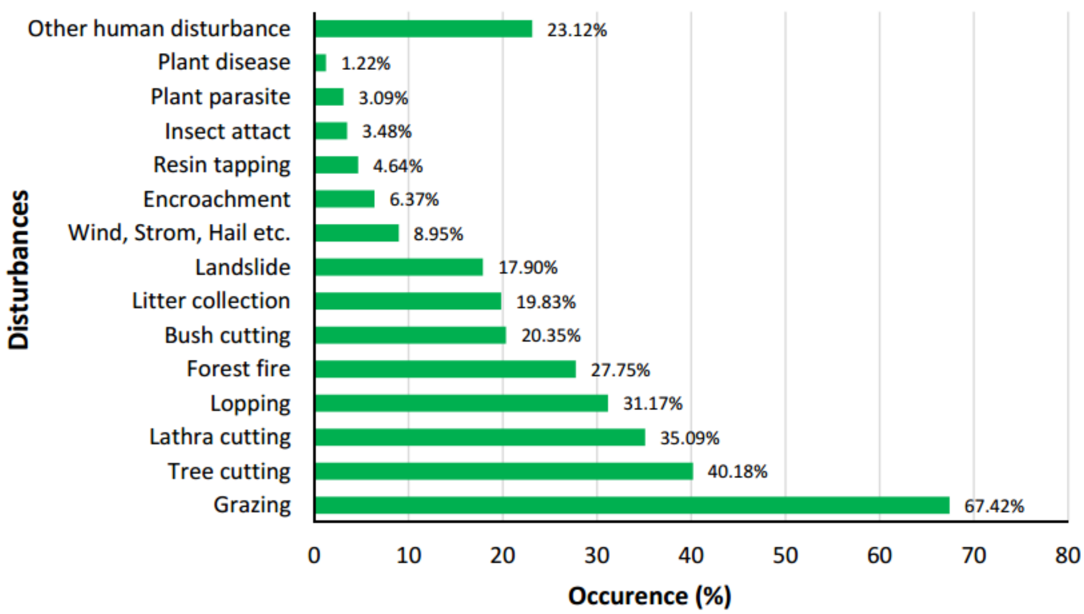


Figure 15: NFI data showing grazing as most occurring forest disturbance – Source NFI report, DFRS 2015

The above figure based on NFI (2014) 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)

Grazing and livestock management is expected to have a two-fold degrading impact on the forest structure and carbon stock : (1) Through direct emissions from forest degradation as a result of biomass extraction from grazing and fodder/feed collection and (2)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. Conversely reducing degradation by grazing and livestock management activities in the forest through improved forest management leads to restoration of forests. In this context, given that the FRL is a benchmark for assessing performance of a country in implementing REDD+ activities, it is therefore deemed important to include grazing as one of the activity in the FRL.

As on date at country level there are no well-defined field measurements on temporal basis to compare and assess different grazing intensities and management regimes on regulation of forest carbon fluxes. Several studies mentioned above on the impact of grazing on forest biomass and role of different management regime in reducing grazing based degradation do not support to make national level estimates. However an attempt has been made to assess the supply demand scenario of grazing resources, its associated impact on forest degradation using available national data on different fodder and grazing resources, livestock data, accessibility functions, feeding habits and 4200 NFI plot level databases on qualitative grazing disturbances and biomass.

The analysis was found difficult due to several assumptions to be made and lack of reliable field measurements. Different spatial statistical approaches were also applied to assess the relationship between qualitative grazing intensities and biomass changes. However the results were not found relevant to submit with more scientific robustness. In view of this, this activity is not included in the current submission due to lack of sufficient information. In the coming years, Nepal would develop scientifically robust field designs and undertake measurements to asses grazing induced forest degradation and impact of different management for restoration of forests through controlled grazing.

ANNEX2: 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 17 shows the increase in forest area managed by CFUGs between 1988 and 2010.

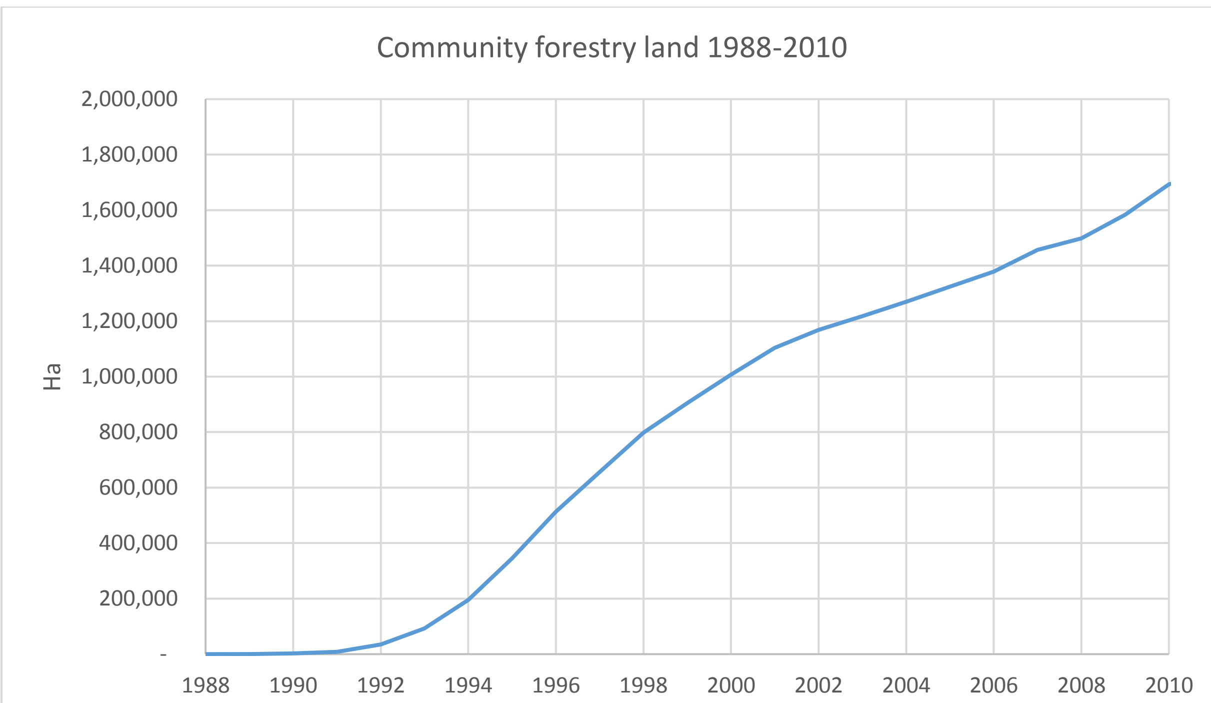


Figure 16: Community Forestry handover information from (Source: DOF CF Division Database 2015)

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.

ANNEX 3: Landsat TM tiles used for Land cover classification of year 2000 and 2010

	Image Acquisition Date	
TM Scenes	**Year 2000**	**Year 2010**
144_39	Oct-01	Oct-10
144_40	Nov-99	Dec-10
143_39	Oct-00	Dec-10
143_40	Dec-01	Dec-10
143_41	Nov-00	Feb-10
142_40	Sep-98	Dec-10
142_41	Sep-98	Dec-10
141_40	Nov-00	Dec-10
141_41	Dec-01	Oct-10
140_41	Nov-99	Oct-09
140_42	Oct-99	Feb-10
139_41	Dec-00	Feb-10
139_42	Feb-00	Dec-10

ANNEX 4: Accuracy assessment error matrix for landcover maps of year 2000 and 2010

Following tables show contingency (error) matrix for accuracy assessment of year 2000 and year 2010 land cover maps:

Class	Forest	Agriculture	Grass	Shrub	Barren area	Built-up area	Water body	Snow and glacier	Total	User's Accuracy (%)
Forest	132	5	1						138	96
Agriculture	18	130	2	1			1		152	86
Grassland	4	2	28		2				36	78
Shrubland	3	3	2	6		1			15	40
Barren area	1		4		33			3	41	80
Built-up area		1				8			9	89
Water body		1			1		13	1	16	81
Snow and glacier			3					40	43	93
Total	158	142	40	7	36	9	14	44	450	
Producer's Accuracy (%)	84	92	70	86	92	89	93	91		

Annex Table 5.1: Accuracy assessment report for landcover map of year 2000

Class	Forest	Agriculture	Grass	Shrub	Barren area	Built-up area	Water body	Snow and glacier	Total	User's Accuracy (%)
Forest	231	15	2						248	93
Agriculture	45	250	3	1	4	1			304	82
Grassland	5	1	42						48	88
Shrubland	3	3		15					21	71
Barren area	1	1			32		1	1	36	89
Built-up area		7				13			20	65
Water body		2	1		4		15	1	23	65
Snow and glacier			1		1		2	46	50	92
Total	285	279	49	16	41	14	18	48	750	
Producer's Accuracy (%)	81	90	86	94	78	93	83	96		

Annex Table 5.2: Accuracy assessment report for landcover map of year 2010

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

Annex Table 5.3: Summary of Accuracy Report for Landcover 2000 and 2010

ANNEX 5: Forest Change accuracy assessment using Open Foris Collect Earth tool

Accuracy Assessment (Response Design)

Agreement of map data and reference data is determined using Response Design as provided by. FAO Open Foris Collect Earth tool. Google Earth high resolution imagery tiles are taken as reference data source and sample data collection was done using *collect earth*, a tool with html based data entry platform that runs on top of Google Earth used to collect sample based reference data.

Sample plots earlier defined as per the sampling design were uploaded into collect earth and considering the minimum mapping unit of change as 2.25 hectare, following labeling protocol were defined for reference data in collect earth software:

Project: Forest change accuracy

Number of sample Points: 5X5

Distance between sample points: 30m

Margin with plot border: 15m

Side of sampling dots: 2m

Sampling window size: 150m X 150m (2.25 hectare)

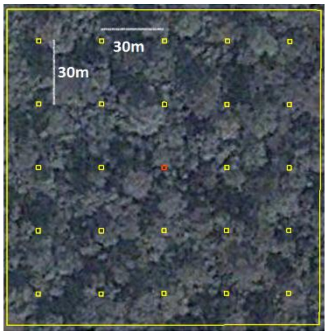


Figure 17: Collect earth plot Design

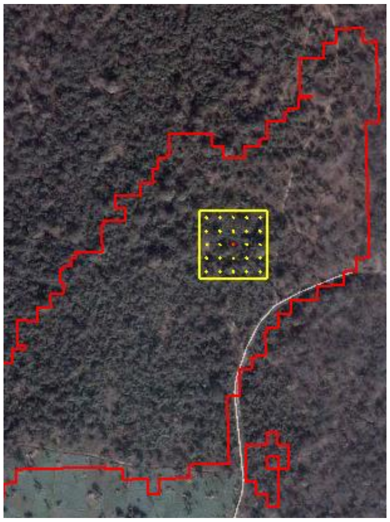
Map and reference class agreement are defined for the minimum unit of 2.25 hectare. Agreement definition mainly refers to the decision on reference class in case of a mixed landuse/landcover situation following the hierarchy threshold criterion from IPCC good practices guidelines.

Location of sample plots, change area (Forest loss and gain polygons) and other supporting documents are available to download at REDD IC Nepal website: http://mofsc-redd.gov.np/?page_id=948.

All 632 plots were verified for change in collect earth. Following figures show the response design and data collection using collect earth:

Reference data collection in Collect Earth

Plot no 233 located at 28°52'42.65"N and 80°29'26.62"E: Shows boundary of forest loss and verification of sample plots conducted in Google Earth using collect earth software



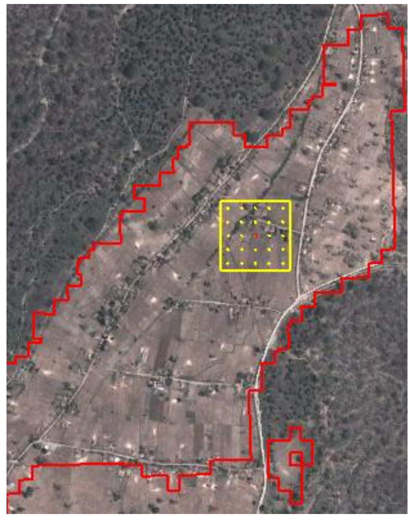
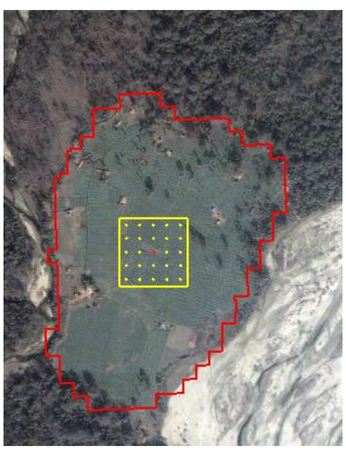
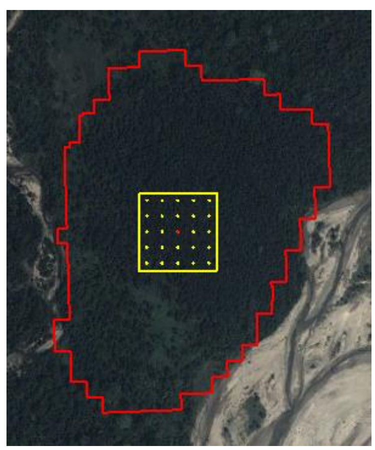


Image date: 1/26/2001 *Image date: 4/8/2011*

This above area has changed from forest in 2000 to Non Forest in 2010

Plot no 255 located at 28°53'20.69"N and 80°27'31.68"E: Shows boundary of forest gain and verification of sample plots conducted in Google Earth using collect earth software





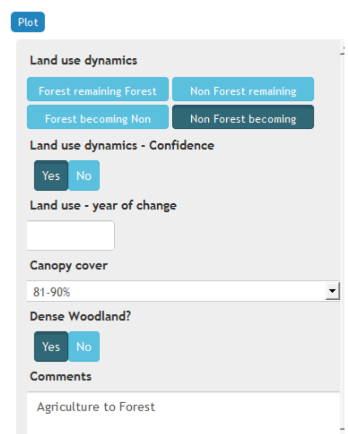
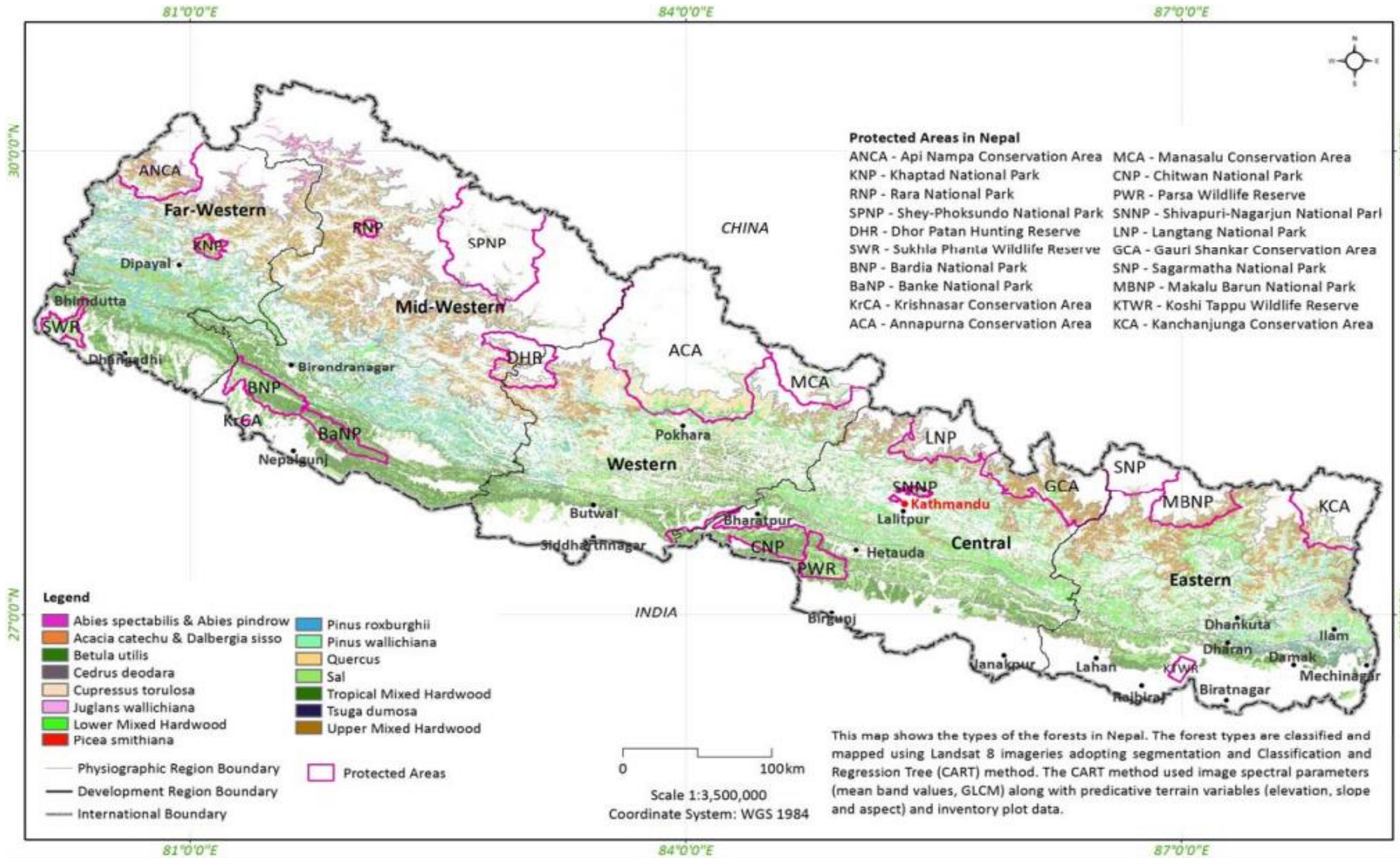


Image date: 1/26/2001 *Image date: 9/27/2012*

Figure 18: Reference data collection in Collect Earth

The above area changed from Non forest in 2000 to Forest in 2010 with canopy cover of 80 to 90%.

ANNEX 6: Forest Type Map of Nepal (Source DFRS Nepal – State of Nepal's Forest)



ANNEX 7: Comparative Assessment of National Level Fuelwood Supply and Demand Estimates

(Units - Kt DM/yr)

S.No	National Assessment	Potential Supply/Increment	Availalble Supply	Fuelwood Consumption	Total Biomass Consumption	Data Source/Remarks
1	WECS,2008/09	NA	12506	20,519		Supply - DFRS/FRISP (1994) Invnetory and MPFS (1988b),Includes CF areas resulting in high supply Demand - Projected estimates based on 1996 energy consumption survey data and population growth rates
2	First SNC,2004	11,280.42	NA	13,167.35	14482.35	Potential Supply - Estimated based on MAI,No Estimates on Accessible Supply Consumption - Based on WECS 2001 with adjustments
3	REDD IC Report,2012	NA	11,353	10,537	NA	Supply - DFRS/FRISP (1994) Invnetory and MPFS (1988b),Pas were totally excluded hence low estimates Consumption - National Living Standards Data-III(2011) and MPFS 1988
4	Second SNC,2014	28,388.70	NA	15,308.00	15,445.72	Supply: Table-3.3 of SNC - Potential Supply - Estimated based on MAI,No Estimates on Accessible Supply Consumption - Based on WECS 2010 reprot with adjustments
5	Current FRL study	22,949	15,692	9260	11087	**Supply - DFRS 2010-15 Forest Inventory** **Consumption - National Living Standards Data-III(2011) and MPFS 1988 with spatial explict process** **FRL further spatially processed this data to assess deficit and degradation using WISDOM model**

Remarks on Supply

NA - data not available

- FRL study has used latest 2015 DFRS Inventory and Land Cover data and generated spatially explicit outcome.
- WECS (2008/09) and REDD IC 2014 assessments are slightly different as REDD IC did not consider total PA areas.
- The available supply by three estimates (WECS,2008;REDD IC 2012; and FRL submission) broadly on same range with differencesowing to inventory periods, samplings designs and input data
- Second SNC did not make Estimates on Available Supply but directly used potential supply (MAI) as available supply.

Remarks on Demand

- FRL study and REDD IC study have used latest NLSS -III data of 2011 data and have close estimates.
- FRL also has used spatial explicit estimate approach using details given in fuelwood demand sub section.

- Differences with Second SNC Demand are largely due to the use of WECS Estimates by Second SNC. The WECS estimates are based on projections using 1996 energy consumption survey and population growth
- Since FRL estimates is recent and spatial explicit approach, based on discussion with WECS, FRL estimates is taken as most representative of the 2010.

ANNEX 8: Data analysis for estimating emissions from forest degradation due to fuelwood harvesting - Analytical steps and outputs

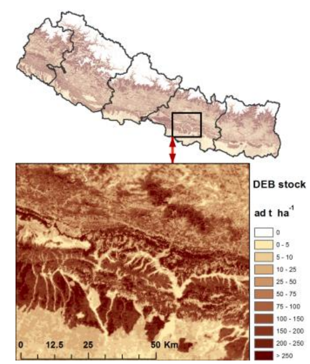
See full documentation in:
Drigo R. 2016. Data analysis for estimating emissions from forest degradation due to fuelwood harvesting in the context of Nepal's Forest Reference Level (FRL). FAO/UN-REDD Programme Targeted Support (UNJP/GLO/386/UNJ) – Nepal.http://www.wisdomprojects.net/global/csdetail.asp?id=30#

The main map products of the estimation procedure leading to the mapping and quantitative estimation of the probable degradation rate are presented in Table 1. The scenario is based on Medium Supply variant, Conventional Demand, Partial Market, 8-hours transport threshold and intermediate use of deforestation by-products, which represents the Leading Scenario.

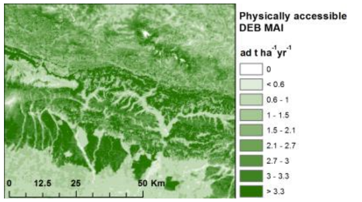
TABLE 1
Map outputs of the main analytical steps leading to the mapping and quantitative estimation of forest degradation rate due to unsustainable woodfuel harvesting.

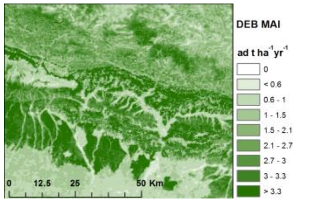
Ref.	Module and data layer Relative to Leading Scenario (pixel size: 1 ha)	National summary value		Map name	Map content and methodology
		Air-dry (ad) weight	Dry Matter (DM) weight		
1	**Supply module data**				
1.1	**DEB stock - Medium variant (mean value)**	1,287, 807 kt ad	1,171,904 kt DM	**stkadkg_md**	Dendroenergy biomass (DEB) stock is estimated using NFI sample plot data for 26 strata and mapped based on Land Cover, Forest Type maps (DFRS 2015) and using Tree Cover % as spatial proxy for distribution within strata.

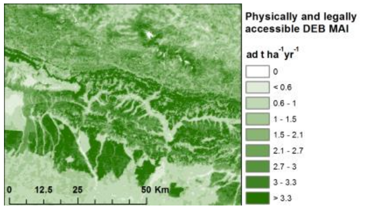
Example of map outputs

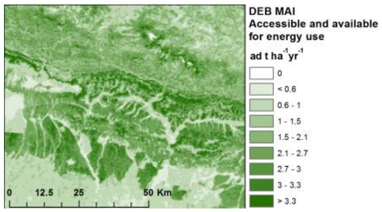


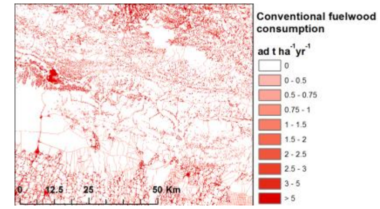
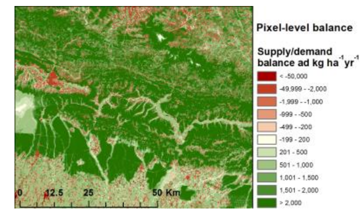
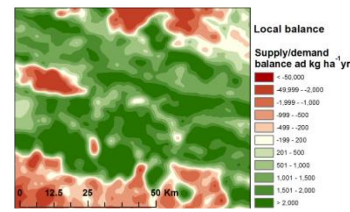
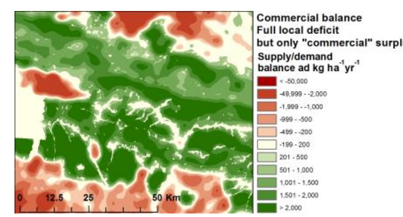
1.2	**DEB MAI - Medium variant**	25,219 kt ad	22,949 kt DM	**mai_md**	The Mean Annual Increment (MAI) is estimated applying stock-MAI equations to the map of stock. Separate equations are used for broadleaves and coniferous formations.
1.3	**Physically accessible DEB MAI– Medium variant**	20,891 kt ad	19,011 kt DM	**phacmai_md**	The physical accessibility of resources from the nearest accessible feature (road, track or settlement) is based on several factors (slope, altitude, friction of land cover types) and cost-distance algorithm. The accessibility, originally estimated in transport time is then converted to percent accessible. The accessibility map is then multiplied to the DEB MAI map to obtain the physically accessible DEB MAI
1.4	**Physically and legally accessible MAI for <u>local consumption</u>**	19,252 kt ad	17,519 kt DM	**acmai_md**	The physically accessible resources are further reduce on account of access restrictions applied in protected areas.
1.5	**Available (and accessible) MAI – Medium variant**	17,244 kt ad	15,692 kt DM	**av2mai_md**	The timber production (based on REDD 2012 report) is deducted from the accessible resources in order to obtain the map of resources potentially available for energy uses.
2	**Demand Module data**				



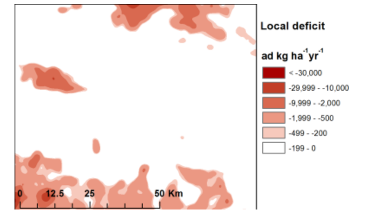


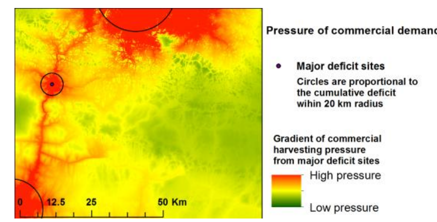


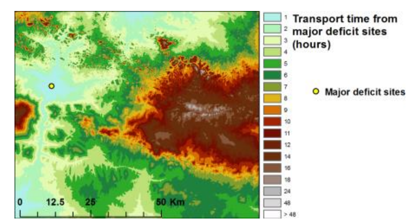


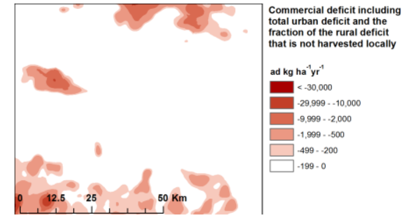
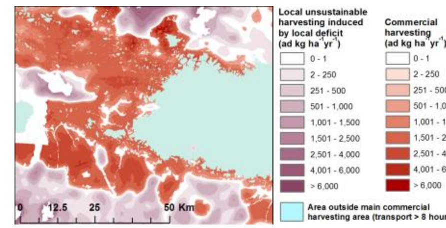
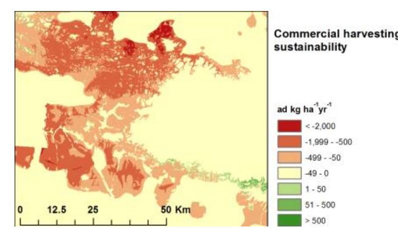
2.1	**"Conventional" Fuelwood consumption Medium variant**	10,176 kt ad	9,260 kt DM	**cons_rev2_md**	This Includes HH, industrial and commercial sectors, cremation wood and construction material. Revised for rural Terai in consideration of probable use of "marginal" fuelwood (twigs and annual pruning of farm trees and shrubs) to fill 1/2 of the gap estimated within a 6km horizon.	
3	**Integration Module data**					
3.1	**Pixel-level balance**	+7,068 kt ad	+6,432 kt DM	**bal22_md**	Simple supply/demand balance calculated pixel-by-pixel as supply potential <minus> revised consumption(excluding marginal woody biomass used in rural Terai)	
3.2	**Local balance assuming a harvesting horizon of 3km**	+7,065 kt ad	+6,429 kt DM	**l_bal22_md**	Supply/demand balance calculated on a 3km harvesting context. This map presents negative values (local deficit areas) and positive values (local surplus areas)	
3.3	**Commercial balance**	+5,429 kt ad	+4,940 kt DM	**combal2_md**	The commercial balance reports the deficit values of the local balance but only the surplus values that may be considered suitable for commercial fuelwood harvesting (commercial surplus), as discussed in Section 2.4.3 above.	

3.4	**Local deficit**	- 2,830 kt ad	-2,575 kt DM	**l_def22_md**	Map of local deficit areas
4	**Commercial demand pressure from major deficit sites**				
4.1	**Peak deficit locations**	n.a.	n.a.	**pnts_defsum20km_md.shp**	Point map with cumulative deficit estimated on a 20 km radius. 26 major deficit sites are identified.
4.2	**Map representing the pressure of the commercial demand onto the landscape**	n.a.	n.a.	**wcd_def2_md**	Interpolation map for each individual deficit site using the deficit value associated to the point as starting value and the friction map as weighting factor. The 26 maps are then added up to form the cumulative "pressure" map determined by the intensity and location of the major deficit areas.
5	**Travel time from major deficit sites**				
5.1	**Transport time from major deficit sites** (minutes)	n.a.	n.a.	**time_wcd2_pnt (minutes)**	Map showing transport time (going and back) from/to the nearest deficit site considering along-road and off-road transport components. This map is used to delimit the commercial harvesting zone (8 hours for the Leading Scenario).
6	**Commercial woodsheds and estimation of harvesting intensity**				

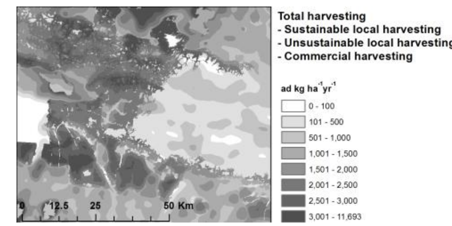


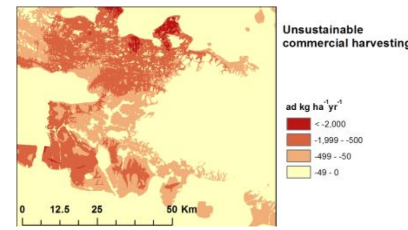


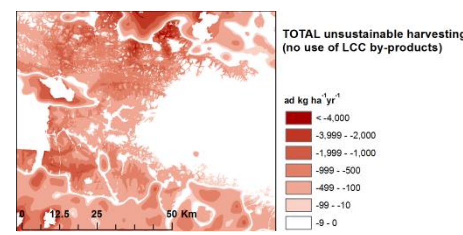


6.1	**Commercial deficit**	- 1,868 kt ad	-1,700 kt DM	**c_def22_md_8h**	Commercial deficit including total urban deficit and the fraction of the rural deficit within 8 hours (transport time) from major deficit sites that is not harvested locally.	
6.2	**Commercial harvesting by pixel**	1,868 kt ad	1,700 kt DM	**ch22_md_8hpm**	This map represents the expected distribution of commercial harvesting. The total is equal to that of the commercial deficit above but the spatial distribution is completely different, depending on the estimated harvesting pressure and on the availability of commercial surplus resources.	
6.3	**Rural and minor urban deficit generating unsustainable local harvesting**	- 962 kt ad	-875 kt DM	**lh_22md_8h**	According to the Partial Market scenario, 1/2 of the local rural deficit (within the 8hr zone) remains on site as unsustainable local harvesting (up to a maximum of 30% of the local stock), while the rest of the deficit generates commercial harvesting. Outside the 8hr zone, the deficit remains entirely on site as unsustainable harvesting	
6.4	**Commercial harvesting sustainability**	n.a.	n.a.	**chs22md8h80pm**	Commercial harvesting sustainability assuming a management factor called Sustainable Increment Exploitation Factor (SIEF, here assumed 0.8). It is calculated pixel-by-pixel, by subtracting the expected harvesting from the commercial surplus * SIEF	

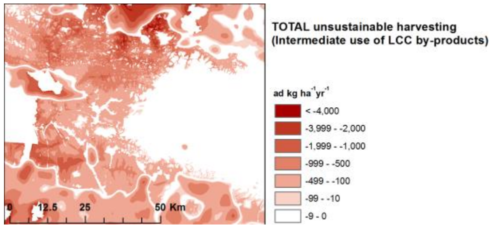
6.5	**Total harvesting**	10,181 kt ad	9,265 kt DM	**h_22md8h**	Total harvesting, including: • sustainable local harvesting (sus_l_h_r2md) • Rural and minor urban deficit generating unsustainable local harvesting (lh_22md_8h) • Commercial harvesting (ch22_md_8hpm)
6.6	**Unsustainable commercial harvesting**	-177 kt ad	161 kt DM	**nrch22md8h80p**	Non-Renewable commercial harvesting within 8 hrs from major deficit sites assuming a SIEF of 0.8 This map includes only the unsustainable fraction of commercial fuelwood harvesting (i.e. negative values of map chs22md8h80pm
7	**Unsustainable harvesting and Degradation rate – Assuming no use of LCC by-products**				
7.1	**TOTAL unsustainable harvesting (no use of LCC by-products) All land cover classes**	**1,140 ad kt**	**1,038 kt DM**	**tnrh22md8h80p**	TOTAL Non-renewable harvesting merging unsustainable local harvesting (lh_2md_8h) and unsustainable commercial harvesting (nrch2md8h80p). NO USEW of LCC by-products is here assumed. This value refer to all DEB resources, including Forests, Other Wooded Lands and Other Lands
8	**Unsustainable harvesting and Degradation rate – Intermediate use of LCC by-products - LEADING SCENARIO**				

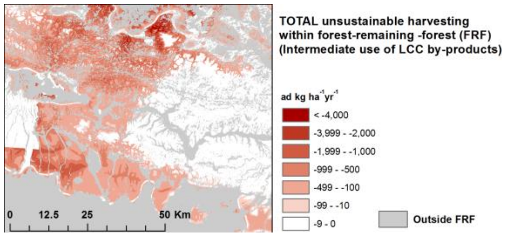






8.1	**TOTAL degradation in all land cover classes due to unsustainable harvesting Assuming intermediate use of LCC by-products (Leading Scenario)**	**1,107 kt ad**	**1,008 kt DM**	**tnrh22md8h_r1**	Procedure of analysis: 1. Estimation of available LCC byproducts by sub-region 2. Estimation and mapping of reduced direct harvesting, deducting the amount replaced by LCC by-products: reduced local harvesting and commercial harvesting. 3. Mapping of the unsustainable fraction of reduced direct harvesting
8.2	**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) due to unsustainable fuelwood harvesting (Leading Scenario)**	**250 ktad yr^{-1}**	**227 kt DM yr^{-1}**	**tnrh22md8h_r1 (masked for mapped FRF area and adjusted for bias-corrected FRF area)**	**Estimation and mapping of the unsustainable fraction of direct harvesting taking place within forest-remaining-forest (FRF) areas. This is obtained through masking of map tnrh22md8h_r1 for FRF (assigning 0 value to all non-FRF map areas). In addition, in order to present estimates in terms of bias corrected FRF area, the final estimates generated using spatial process were normalized with a factor of 1.065 (Bias corrected FRF area [6,302 k ha] / Mapped FRF Area [5,918 k ha]).**
8.3	**Expected annual net CO_2 emission from degradation of the Forest-remaining-Forest due to unsustainable fuelwood harvesting (Leading Scenario) '000 Tonnes of CO_2 e/year**		**408.5kt CO_2 e yr^{-1}**		





ANNEX 9: Highlights of key policies and measures guiding this FRL document

SN	Policy documents and their relevance to REDD+ in Nepal
	• **Constitution of Nepal 2015**: prioritizes on environmental and social safeguards to its citizens. Recognizes emissions reduction and carbon enhancement function of forest resources as an environmental service.
1	• **The Climate Change Policy 2011**: specifically mentions REDD+, addresses climate change mitigation and adaptation issues.
2	• **National Biodiversity Strategy Action Plan (NBSAB)** 2014: focuses on the promotion and harmonization of Aichi targets for biodiversity conservation with REDD+ safeguards.
3	• **Forest Encroachment Control Strategy 2012**: strongly emphasizes on the expansion of forest cover and restoration of illegally occupied forests.
4	• **National Forestry Sector Strategy 2015**: aims establishing forest carbon trade or payment mechanisms by linking forests, biodiversity and watershed conservation and management
5	• **Forest Encroachment Control Strategy 2012:** strongly emphasizes on the expansion of forest cover and restoration of illegally occupied forests.
6	• **Land Use Policy 2012:** focuses on classification of the land based on their use. It encourages an expansion of forest cover and discourages conversion of forest land and forests into other land use systems.
8	• **Rangeland Policy 2012:** stresses on the need to enhance rangeland, conserve biodiversity and improve livelihoods of the communities dependent on the rangeland resources.
9	• **Investment Board Act 2012:** focuses on the engagement and promotion of private sector in forest management.
10	• **Low Carbon Economic Development Strategy** (yet to be endorsed): identifies forestry sector as one of the six sectors for pursuing a low carbon growth path by adopting climate change mitigation options.
11	• **Subsidy Policy for Renewable Energy 2013 and Rural Energy Policy 2006**: intend to promote technological and institutional support in innovation and production of alternative energy sources which have positive implications on forest resource management.
12	• **Agriculture development Strategy (ADS, 2014)**: recognizes forestry as flagship program to contribute in improved crop production and productivity of the land.
13	• **Forest Act 1993 and Regulation 1995**: ensure a bundle of rights to the local communities for protection, development, management and use of forest products under community based management of forests.