Ministry of Forests and Soil Conservation
REDD-Forestry and Climate Change Cell

Development of a REDD+ Forest Reference Level in Nepal

Methodological Steps and Presentation of the Forest Reference Level

Contract No: FCPF/REDD/S/QCBS-9



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camco clean energy

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ACRONYMS AND ABBREVIATIONS

A/R	Afforestation/Reforestation
AD	Activity Data
ANSAB	Asia Network for Sustainable Agriculture and Bioresources
CDM	Clean Development Mechanism
CH_4	Methane
CO_2	Carbon Dioxide
COP	Conference of the Parties
d.m.	Dry Matter
DFRS	Department of Forest Research and Survey
DoF	Department of Forestry
DTC	Decision Tree Classifier
ENVI	Environment for Visualizing Images
ETM	Enhanced Thematic Mapper
FAO	Food and Agriculture Organization (of the United Nations)
FC	Forest Cover/Fractional Cover
FCPF	Forest Carbon Partnership Facility
FCPF	Forest Carbon Partnership Facility
FECOFUN	Federation of Community Forest Users, Nepal
FRA	Forest Resource Assessment
GDP	Gross Domestic Product
GFOI	Global Forests Observations Initiative
GHG	Green House Gas
GIS	Geographical Information Systems
GOFC-GOLD	Global Observation for Forest Cover and Land Dynamics
GoN	Government of Nepal
GPG LULUCF	(IPCC) Good Practice Guidance for Land Use, Land-Use Change and Forestry
Ha	Hectare
ICIMOD	International Centre for Integrated Mountain Development
IPCC	Intergovernmental Panel on Climate Change
LRMP	Land Resource Mapping Project
LU	Land Use
LUC	Land Use Change
MAI	Mean Annual Increment
MoFSC	Ministry of Forestry and Soil Conservation
MPFS	Master Plan for the Forest Sector
MRV	Monitoring, Reporting and Verification
MSAVI	Modified Soil-adjusted Vegetation Index
N_2O	Nitrous Oxide
NDVI	Normalized Difference Vegetation Index
REDD	Reducing Emissions from Deforestation and (forest) Degradation
REL	Reference Emission Level
RL	Reference Level
ROI	Region Of Interest
R-PP	(REDD) Readiness Preparation Proposal
RS	Remote Sensing
SAVI	Soil Adjusted Vegetation Index
SOC	Soil Organic Carbon
t	tonne
TAL	Terai Arc Landscape
tCO_2	Tonnes of Carbon Dioxide
tCO_{2e}	Tonnes of Carbon Dioxide equivalent
TIPS	Tennessee Information for Public Safety
UNFCCC	United Nations Framework Convention on Climate Change
VI	Vegetation Index
WWF	World Wide Fund for Nature

SUMMARY PAGE

Assignment Title: Development of a REDD+ National Forest Reference Level for Nepal
Objective: To develop a REDD+ Reference Level for Nepal

Approach followed: Step-wise approach for RL development

Scale: National Level
Activities included: Deforestation, Forest Degradation, and Enhancement of Forest Carbon Stocks

Pools included: Above Ground Biomass (AGB), Below Ground Biomass (BGB)
Gases included: Carbon dioxide (CO_2)

Sources of data/information: Remote sensing image analysis (Landsat), IPCC defaults, expert consultation, forest inventory data (FRA, Terai)

Key inputs: National scale activity data (AD), emission factors (EFs)

Approach for estimation of emissions/removals: Average of period 2000 – 2010
- Gross Emissions: AD*EFs
- **Gross Removals:** AD*Incremental data
- **Net Emissions:** Gross Emissions – Gross Removals

Projection: Long term average (10 years)
Financial Support: Forest Carbon Partnership Facility
Beneficiary: Government of Nepal/REDD Forestry and Climate Change Cell
Consultancy Services: Camco Advisory Services (Kenya)

Key results:

Gross Historical Emissions – Deforestation (tCO_2):

Region	2000-2010
Terai	12,188,708
Siwalik	1,274,870
Hills	-
Mid Mountain	-
High Mountain	9,389,287
National	22,852,865

Gross Historical Emissions - Degradation (tCO_2):

Region	2000-2010
Terai	5,522,341
Siwalik	37,995,890
Hills	153,772,344
Mid Mountain	63,289,531
High Mountain	9,798,674
National	270,378,779

Gross Historical Removals - Non Forest to Forest (tCO_2):

Region	2000-2010
Terai	166,911
Siwalik	161,936
Hills	5,773,567
Mid Mountain	2,273,627
High Mountain	-
National	8,376,041

Gross Historical Removals – Enhancement (tCO_2):

Region	2000-2010
Terai	7,392,258
Siwalik	19,804,644
Hills	30,719,030
Mid Mountain	17,930,672
High Mountain	1,741,966
National	77,588,571

Net Historical Emissions (tCO_2):

Region	2000-2010
Terai	10,151,880
Siwalik	19,304,180
Hills	117,279,747
Mid Mountain	43,085,232
High Mountain	17,445,994
National	207,267,033

Average Projection of Emissions - 2010 – 2020 (tCO_2/yr):

Region	Projected Emissions (tCO_2)
Terai	922,898
Siwalik	1,754,925
Hills	10,661,795
Mid Mountain	3,916,839
High Mountain	1,585,999
National	18,842,458

According to Nepal's (REDD+) Readiness Preparation Proposal (R-PP), population growth and forest product and land demands are likely to aggravate deforestation and degradation in the years to come, affecting the livelihoods of a large number of forest-dependent people and Nepal's environmental sustainability (Government of Nepal, 2010). The Government of Nepal is therefore committed to REDD+ through reversing deforestation and forest degradation, conservation of existing forest and enhancing forest carbon stocks, while addressing livelihoods concerns at the same time.

Nepal's REDD+ strategic goals include reversing deforestation and forest degradation, conservation of existing forest and enhancing forest carbon stocks, while addressing livelihoods concerns at the same time.

Direct and Underlying Causes of the Problem
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.

Goal and Objective
The key objective of the assignment is to determine Nepal's Forest Reference Level with the goal of informing the development and implementation of REDD+ policies in Nepal, underpin the credibility of REDD+, and inform assessment of performance of results-based REDD+ activities.

Outcomes
A key outcome of this assignment is a quantification of changes in forest carbon stocks and a projection of future carbon stock trends in Nepal. A secondary outcome is increased capacity within the REDD Cell to understand the implications of REDD+ interventions in terms of carbon emissions/fluxes that enables an informed assessment of the strategic options. Although the historical reference period for Nepal is 2000 – 2010, the data analysis undertaken as part of this assignment also included the period 1990 – 2000. The results from the period 1990 – 2000 are presented in some parts of this report in order to help illustrate trends and highlight where there are either consistencies or inconsistencies with the reference period (2000 – 2010).

Key Results:

The main outputs from this assignment show that:

I. Gross historical emissions from deforestation and forest degradation totalled **132,742,895** tCO_2ebetween 1990 to 2000, increasing to **293,231,645** tCO_2e in the period between 2000 and 2010. The overall trend shows an increase in emissions within the period 1990-2010.
II. In the period 2000 – 2010, forest degradation accounted for more emissions from the forest sector, totaling **279,378,779** tCO_2e, whilst deforestation accounted for only **22,852,865**tCO_2e during the same period.
III. There has been an increase in GHG removals, estimated at **33,608,560** tCO_2ebetween 1990 – 2000, which increased to **85,964,612** tCO_2e between 2000 – 2000.

IV. Going forward to 2020, net emissions are projected to continue in line with the reference period average at **18,842,458** tCO_2e / year,with deforestation accounting for **2,077,533** tCO_2e / yearwhile forest degradation will account for **24,579,889** tCO_2e / year. During the same period, enhancement of forest carbon stocks is predicted to result in the removal of **7,814,964**tCO_2e / year based on a continuation of the average removals achieved during the period 2000 - 2010.

Recommendations for updating Nepal's reference level

The RL presented was developed following the stepwise approach, which allows the use of available data (even if uncertain) to provide a starting point for RL establishment with simple projections, based on historical data (Step 1), progressively updating the RL based on more robust national datasets for country-appropriate extrapolations and adjustments (Step 2) and ultimately basing the RL on more spatially explicit activity data and driver-specific information support (Step 3). To assist this progression from Step 1 to Step 3, this report recommends:

1) including more historical datasets and pools,
2) including more historical reference data points
3) improving the compilation of activity data through the use of higher resolution data and ground truthing, and mapping of community forests,
4) improving collection of more robust drivers data,
5) develop better EFs through improved forest inventory data (spatially linked, permanent sampling, consistent, accessible) and obtain incremental data for reforestation and enhance in order to develop more complex growth curves, and
6) focus training on select members of staff in the REDD Cell (through one- to-one training sessions) who would develop the required skills to actually make RL updates when needed

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1 INTRODUCTION

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

Decision 12/CP.171 and its Annex establish the basis for REDD+ forest reference levels/reference emission levels (RLs) and contains guidance on the content of REDD+ RL submissions. This decision also calls for a process to enable the technical assessment of proposed RLs once they have been submitted.

Within the context of the UNFCCC, the reduction of emissions from deforestation and forest degradation, or increase in sequestration through improved forest management or enhancement of forest carbon stocks is measured against forest Reference Levels or forest Reference Emissions Levels (RLs). RLs thus set a performance benchmark for mitigation activities by providing a reference point to which current and actual efforts can be compared throughout a pre-determined timeframe and are strongly linked to measurement, reporting, and verification (MRV) of mitigation efforts.

Nepal therefore welcomes the opportunity to submit a forest reference level (RL) 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 United Nations Framework Convention on Climate Change (UNFCCC).

Nepal underlines that the submission of the RL and subsequent Technical Annexes and Working Papers with results are voluntary and exclusively 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.

The step-wise approach followed in this submission reflects Nepal's national circumstances by enabling the development of a relatively simple forest reference levels that will be improved over time. These levels will be set alongside efforts to improve measurement and monitoring capacities and reduce uncertainties conducted as part of the three REDD+ implementation phases. The RL is constructed following a combination of national scale (using IPCC defaults and other local research findings) and a sub-national approach based on related work through the Forest Resources Assessment Project in the Terai Arc Landscape as well as other initiatives. The development of the RL was undertaken alongside some other related initiatives which provided valuable technical contributions to the implementation of REDD+ in Nepal through enrichment of the methodological approach as well as data sharing. The Government of Nepal through the 5-year Forest Resource Assessment (FRA) Project, the World Wildlife Fund, and Arbonaut Ltd. have made significant investments in extensive ground surveys, aerial LiDAR data collection, and other data collection and analysis in the Terai. Completion of the FRA project will present the first significant opportunity to update the RL. Details of these past and ongoing initiatives are provided in **Working Paper 1** on the *Context, Background and Methodological Approach* to developing the RL.

1.2 Area covered by this reference level

The approach adopted in creating an updated land cover map was to generate an estimate of RL at national scale. The land cover maps (for the defined time points) generated for development of this RL are wall-to-wall and therefore the approach is consistent for the entire country. The RL presented here therefore relates to the entire forest land contained within the borders of Nepal, comprising the five physiographic regions: Terai, Siwaliks, Hills, Middle Mountain and High Mountain. The RL has been calculated following the step-wise approach, where spatially explicitly data has been used to construct the subnational RL for Terai while IPCC default values have been used for the rest of the country.

This submission of the forest reference level focuses only on net CO_2 emissions and removals and includes emissions from the above and below-ground biomass carbon pools. Sections 2.3 - 2.5 in this submission (Pools, gases and activities included in the construction of the forest reference level) provide more detailed information regarding activities, carbon pools and gases.

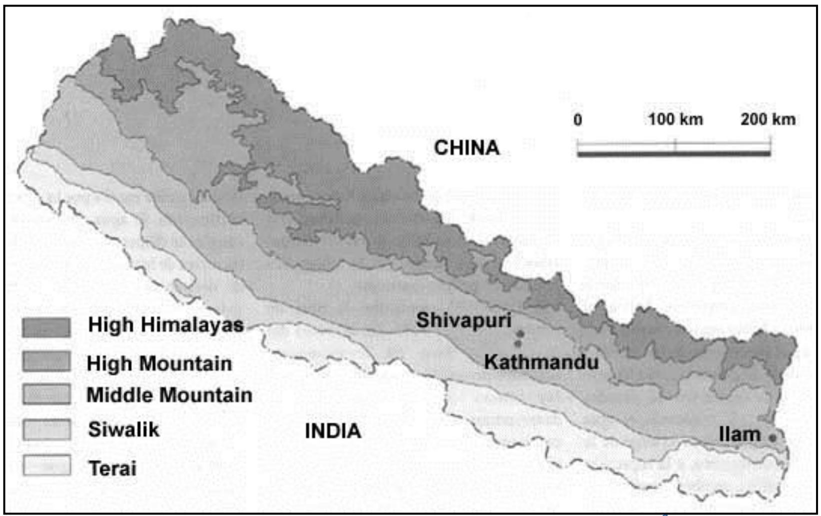

Figure 1: Physiographic regions of Nepal (Source: fao.org[1])

1.3 Sources of information and steps in constructing the reference level

Pursuant to the guidelines for submission of information on reference levels as contained in the Annex to Decision 12/CP.17, this submission includes a) Information that was used in constructing a forest reference level; b) Transparent, complete, consistent, and accurate information, including methodological information used at the time of construction of forest reference levels; c) Pools and gases, and activities which have been included in forest reference emission level; and d) The definition of forest used.

1.3.1 Sources of information

The construction of the forest reference level for reducing emissions from deforestation and forest degradation and quantification of emissions 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 RL was constructed based on remote sensing approach, which has been complemented with statistical data relating to timber/roundwood and fuelwood extraction, and forest fires.

Besides emissions from deforestation, the RL includes an estimate of emissions from forest degradation (from various sources) as well as emissions removals resulting from forest enhancement. Time series Landsat images were used to quantify deforestation, forest degradation, enhancement and forest conservation.

[1] http://www.fao.org/countryprofiles/maps/map/en/?iso3=NPL&mapID=609

The REDD+ forest Reference Level presented is informed by the "FCPF Methodological Framework for Developing Reference Levels" while applying key UNFCCC/IPCC principles and guidance for estimating emissions and removals of greenhouse gases from anthropogenic origin.

Land use/ land cover change analysis was used as a tool to generate Activity Data for deforestation, forest degradation and enhancement of forest carbon stocks (2000 – 2010) employing a Land Use Transition matrix. These are presented for each of Nepal's five physiographic regions of Terai, Siwaliks, Hills, Mid Mountain and High Mountain. From the change analysis matrices, Activity Data for the change period were flagged out and presented in a table, separately in the form of MS Excel spreadsheets.

Emissions/removals resulting from land-use conversion are presented consistent with the IPCC Guidelines in units of metric tons of carbon dioxide per hectare (tCO_2 ha^{-1}), to express carbon-stock-changes for deforestation, enhancement and forest degradation. The development of emission/removal factors was undertaken following two major steps:

A. Estimating the Carbon stocks in selected pools for each Land Use Category

The starting point for developing Emission and Removal Factors was to establish the carbon stocks for each selected pool in each Land Use Category (and stratum, if possible). The land use categories include forestland, crop land, grassland, wetlands, settlements and other lands (i.e. bare rock, soil, ice, snow, etc.). Carbon stocks in the selected pools (above ground and below-ground biomass) were used to quantify carbon fluxes as a result of transitions between categories. A combination of Tier 1, 2 and 3 approaches were used to come up with emission factors, depending on the availability of data:

1. For Terai, FRA and WWF data generated from work in the TAL were used to calculate the carbon stocks in each land use category.
2. For the Siwaliks, Hills, Mid Mountain and High Mountain, a combination of IPCC defaults and other research data were used estimate the stocks in each LU category. The principal IPCC source documents consulted in preparing this report are:

- IPCC 2000 Good Practice Guidance and Uncertainty Management
- IPCC 2003 Good Practice Guidance for Land Use, Land-Use Change and Forestry (GPG LULUCF)
- IPCC 2006 IPCC Guidelines for National Greenhouse Gas Inventories
- 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol

Other Guidance documents including the "FCPF Decision Support Tool for Integrated REDD+ Accounting Frameworks" and the "GOFC-GOLD sourcebook of methods and procedures for monitoring and reporting anthropogenic greenhouse gas emissions and removals caused by deforestation, gains and losses of carbon stocks in forests remaining forests, and forestation" were also used to the extent that they were consistent with the UNFCCC framework.

Other sources of data for quantifying forest carbon stocks include:

- Forest Resource Assessment Project 2010 -2013 (for Terai Arc Landscape)
- DFRS 1999, Publication No 74.
- Peter Branney and K P Yadav 2008: Community Forest Resource Assessment between 1994-2008 (unpublished)

- Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests by Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Federation of Community Forest Users, Nepal (FECOFUN), International Centre for Integrated Mountain Development (ICIMOD), ISBN: 978-9937-2-2612-7. First edition: July 2010

B. Calculating Emission/Removal Factors

Following the estimation of forest carbon stocks, the next step is to develop Emission/Removal Factors for each detectable transition between the different LU categories. The Emission/Removal Factor for the selected pools for a LU transition from A to B is the difference in the carbon stocks between the two LU categories (i.e. B-A).

With respect to forest enhancement (including AR activities) carbon removals were estimated using the Biomass Gain-Loss Method whereby the annual increase in biomass carbon stock was estimated following Volume 4 of the IPCC Guidelines for GHG Assessment using Equation 2.9 of the IPCC Guidelines on AFOLU, where the area under each forest sub-category is multiplied by the mean annual increment in tonnes of dry matter per hectare per year. Below-ground biomass was estimated using appropriate nationally specific expansion factors derived from report by ANSAB on Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests (2010).

1.4 Compliance with the principles of RL development: Transparent, complete, consistent and accurate information used in the construction of the forest reference level

1.4.1 Complete information

Complete information for developing the forest reference level for each of the three time points for which emissions/removals have been estimated is provided including:

i. All the satellite images used for 1990, 2000 and 2010 to map deforestation, forest degradation and enhancement of forest carbon stocks;
ii. Forest cover changes through the use of change matrices for the three time points;
iii. Default values used;
iv. The calculation of emission/removal factors for each of the physiographic regions.

The information is provided in form of GIS/Remote Sensing data and excels files in the custody of the Nepal REDD and Climate Change Cell and which will be made available through a yet-to-be established data sharing platform. A detailed explanation of the analysis of land cover and forest cover change is provided in section 3.1.

1.4.2 Transparent information

A detailed explanation of all assumptions, data sources, equations, land cover/forest cover change analysis methodological approach and tools, default equations and derivation of emission/removal factors is provided with each relevant product.

1.4.3 Consistency

Paragraph 8 in Decision 12/CP.17 requires that the forest reference levels shall maintain consistency with anthropogenic forest related greenhouse gas emissions by sources and removals by sinks as contained in the country's national greenhouse gas inventory. The 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 activity data as well as the assessment of deforestation for the purposes of this submission rely on the use of remotely sensed data of similar spatial resolution (Landsat-class, up to 30 meters).

1.4.4 ***Accuracy***

Following the post-classification operations described in section 3.1, the land cover /land-use maps of 1990, 2000 and 2010 were assessed of their respective accuracy and/or suitability for use in other subsequent tasks in the process of developing national reference scenario for Nepal. The accuracy assessment was carried out both qualitatively and quantitatively.

- Qualitatively, the products have been compared with existing maps/spatial data. This check forms a general control on the spatial distribution and class labels of the maps.
- Quantitatively, available reference data (including biomass-plot data over Terai sourced from FRA Project; sample data across the whole country sourced from FRA Project; and data over Terai Arc landscape sourced from WWF) was used to evaluate the accuracy of the land cover maps.

With respect to the quantitative accuracy assessment, confidence intervals were constructed for the key accuracy measures as an indicator of accuracy estimates.

For the purpose of the accuracy assessment of ICIMOD generated land cover map (2010), the available FRA dataset was used as a reference, since it had been prepared using very high resolution satellite images (Rapid Eye) and complimented by extensive field survey. This dataset was a land cover map showing the distribution of the three major land cover types, namely forest, other wooded land, and non-forest as well as ground-based reference data. Subsequent accuracy assessment followed three approaches described below with their respective results. The fourth approach used the WWF field survey data as the reference data. Quality assessment of the 2000 land cover map was accomplished in two ways. First, the forest extent estimated by the RL Team was compared with the forest mask defined in the Topographic Base Maps of 1998. The second approach entailed comparing the forest extent in High Mountain Regions of Nepal estimated by the RL Team against those corresponding estimates recorded in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012". Quality assessment of the 2000 land cover map was accomplished in two ways. First, the forest extent estimated by the RL Team was compared with the forest mask defined in the Topographic Base Maps of 1998. The second approach entailed comparing the forest extent in High Mountain Regions of Nepal estimated by the RL Team against those corresponding estimates recorded in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012". FRA inventory-plots data (spread across the country) was also used as reference data, in particular the 1,949 data-plots that had been re-organized.

With respect to 2010 data, comparison of FRA data with ICIMOD data over Terai showed a good correspondence between data generated by ICIMOD and the final map generated by FRA. For Siwalik, the reference dataset provided by FRA was then provisional and therefore not much could be inferred regarding the accuracy of the data. Comparing the ICIMOD dataset with WWF dataset over Terai Arc-Landscape showed that apart from the district of Rautahat where estimates of the two datasets were closely matching (27,667 ha versus 25,659 ha respectively), the estimates for the other districts exhibited great variation between ICIMOD 2010 dataset and WWF dataset by over 25% difference, the former yielding higher estimates than the latter. Using FRA biomass-plot data (over Terai) as reference to assess the accuracy the ICIMOD 2010 data yielded an overall accuracy of about 90% of ICIMOD 2010, with both forest and non-forest yielding high user's and producer's accuracies. However, the accuracies of 'Shrubs' was very poor, perhaps because of the low coverage of this category in Terai as well as the proportion of reference data representing this category. Generally, the result of the accuracy assessment over Terai was consistent with the results based on comparative statistics that had indicated good match between the reference FRA dataset and the corresponding ICIMOD 2010 dataset. Accuracy assessment of ICIMOD 2010 dataset using the FRA sample plots as reference data yielded and the overall accuracy is about 76%.

For 2000 land cover map, comparison of the forest mask with corresponding estimate captured in the Topographic Base Maps of 1998 showed a close match. Similar comparison between the forest mask (over High Mountain Region) estimated by the RL Team for the 2000 reference period against estimates reported in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012, Table 2.4", indicated that forest estimates based on the two products were fairly similar. For quantitative accuracy assessment of the 2000 land cover map, use of the FRA inventory-plots data (spread across the country) as reference data yielded an overall accuracy of 68.5%, with forest land having the highest producer's accuracy (84%) followed by crop land (63%).

For the 1990 land cover data (used as an ancillary dataset to the RL), comparison of the estimated extent of land cover distribution sourced from Master Plan for Forestry Sector (MPFS, 1988) and cited in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012" against similar estimates generated by ICIMOD for 1990 showed a good match between the two datasets. The quantitative accuracy assessment of the ICIMOD 1990 land cover map based on the use of the FRA inventory-plots data (spread across the country) as reference data yielded an overall accuracy of 69.8%, with forest land having the highest producer's accuracy (82%) followed by crop land (57%).

Other uncertainties associated with the carbon map may arise from other sources, including the following:

(i) data collection, sampling design;
(ii) allometric equation;
(iii) aggregated forest type;
(iv) emission factors

It is difficult to associate uncertainties to most of these elements. However, a **simple propagation of error approach** has been adopted for estimating the uncertainty associated with the emissions/removals reported in the RL. Nevertheless, the overall accuracy and uncertainty analysis associated with the reported emissions/removals is presented in section 3.5 while a detailed accuracy assessment of the analysis of land cover/forest cover change (for which relatively better analysis was possible) is presented in Annex 5.

1.5 Limitations of the reference level reported

Developing an accurate RL is a data-driven process relying on accurate spatially-explicit data that allows adjusting for national circumstances in the quantification of the pools and gases that have been included. Although considerable effort was invested in developing a national level RL, the quality of data with regard to activity data, emission factors and drivers of forest change limited the team's ability to make use of complex analysis and modelling, as this would multiply the already existing uncertainties. To partially mitigate these limitations, the RL team undertook a detailed analysis of census data to relate emissions to specific drivers. While it may be difficult to reconcile this analysis with satellite-based land cover change analysis, the census data helps to provide at least a qualitative understanding of the magnitude of two of the major drivers (fuel wood and roundwood/timber harvesting) as well as fires.

On the analysis of forest cover change, It should also be borne in mind that the temporal interval of 10-years adopted for this exercise is quite coarse to allow discrimination of subtle changes. For example, it is very likely that over the 10-year period, a forest patch may have been harvested and re-established/regenerated, and may never be detected. The decision of the 10-year interval was only arrived at in view of the limited time allocated to the assignment. Being aware of this limitation, the RL Team made efforts to incorporate the use of statistical data/records for the development the reference level, to complement and corroborate the use of satellite data.

2 SCOPE AND SCALE OF NEPAL'S REFERENCE LEVEL

2.1 Scope of RL development

The approach adopted in creating an updated land cover map was to generate an estimate of the RL at national scale. The updated land cover maps (1990 – 2000 - 2010) are wall-to-wall and therefore the approach is consistent for the entire country. Establishing a set of national standards for data collection and analyses is essential for a national scale RL and this was the approach implemented.

2.1.1 Compatibility between subnational and national scale reference level efforts

Sub-national REDD+ activities can either apply the national RL or develop a more situation specific sub-national RL. While the former approach ensures consistency at the national scale, it will also most likely underestimate deforestation and forest degradation in the without-project scenario. Sub-national RLs require transparent development protocols and a standardized approach to reconcile and harmonize the sub-national RL with the national RL. Sub-national REDD+ activities will typically be located in REDD+ hotspot areas that have medium to high carbon stocks, high deforestation and forest degradation threats and medium-high biodiversity or other co-benefits. Careful consideration of these factors is therefore needed in making a decision. This is illustrated in the work by FRA, WWF and Arbonaut in the Terai as a sub-national component of the reference level. This is especially important in the Terai because of the significant difference in carbon/biomass values between sal forests and all other forest types.

In a joint effort, WWF, the REDD-cell, and Arbonaut, developed a sub-national Reference Level (RL) for the Terai Arc Landscape of Nepal which covers the period from 1999-2011 and encompasses the geographic area of 12 lowland districts in Nepal with total land area of 2.3 million hectares (Gautam *et al*., 2013). The parameters for the development of the sub-national RL are consistent with the FCPF CF Methodological Framework and the RL accounts for all of the activities included in the ER program, including deforestation, degradation, regeneration, and enhancement. Three important outputs are of relevance to the current National RL development:

i. Development of Activity Data based on landcover/forest cover change analysis;
ii. Development of Emission Factors based on modeling of LiDAR data, field plot data, allometric equations, and classifications of forest type and structure. Considering that the National RL is based on Landsat imagery, this provides a useful comparison between different techniques and satellite imagery;
iii. Assessment of accuracy and uncertainty of carbon estimates.

In this exercise, a landscape-level forest carbon inventory in Terai Arc Landscape (TAL) of Nepal was conducted. Aboveground forest carbon was estimated using a novel LAMP approach. A Sparse-Bayesian method was used to calibrate data from well-measured 738 ground-truth plots with airborne discrete-return LiDAR data in selected sample areas from the same season. In the second step, the LiDAR estimates were used as simulated ground truth and regressed with variables derived from satellite imagery to cover the whole study area with continuous AGB values. The resulting carbon/biomass map was validated against highly accurate LiDAR-based carbon estimates. The accuracy of the LiDAR model was verified against 46 independent field plots. The LAMP combines LiDAR information with field plots and satellite data to develop a forest carbon map of one hectare resolution that will be useful for the Nepalese REDD+ process, in particular to derive subnational reference levels and support future forest monitoring activities in the country.

2.2 **Definition of 'forest'**

The UNFCCC Guidelines provide that Parties should 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". This is reiterated in the Durban SBSTA text (2011).

In respect to the definition of forest, the Guidelines identify three broad categories of forest definition: administrative, land use, and land cover. Under the Kyoto Protocol, "forest" is defined as:

- Minimum area: 0.05 – 1.00 ha
- Minimum crown cover 10 – 30%
- Minimum potential height 2 – 5m
- Young forests with the potential to meet the above 3 criteria

In accordance with the thresholds set by the UNFCCC, the definition of forest used in the FRA project 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 monitoring, reporting and verification (MRV) system for REDD+.

The definition adopted for developing the RL therefore is:

> *"Land with tree crown cover of more that 10 percent and area covering more than 0.5 ha, with minimum height of the trees to be 5 m at maturity and in-situ conditions. The land may consist either of closed forest formations where trees of various storeys 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 unstocked as a result of human intervention or natural causes but which are expected to revert to forest. This includes forest nurseries and seed orchards that constitute an integral part of the forest; forest roads, cleared tracts, firebreaks and other small open areas within the forest; forest in national parks, nature reserves and other protected areas such as those of special environmental, scientific, historical, cultural or spiritual interest; windbreaks and shelterbelts of trees with an area of more than 0.5 ha and a width of more than 20 m. Land predominantly used for agricultural practices are excluded".*

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

2.3 Activities included in the RL

Nepal's R-PP 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 the Bali Action Plan which in paragraph 70 of the AWG/LCA outcome "Encourages developing country Parties to contribute to mitigation actions in the forest sector by undertaking the following activities, as deemed appropriate by each Party and in accordance with their respective capabilities and national circumstances:

a) Reducing emissions from deforestation;
b) Reducing emissions from forest degradation;
c) Enhancement of forest carbon stocks;"

Deforestation: Deforestation is the long term or permanent conversion of forest to other (non-forest) land. In remote sensing terms, when a pixel that in Y1 was forest changes to other land uses in Y2, then the pixel is said to have undergone deforestation. The reported value for deforestation relates to net deforestation. During the historical reference period some areas that have been converted from forest to non-forest may have been reconverted to forest and all these have been taken in to account.

Degradation: the IPCC (2003) defines forest degradation as "a direct human-induced loss of forest values (particularly carbon), likely to be characterized by a reduction of tree cover. Routine management from which crown cover will recover within the normal cycle of forest management operations is not included". Degradation was detected through a decrease in carbon stocks, based on the assumption that transition from one forest stratum to another is accompanied by a proportional (percentage) change in carbon stocks.

Forest Enhancement: Enhancing the carbon stock in the context of this assignment is viewed as the positive complement of forest degradation, i.e. improving the quality of forest through natural regeneration or by planting trees to increase the already existing carbon stock therein. Enhancement was detected through an increase in canopy cover and/or carbon stocks. Quantification of enhancement was implemented using LUC time series analysis. Maps for canopy cover classes and related matrixes were generated from which degradation and forest enhancement were quantified.

2.4 Pools included

As per the Durban SBSTA text, significant pools and gases should be included. Parties are required to give reasons for omitting a pool or a gas from the construction of forest RL/RELs. It is recommended that countries perform a key category analysis to determine which pools are significant, i.e., is a given pool <5% of the total or <10% of the total. Excluding pools that represent a very small proportion of the total can save time and resources. Similarly, where costs of data collection and analysis exceed the benefit of including the specific pool or gas in the RL/REL, such may be excluded, even if such pools are significant. Alternatively, conservative defaults can be considered for insignificant pools if they must be included. Further guidance on selection of pools is provided in the "2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol" (IPCC, 2014).

The Marrakech Accord (COP 7 2001) in Decision 11/CP.7 provides that "A Party may choose not to account for a given pool in a commitment period, if transparent and verifiable information is provided that the pool is not a source". The import of this is that project participants may choose not to account for one or more carbon pools if they provide transparent and verifiable information that indicates that the choice will not increase the expected net anthropogenic GHG removals by sinks.

Decision 11 also directs that “good practice guidance, and methods to estimate, measure, monitor and report changes in carbon stocks and anthropogenic greenhouse gas emissions by sources and removals by sinks resulting from land use, land-use change and forestry activities, as developed by the Intergovernmental Panel on Climate Change, shall be applied by Parties...”

i. A given carbon pool can be excluded:

   a. If it represents a very small proportion of the total (<5% of total or <10% of the total) to save time and resources;
   b. Where costs of data collection and analysis exceed the benefit of including the specific pool or gas in the RL/REL, 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.

ii. Include emissions of N_2O and CH_4 if fire constitutes a major cause of forest degradation;
iii. Conservative defaults can be considered for insignificant pools if they must be included;
iv. Both the reference level and subsequent estimations based on the MRV system established must include exactly the same pools.

In addition to these general guidelines, the CDM **“Tool for testing significance of GHG emissions in A/R CDM project activities”** was used in the determination of which GHG emissions by sources, possible decreases in carbon pools, and leakage emissions are insignificant for a particular CDM A/R project activity as follows:

I. Estimate the GHG emissions by sources (per each source) and possible decreases in carbon pools based on site/project specific data, scientific literature, or the most recent default emission factors provided by IPCC.
II. Recalculate all GHG emissions into CO_2 equivalents using the GWP impact factors as decided by COP3 or as amended later.
III. Calculate the relative contributions of the project GHG emissions by sources and possible decreases in carbon pools and emissions by leakage activities according to the following equation (IPCC 2003, Eq. 5.4.1):

$$RC_{Ei} = \frac{E_i}{\sum_{i=1}^{I} E_i}$$

Where:
R_{Ei} = Relative contribution of each source *i* to the sum of project and leakage GHG emissions*;*
E_i = GHG emissions by sources of project and possible decreases in carbon pools and leakage emissions *i* as estimated under;
i = Index for individual sources of project and leakage GHG emissions (I = total number of sources considered).
IV. Rank the source emissions in descending order of their relative contributions RC_{Ei} and order them according to their ranks (i.e. the lowest emission shall get the highest rank and shall occupy the last position in the ordered sequence of emissions).

V. Start calculating the cumulative sum of the relative contributions RC_{Ei} (ordered according to the step IV) beginning with the lowest rank. Mark each individual source of emissions as it is included in the summation. Cease the summation when the cumulative sum reaches the lowest value not less than the threshold of 0.95.

The GHG emissions by sources and possible decreases in carbon pools not marked in the step V are considered insignificant if their sum is lower than 5% of net anthropogenic removals by sinks. Otherwise, the procedure described in the step V shall be continued beyond the threshold of 0.95 until the above condition is met.

Application of this process yielded the following results (much simplified because of the small number of the sources of emission and removals) as shown in tables 1and 2:

Table 1: Summary of emissions and removals

Gross emissions (tCO_2)	293,231,645
Gross removals (tCO_2)	85,964,612
Net emissions / removals (tCO_2)	207,267,033

The sources of emissions considered are deforestation and forest degradation. The sources of removals are enhancement through CFUGs, CFM and AR with the support of the Department of Forests.

Table 2: Relative contribution of emissions and removals (tCO2)

Source	Emission (tCO_2) - sum from 2000 to 2010	Proportion of gross emissions / removals	Proportion of net emissions
Deforestation	22,852,865	8%	11%
Degradation (total)	270,378,779	92%	130%
	Sub total	100%	
Enhancement (CFUGs/CFM)	77,588,571	90%	-37%
Afforestation / reforestation	8,376,041	10%	-4%
	Sub total	100%	

Based on these guidelines as well as stakeholder consultations only **Above Ground** (Tree) **Biomass** and **Below Ground Biomass** carbon pools are included in the RL. The excluded pools are:

- DOM because in line with the *IPCC Guidelines* we assume as a default that changes in carbon stocks in these pools are not significant and can therefore be assumed zero;
- Soil Organic Carbon (SOC) because no credible data is available for SOC whilst the cost of data collection is likely to exceed the benefit of including SOC.
- HWP because they are not considered under REDD+.

2.5 Gases included

Only the major GHG, i.e. CO_2 was considered in the construction of the RL.

Flooded lands may emit CO_2, CH_4 and N_2O in significant quantities, depending on a variety of characteristic such as age, land-use prior to flooding, climate, and management practices (IPCC, 2006). Emissions of CO_2, N_2O and CH_4 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 CO_2, 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 vegetation as provided in the 2013 Wetlands Supplement to the 2006 IPCC Guidelines.

Experience under the Kyoto Protocol's CDM also suggests that emissions from burning fossil fuels, from using fertilizer and planting leguminous plants and trees will not be significant (FCPF Decision Support Tool Part 1).

A major chunk of methane emissions in Nepal comes 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).

According to the IPCC Guidelines (2006), nitrous oxide (N_2O) emissions from Flooded Lands are typically very low, unless there is a significant input of organic or inorganic nitrogen from the watershed. The guidelines point out that it is likely that such inputs would result from anthropogenic activities such as land-use change, wastewater treatment or fertilizer application in the watershed. In order to avoid double-counting N_2O emissions already captured in the greenhouse gas budget of these anthropogenic sources, these emissions were therefore left out in constructing Nepal's REDD+ RL.

The excluded GHGs therefore are:

- 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 cause of deforestation or forest degradation.

3 NEPAL'S FOREST REFERENCE LEVEL

3.1 Analysis of land cover and forest cover change

Creation of Activity Data (AD) is a key element of the overall procedure of determining forest Reference Level (RLs). The AD was estimated at the national scale following the decision to develop a national level RL. The other decision relates to the use of historical approach in establishing the reference levels, entailing the use of historical data, including remotely sensed data and land cover/forest cover maps.

For the purpose of creating historical AD the period 2000 – 2010 was selected (although originally three reference periods were selected, namely 1990, 2000 and 2010. The period 1990 – 2000 was therefore used as essential ancillary data to inform and corroborate data from the period 2000 – 2010 and to assist with improved land use classification).

In preparation of thematic land cover maps to be used in creating AD, the first step entailed cataloguing and examining the existing maps and/data. Actual assembling involved different approaches, depending on availability of supporting data. For the 1990 and 2010 time points, respective International Centre for Integrated Mountain Development (ICIMOD) land cover products were used as the key inputs as a time saving measure, subjecting them to minimal 'data cleaning' procedures, while for the 2000 reference period, raw Landsat-based imagery data was processed as a step towards generating land cover maps. Finally, post-classification 'data cleaning' operations were implemented following a similar process, employing the use of a key ancillary data, 'Land Resource Mapping Project dataset, 1979' to aid the 'cleaning' as well as stratification operations.

Based on the assessment of these datasets, the following key conclusions were drawn:

- ✓ The land use/land cover map based on the Land Resource Mapping Project (LRMP), being an authentic product of the government and a comprehensive database, could be used to create updated products for subsequent target years/reference periods;
- ✓ The 1996 Topographical map, equally being an authentic government product, could also be used to cross-check quality of other generated products;
- ✓ The Forest Cover Change Analysis of the Terai Districts based on analysis of Landsat images of 1990/91 and 2000/01 was used to complement similar Landsat-based products that were generated to cover the rest of Nepal territory;
- ✓ The FRA dataset (2010) covering Terai/Siwalik, would be used to cross-check the accuracy of Landsat-based products that would be generated for the same nominal year covering the whole of Nepal territory;

The Landsat-based land cover maps generated by ICIMOD for 1990 and 2010 nominal year are the only datasets available covering the whole territory of Nepal and falling within the reference period considered.

3.1.1 Cleaning the Land Cover maps generated by ICIMOD for 1990 and 2010 time points

The land cover maps of 1990 and 2010 time point initially produced by ICIMOD had the following legend shown in Table 3.

Table 3: Legend for 1990 and 2010 land cover maps produced by ICIMOD

Legend
Needle-leaved closed forest
Needle-leaved open forest
Broad-leaved closed forest
Broadleaved open forest
Lake
Snow/glacier
Shrubland
Grassland
Agriculture
Bare area
Built-up area
River
Unclassified

Some datasets were available for comparison with the 2010 reference point at least for Terai; thus preliminary analysis was only performed on the 2010 dataset obtained from ICIMOD (see Table 4 below), which pointed to the need for minimum correction before being used for deriving activity data. For example, the estimate of forest extent over Terai was underestimated by the original ICIMOD 2010 land cover map in comparison to FRA reference dataset.

Table 4: Comparison of original 2010 land cover map generated by ICIMOD against the FRA dataset over Terai

	FRA Reference dataset over Terai	Corresponding ICIMOD 2010 Mask Dataset
Forest	411,580	385,779
Shrub	9,502	24,396
Non-forest	1,595,916	1,603,713

For the two datasets produced by ICIMOD (i.e. for 1990 and 2010reference periods), improvement was rendered by use of the LRMP (1979) dataset. As noted, the LRMP dataset was generated using aerial photos and field survey and subsequently authenticated by government. The improvement process was accomplished using GIS techniques including combine, join and overlay operations implemented in ArcGIS 10.2 and entailed the following steps:

- The forest mask had to be cleaned of erroneously misclassified non-forest materials, which had a similar spectral signature as forest materials, accomplished by flagging out those ‘stable’ non-forest areas. These ‘stable’ materials were identified based on the 1979 dataset and co-located to the target forest mask, thus aiding erasure of such materials from the target forest mask. The result was “refined” forest mask map, for 2010 reference period.

- Stratifying the forest mask into forest types as well the non-forest mask into various land cover categories. Since ICIMOD products had provided stratification for forest cover, these categories were adopted and renamed to hardwoods, coniferous and mixed forests classes and superimposed onto the respective forest mask. The results were forest mask stratified by forest types, for each reference period.

- Similarly, the non-forest masks (1990 and 2010 reference periods, their delineation into specific land cover categories also employed the delineation captured by original ICIMOD products. The overall non-forest mask was thus split into the various likely classes captured by the original ICIMOD datasets.

- Finally, mosaicking the stratified forest and non-forest mask generated detailed classified maps for 1990 and 2010 reference periods.

3.1.2 Implementation steps for generating benchmark thematic land cover/land use map for 2000 time point

Generating the 2000 land cover map followed a purely remote sensing approach, with minimum to no ground-based data. The tools used included ENVI, ERDAS Imagine, ArcGIS 10.2 and Microsoft Excel.

3.1.2.1 Assembling Landsat images for 200 time point

Assembling satellite images for the purpose of generating benchmark thematic land cover maps based on existing base maps entails consideration of the weather seasons in Nepal but also the quality of the available images (see Table 5 below). Since the objective is to delineate land cover categories especially forest materials, Landsat data acquired during the season most likely to have on-leaf woody vegetation and ideally drying or senescing herbaceous vegetation. Images acquired during the last two quarters of the year (possibly up to early February) are the most eligible, as the woody vegetation are still leafed while herbaceous plants are drying out.

Table 5: Generalized seasonality regime in Nepal

Months	J	F	M	A	M	J	J	A	S	O	N	D
Weather Seasons	**Mild Wet** Short Winter Rain	⟺	**Dry**		⟺	**Very Wet** Intense monsoon rain			⟺	**Mild Dry**		

With respect to USGS WRS 2, 14 Landsat scenes straddle across Nepal territory. Most of these images were already available with Nepal REDD Cell and were shared with the RL Team while a few were downloaded from Landsat.org website which provides ortho-rectified including those from circa 2000(see Table 6).

Table 6: Landsat scenes applied in generating land cover map for year 2000

Path/row	2000 Nominal Year/Date of acquisition
139/041	2001/Dec/26
139/042	2001/Oct/26
140/041	2000/Oct/30
140/042	1999/Oct/28
141/040	2000/Nov/22
141/041	2001/Dec/27
141/042	2001/Oct/24
142/040	1999/Dec/13
142/041	1999/Dec/13
143/039	2000/Oct/03
143/040	2001/Dec/25

Path/row	2000 Nominal Year/Date of acquisition
143/041	1999/Oct/17
144/039	2001/Oct/13
144/040	1999/Nov/09

3.1.2.2 General approach for generating landcover map for 2000 time point

The general methodology followed several steps.

- Data preparation and pre-processing of satellite images,
- Application of classification technique/method that would adequately distinguish forest areas from non-forest areas
- Post-classification operations and production of a final land-cover map and undertaking an accuracy assessment.

3.1.2.3 Satellite image pre- processing

Pre-processing of the Landsat images (Table 5) was implemented for purpose of:

- Cloud removal whenever necessary,
- Dark object subtraction to minimize atmospheric effects

Relative atmospheric correction using dark object subtract method was implemented in ENVI, which required masking off the “NoData” bracket round the image and subsequent determination of the minimum pixel value per band.

3.1.2.3.1 Application of classification techniques /methods

Processing of products followed suit, being implemented on a scene-by-scene basis and based on standard procedure. Decision tree classifier (DTC) technique was employed as a first level method. DTC is based on decision-rules approach of flagging out materials of interest based on the application of threshold values to the input variable(s). A combination of variables was explored including key reflectance bands, vegetation index (e.g. MSAVI), fractional images generated by matched-filtering technique (ENVI). On a scene-by-scene basis, the combination that yielded the best result was adopted. The products from respective scenes were mosaicked. The DTC procedure yielded country-wide first level preliminary maps of forest/ non-forest map for the 2000 reference point.

The following sub-sections describe the production of some of the above key inputs employed by the DTC and the actual implementation of the DTC.

Creation of Vegetation Index Product

The use of vegetation indices to characterize temporal and spatial vegetation patterns have been demonstrated by many researchers (Qi *et al.* 1994; Matricardi *et al.* 2010). Vegetation indices improve vegetation sensitivity by accounting for atmosphere and soil effects. According to Qi et al. (1994), soil adjusted vegetation index (SAVI) was developed to minimize soil influences on canopy spectra by incorporating a soil adjustment factor L into the denominator of the normalized difference vegetation index (NDVI) equation. A modified SAVI is an improvement over SAVI where the constant L in SAVI equation is replaced with a factor L that varies inversely with the amount of vegetation present. MSAVI effectively increases the dynamic range of the vegetation signal while further minimizing the soil background influences, resulting in greater sensitivity.

In view of the above, modified soil adjusted vegetation index (MSAVI) was employed in this assignment, calculated as:

$$MSAVI = \frac{(\rho_{NIR} - \rho_{red})}{(\rho_{NIR} - \rho_{red} + L)} * (1 + L)$$

Where ρ is reflectance in NIR or red band and L is a soil adjustment factor. MSAVI products generated were used to generate fractional vegetation cover, the procedure elaborated in Annex 1.

Fractional images generated by matched filter technique

Matched filtering technique is based on the principle of spectral un-mixing of pixel-based values into sub-pixel values corresponding to constituent endmembers. The basic assumption is that a pixel value is assigned on the basis of the weighted summation of the reflectances of the different materials (endmembers) in the pixel, based on their proportional abundance. Using linear spectral un-mixing algorithm, the pixel value can be disaggregated to their proportional endmember as long as the spectral profile of selected endmembers are provided. ENVI has an inbuilt module to implement this algorithm, allowing the endmember spectra to be defined from the image as regions of interest (ROIs). The result of matched filtering appears as a series of gray scale images (fractional images), one for each selected endmember. Floating-point results provide a means of estimating the relative degree of match to the reference spectrum and approximate sub-pixel abundance, where 1.0 is a perfect match. Subsequent classification/delineation of the extent of the target endmember employs these fractional images using decision-tree classifier in ENVI which operates on the logical application of threshold values. Utilizing expert knowledge, the analyst chooses the most appropriate range of values for a particular fractional image which would allow the best delineation of the target material. By using a series of such fractional images and logical rules organized as a decision-tree, a preliminary map delineating the extent of the target material(s) (e.g. forest) would be generated.

Collection of endmember spectra entailed exploring the image to determine the different land cover categories/materials. It required that, prior to this process, the image be enhanced through appropriate band-compositing as well as stretching to enhance contrast of such endmembers materials. Since the main material of interest was forest, every effort was made to collect endmember spectra from the varied tones or appearance of forest material. The regions of interest (ROI) tool were used to delineate specific pure pixels representative of a particular endmember. For every scene, a ‘matched filtering’ algorithm was then run over the Landsat image, employing the respective endmember spectra, eventually yielding sets of fractional images for the selected endmembers.

Implementation of the decision-tree classifier to generate land cover map

Implementation of this method followed a scene-by-scene approach to generate a preliminary land cover map delineating forest and non-forest surfaces. Scene-based outputs would then be mosaicked and clipped to the extent of Nepal’s sovereign territory.

Where a matched filtering technique was applied to generate fractional images as an input into the decision-tree classifier, the collection of endmember spectra entailed exploring the image to determine the different land cover categories/materials. It required that, prior to this process, the image be enhanced through appropriate band-compositing as well as stretching to enhance the contrast of such endmembers materials. Since the main material of interest was forest, every effort was made to collect endmember spectra from the varied tones or appearance of forest material. The regions of interest (ROI) tool were used to delineate specific pure pixels representative of a particular endmember. For every scene, a matched filtering algorithm was then run over the Landsat image, employing the respective endmember spectra, eventually yielding sets of fractional images for the selected endmembers.

Classification based on decision-tree classifier was then implemented, involving building a new decision-tree for each scene, using as inputs a combination of selected reflectance bands, modified soil-adjusted vegetation index (MSAVI) or fractional images generated by matched filtering technique. Implementation of the decision-tree classifier entailed the application of respective thresholds, carefully determined by visually examining the enhanced color-composite image. The output of this classification process was a preliminary land cover map delineating forest and non-forest surfaces.

3.1.2.4 Applying key thresholds based on the definition of forest

The forest mask output from DTC was subjected to further processing operations meant to qualify forest areas. Two criteria were implemented, namely the >10% or higher canopy cover and the 'contiguous-area' threshold, where neighboring or adjacent pixels must sum-up to 0.5 ha or more to qualify as forest, otherwise they are rendered as non-forest category.

Implementation of the first criterion employed the Landsat-based fractional vegetation map that was generated following the procedure outlined in annex 1. Since the fractional vegetation map is the index map providing the abundance of vegetation materials as a percentage, then it was easy to assign pixels (within the initial forest mask) that met the criterion of forest or non-forest. The 'contiguous-area' criterion was met by further clumping the 'qualified' pixels that were adjacent or neighboring, and then subjecting these clumps to a sieve, such that groups composed of less than a certain number of pixels (usually amounting to 0.5 ha) were sieved out. The final result was a preliminary forest mask product meeting the forest definition criteria.

3.1.2.5 Refining the preliminary product and stratification

The first level product generated above had to be cleaned. In particular, the forest mask had to be cleaned of erroneously misclassified non-forest materials, likely to have had similar spectral signature as forest materials. Based on the 1979 dataset, pixels having "stable" non-forest materials and co-located to the target forest mask were identified, thus aiding erasure of such materials from the target forest mask. Such materials included lakes, rocks, boulders and sand. The result was a "refined" forest mask map, for 2000 reference period. This approach was similar to the one employed while cleaning the original datasets sourced from ICIMOD for the 1990 and 2010 reference points.

For stratification of the refined forest mask, the 1979 dataset was employed. This dataset had stratified forest into three categories; hardwood, coniferous, and mixed forests. The delineations captured by 1979 dataset was superimposed onto the respective forest mask and combine and join operations were applied. The results were forest mask stratified by forest types, for 2000 reference period. In the same manner, for the non-forest mask generated through DTC, respective delineation into specific land cover categories also employed the 1979 LRMP dataset and the overall non-forest mask was thus split into the various likely classes captured by the 1979 LRMP dataset. Finally, mosaicking the stratified forest and non-forest mask generated detailed classified map for 2000 reference period.

3.1.3 *Generating the final benchmark thematic land cover/land use maps with IPCC land classification scheme for target time points (1990, 2000, and 2010)*

Reclassification of land cover types was implemented in order to have legend that is consistent with the classification scheme adopted by IPCC used the description provided in IPCC Good Practice Guidelines (2006) as described in sub-section below.

3.1.3.1 IPCC classification scheme

According to the IPCC Guidelines, the top-level land categories for greenhouse gas (GHG) inventory reporting are:

(i) Forest land
This category includes all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, sub-divided into managed and unmanaged, and also by ecosystem type as specified in the *IPCC Guidelines* 3. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category.

(ii) Cropland
This category includes arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category, consistent with the selection of national definitions.

(iii) Grassland
This category includes rangelands and pasture land that is not considered as cropland. It also includes systems with vegetation that fall below the threshold used in the forest land category and are not expected to exceed, without human intervention, the threshold used in the forest land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvo-pastoral systems, subdivided into managed and unmanaged consistent with national definitions.

(iv) Wetlands
This category includes land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, and grassland or settlements categories. The category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.

(v) Settlements
This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.

(vi) Other land

This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.

Following the reclassification, separate land use/land cover maps consistent with IPCC classification scheme (for each target reference time point -1990, 2000 and 2010) were generated. These maps are presented in Annex 2. Separate PDF files and geo-referenced TIFF files are also available.

3.1.3.2 Stratifying canopy density for the purpose of determining forest degradation and carbon density

Wang *et al* (2005) had successfully assessed fractional vegetation cover from Landsat imageries as one way of measuring forest degradation caused by selective logging in the Amazon. This approach was employed to assess lumped forest degradation for Nepal, using the fractional vegetation cover map previously generated. In each reference period, the respective fractional vegetation cover (clipped to the extent of forest cover only) was used to delineate three forest density classes based on thresholds implemented in ArcGIS raster calculator. The threshold values used are summarized in Table 7below. As applied by Wang et al (ibid), all pixels whose *fc* values were below 0.4 were relegated to degraded forest mask. For each of the reference periods, the respective forest cover map showing the distribution of density classes are shown in Annex 3.

Table 7: Canopy density stratification criteria

***fc*- value range**	**Description**
10% - 39%	Open canopy
40% - 69%	Moderate canopy
>70%	Closed canopy

Scheme rendered to the land cover maps is summarized in Table 8below. It is notable that land cover instead of land use is the actual designation of classification categories.

Table 8: Final classification scheme for land cover maps

Forest, closed canopy
Forest, moderate canopy
Forest, open canopy
Crop cover
Grass cover
Settlement
Wetland
Other lands

3.2 Area changes for 2000 to 2010 (activtiy data)

Table 9 below summarizes the area changes (i.e. activity data) form the wall-to-wall analysis between 2000 and 2010 which is the historical reference period for which the RL has been reported.

Table 9: Table 9: Summary of activity data 2000 - 2010

WALL-TO-WALL CHANGE MATRIX 2000 to 2010	Forest land	Crop land	Settlements	Grassland	Wetlands	Other lands

Forest land	4,491,093	608,837	1,459	209,685	938	26,697
Crop land	906,246	2,872,378	16,782	170,032	0	73,070
Settlement	775	23,072	23,479	383	0	1,032
Grassland	348,807	251,554	1,180	1,842,372	0	75,083
Wetlands	16	1,176	21	66	70,938	124
Other lands	39,515	100,263	356	56,052	4,188	2,526,066

Between 2000 and 2010, again there was large national-scale land cover transitions that occurred with respect to forest conversion to crop cover (608,837 ha) as well as conversion to grass cover (209,685 ha) and to other lands (26,697 ha). Conversely, there was also substantial gain in forest cover related to conversion from crop cover (906, 246 ha), from grass cover (348,807 ha) and from other lands (39,515 ha).

3.3 Estimating Forest Carbon stocks

The estimation of forest carbon stocks for each selected pool in each Land Use Category was implemented using a combination of Tier 1, 2 and 3 data sources as described in section 1.2.

The results are as shown in Table 10 below:

Table 10: Estimates of forest carbon stocks by physiographic region (above ground and below-ground biomass)

Terai	*Forest carbon*	Value	Source of data
	Above ground biomass (average tC / ha)	90	FRA data for Terai (Camco analysis) to quantify carbon pool in above ground tree biomass.
	Root to shoot ratio	1.2	Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests by Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Federation of Community Forest Users, Nepal (FECOFUN), International Centre for Integrated Mountain Development (ICIMOD), ISBN: 978-9937-2-2612-7 First edition: July 2010 Norwegian Agency for Development Cooperation (NORAD)
	CO_2/C Ratio:	3.666666667	
	tCO_2/ha	397.3623519	

Siwalik	*Forest carbon*	Value	Source of data
	Above ground biomass (t dry matter per ha)	180	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.7
	Root to shoot ratio	1.2	Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests by Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Federation of Community Forest Users, Nepal (FECOFUN), International Centre for Integrated Mountain Development (ICIMOD), ISBN: 978-9937-2-2612-7 First edition: July 2010 Norwegian Agency for Development Cooperation (NORAD)
	Carbon Fraction:	0.47	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.3
	CO_2/C Ratio:	3.666666667	
	tCO_2/ha	372.24	

Hills	*Forest carbon*	Value	Source of data
	Above ground biomass (t dry matter per ha)	180	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.7
	Root to shoot ratio	1.2	Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests by Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Federation of Community Forest Users, Nepal (FECOFUN), International Centre for Integrated Mountain Development (ICIMOD), ISBN: 978-9937-2-2612-7 First edition: July 2010 Norwegian Agency for Development Cooperation (NORAD)
	Carbon Fraction:	0.47	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.3
	$C0_2$/C Ratio:	3.666666667	
	tCO_2/ha	372.24	

Mid Mountain	*Forest carbon*	Value	Source of data
	Above ground biomass (t dry matter per ha)	135	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.7. Tropical mountain system, Asia continental mid-point between range of 50 - 270
	Root to shoot ratio	1.2	Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests by Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Federation of Community Forest Users, Nepal (FECOFUN), International Centre for Integrated Mountain Development (ICIMOD), ISBN: 978-9937-2-2612-7 First edition: July 2010 Norwegian Agency for Development Cooperation (NORAD)
	Carbon Fraction:	0.47	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.3
	$C0_2$/C Ratio:	3.666666667	
	tCO_2/ha	279.18	

High Mountain	*Forest carbon*	Value	Source of data
	Above ground biomass (t dry matter per ha)	130	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.7. Temperate mountain system, Asia continental value 130
	Root to shoot ratio	1.2	Forest Carbon Stock Measurement Guidelines for measuring carbon stocks in community-managed forests by Asia Network for Sustainable Agriculture and Bioresources (ANSAB), Federation of Community Forest Users, Nepal (FECOFUN), International Centre for Integrated Mountain Development (ICIMOD), ISBN: 978-9937-2-2612-7 First edition: July 2010 Norwegian Agency for Development Cooperation (NORAD)
	Carbon Fraction:	0.47	2006 IPCC Guidelines for National Greenhouse Gas Inventories. Table 4.3
	$C0_2$/C Ratio:	3.666666667	
	tCO_2/ha	268.84	

The carbon density values used to measure carbon stocks in degraded forest areas of each of the physiographic regions are presented in Table 11.

Table 11: Forest carbon density values for estimating degradation

Region	Canopy cover class	Fraction applied	tCO_2/ha
Terai	More than 70%	1	397.4
	40% to 70%	55%	218.5
	10% to 40%	30%	119.2
Siwalik	More than 70%	1	372.2
	40% to 70%	55%	204.7
	10% to 40%	30%	111.7
Hills	More than 70%	1	372.2
	40% to 70%	55%	204.7
	10% to 40%	30%	111.7
Mid Mountain	More than 70%	1	279.2
	40% to 70%	55%	153.5
	10% to 40%	30%	83.8
High Mountain	More than 70%	1	268.8
	40% to 70%	55%	147.9
	10% to 40%	30%	80.7

3.4 Emission and Removal Factors

Emission/Removal Factors are calculated for each detectable transition between the different LU categories. The Emission/Removal Factor for a LU transition from A to B is the difference in the carbon stocks between the two LU categories (i.e. B-A).

With respect to forest enhancement (including AR activities) carbon removals were estimated using the Biomass Gain-Loss Method whereby:

1. The annual increase in biomass carbon stock is estimated following Volume 4 of the IPCC Guidelines for GHG Assessment using Equation 2.9, where area under each

forest sub-category is multiplied by mean annual increment in tonnes of dry matter per hectare per year.

Equation 2.9

ANNUAL INCREASE IN BIOMASS CARBON STOCKS DUE TO BIOMASS INCREMENT IN LAND REMAINING IN THE SAME LAND USE CATEGORY

$$\Delta C_G = \sum_{i,j}(A_{i,j} \cdot G_{TOTAL_{i,j}} \cdot CF_{i,j})$$

Where:

ΔC_G = annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone, tonnes C yr^{-1}

A = area of land remaining in the same land-use category, ha^{-1} yr^{-1}

G_{TOTAL} = mean annual biomass growth, tonnes d. m. ha

i = ecological zone (i = 1 to n)

j = climate domain (j = 1 to m)

CF = carbon fraction of dry matter, tonne C (tonne d.m.)$^{-1}$

2. Since the biomass growth is given in terms of merchantable volume or above-ground biomass, the belowground biomass is estimated with a below-ground biomass to above-ground biomass ratio (Equation 2.10). Alternatively, merchantable volume (m^3) can be converted directly to total biomass using biomass conversion and expansion factors (BCEF), (Equation 2.10).

$$C_{net\_em} = C_{gr\_em} - C_{rem\_enh}$$

And

$$C_{rem\_enh} = \sum_{i=1}^{m}(A_{enh(i)} \cdot C_{rem\_enh(i)})$$

Where:

C_{net_em} = Net Carbon Emissions

C_{rem_enh} = Emissions removals from forest Enhancement

$A_{enh(i)}$ = Forest Area under Enhancement (ha) for forest type (i)

$C_{rem\_enh(i)}$ = Emissions removals from Enhancement in forest type (i)

G_{TOTAL} is the total biomass growth expanded from the above-ground biomass growth (G_W) to include belowground biomass growth.

Equation 2.10

Tier 1

$G_{TOTAL} = \sum\{G_W \cdot (1+R)\}$ Biomass increment data (dry matter) are used directly

Tiers 2 and 3

$G_{TOTAL} = \sum\{I_V \cdot BCEF_1 \cdot (1+R)\}$ Net annual increment data are used to estimate G_W by applying a biomass conversion and expansion factor

Where:

G_{TOTAL} = average annual biomass growth above and below-ground, tonnes d. m. ha^{-1} yr^{-1}

G_W = average annual above-ground biomass growth for a specific woody vegetation type, tonnes d. m. $ha^{-1} yr^{-1}$

R = ratio of below-ground biomass to above-ground biomass for a specific vegetation type, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)$^{-1}$

I_V = average net annual increment for specific vegetation type, m^3 ha^{-1} yr^{-1}

$BCEF_1$ = biomass conversion and expansion factor for conversion of net annual increment in volume (including bark) to above-ground biomass growth for specific vegetation type, tonnes above-ground biomass growth (m^3 net annual increment)$^{-1}$

The removal factors used to quantify increases in forest carbon due to enhancement are detailed in Table 12.

Table 12: Removal factors used to quantify increases in forest carbon due to enhancement

Terai and Siwalik		**Mid Hills and Middle Mountain**		**High Mountain**	
Main Species:	Sal dominated by *shorea robusta*	Main Species:	Mixed (includes all broadleaved forest, conifer and mixed)	Main Species:	Mixed (includes all broadleaved forest, conifer and mixed)
Average Dry Wood Density (tons/m^3):	0.5	Average Dry Wood Density (tons/m^3):	0.5	Average Dry Wood Density (tons/m^3):	0.5
Root-to-shoot ratio:	1.2	Root-to-shoot ratio:	1.2	Root-to-shoot ratio:	1.2
Crown-to-stem ratio:	1.2	Crown-to-stem ratio:	1.27	Crown-to-stem ratio:	1.24
Carbon Fraction:	0.47	Carbon Fraction:	0.47	Carbon Fraction:	0.47
$C0_2$/C Ratio:	3.666666667	$C0_2$/C Ratio:	3.666666667	$C0_2$/C Ratio:	3.666666667
MAI (m^3/ha/yr):	1.35	MAI (m^3/ha/yr):	2	MAI (m^3/ha/yr):	1.47
Annual increment (tCO_2/ha/yr^{-1})	**1.67508**	Annual increment (tCO_2/ha/yr^{-1})	**2.62636**	Annual increment (tCO_2/ha/yr^{-1})	**1.8847752**

3.5 Nepal's REDD+ Forest Reference Level

Because of the data challenges, a scenario approach has been adopted in construction of Nepal's RL. The scenario presented in this section is considered to be the most plausible under the present circumstances, i.e. the availability and nature of the data used (see table 13 below). Alternative scenarios are presented and explained in Annexes 6 -10.

In this scenario we have used net AD values rather than gross values for deforestation and AR. Carbon stock changes are measured using emission factors for deforestation and degradation whilst all removals (reforestation and enhancement) are measured using annual incremental data. The reference period only covers the period 2000 - 2010. No projections have been made. The data from this period has been used to calculate average emissions during the 2000 – 2010 period. AD for removals (enhancement including AR) are based on area data gathered from the historic period 1990 – 2000 in addition to the period 2000 – 2010 i.e. in this scenario we include forest carbon stock enhancement (increments) on land areas identified as undergoing enhancement during the preceding period (1990 –2000) as well as the 2000 – 2010 period.

Table 13: Estimation of average emissions during the 2000 – 2010 period

	Gross defor emission	Gross degradation emission	Gross emissions	Gross non-forest to forest	Gross enhancement	Gross removals	Net emissions	Average
Terai	12,188,709	5,522,341	17,711,050	166,911	7,392,258	7,559,169	10,151,880	922,898
Siwalik	1,274,870	37,995,890	39,270,760	161,936	19,804,644	19,966,580	19,304,180	1,754,925
Hills	-	153,772,344	153,772,344	5,773,567	30,719,030	36,492,597	117,279,747	10,661,795
Mid Mountain	-	63,289,531	63,289,531	2,273,627	17,930,672	20,204,299	43,085,232	3,916,839
High Mountain	9,389,287	9,798,674	19,187,960	-	1,741,966	1,741,966	17,445,994	1,585,999
Total	22,852,865	270,378,779	293,231,645	8,376,041	77,588,571	85,964,612	207,267,033	18,842,458

3.6 Adjustment for national circumstances

Paragraph 9 of Decision 12/CP.17 invites Parties to submit information and rationale on the development of their forest reference emission levels and/or forest reference levels, *including details of national circumstances and if adjusted include details on how the national circumstances were considered*, in accordance with the guidelines contained in the annex to this decision and any future decision by the Conference of the Parties.

Consideration of the need for adjustment was done on the premise that the most likely approach for the projection of Nepal's RL is that future emissions are either the same as those recorded historically or expected to increase or decrease on the same trajectory. A historic average approach needs to be applied if no statistically significant relationship can be established between historic emissions (i.e. those estimated from 1990, 2000 and 2010). A continuation of an existing trajectory on the other hand could be applied where a significant relationship exists with time. An acceptable fit would be a p value of ≤0.05 combined with an r2 value of ≥0.70.

In order to apply a suitable adjustment for national circumstances it was necessary to assess whether a statistically significant relationship between emissions and specified indirect factors related to national circumstances such as policies, human population, Gross Domestic Product (GDP), or some other development indicator.

The conclusion reached was that there is no sufficient data to enable this kind of analysis in order to arrive at a suitable adjustment.

- There are no migration policies which may either increase or decrease pressure on forest resources. There have been no resettlement plans since before 1990 (prior to reference period). The occurrence of any migration since then has occurred in an informal way.

- There are no plans for the development of a specific economic sector such as biofuels, tea, rubber etc. which may increase deforestation. The Forest Regulation of 1995 states that it is prohibited to clear any forest for agricultural purposes.
- There are no plans for development of a particular region with, for example road building, electrification which would be likely to deviate rates of deforestation from those during the reference period.

Following the above conclusion, the conclusion was reached that there is no compelling policy or socio-economic factors to indicate deviation of future emissions from the historical trend; however, as part of the iterative process for the development of RL Nepal may wish to undertake a more detailed study of the key socio-economic factors to improve future projections. For this reason, the projection of future emissions is based on an assumed continuation of the historical average as calculated from the period 2000 - 2010. A detailed description of the review process is presented in Working Paper 4 (Adjustment for National Circumstances).

Furthermore, Working Paper 3 (Forest Risk Assessment) shows that if we assume a timeframe of 10 years in the high risk forest areas, then 1% of the remaining forest would be impacted by deforestation and forest degradation each year during this ten year period, which is line with current trends and would create GHG emission similar to the average from the reference period. These findings broadly corroborate with the data on the historical trends of deforestation and forest degradation indicating that no adjustment is required.

3.7 **Overall Uncertainity Analysis**

The calculation of the overall uncertainty is demonstrated in the workbook: "Nepal RL - Workbook 11 - Uncertainty Analysis.xlsx"

The uncertainties in this assignment were computed using the *IPCC Approach 1 Model* where simple combinations of uncertainties by category are combined to estimate overall uncertainty for one year and the uncertainty in the trend.

The model requires as input the base year net emissions, a given years net emissions, activity data uncertainty and emission factor parameter uncertainty.

The following assumptions and considerations were made when calculating the uncertainties:

- Emission factor and activity data uncertainties were combined
- Correlations occur between some of the activity data sets, emission factors, or both
- The distributions of the uncertainties are Gaussian
- The relative ranges of uncertainty in the emission and activity factors are the same in the base year and in year *t*.

The combined uncertainties were taken to be the mean square error for scenario 1, 2 and 3 and are computed as follows.

$$\%\, Error = \frac{1.96\hat{\sigma}_{\varepsilon}/\sqrt{n}}{Value} * 100$$

The error is based on the 95 % confidence level.

σ_{ε}^{2} is estimated using the Mean Square Error

$$\hat{\sigma}_{\varepsilon}^{2} = \frac{\sigma_{y}^{2}}{n}$$

For scenario 4, 5 and 6 a 95 % confidence in the data was assumed hence the uncertainties in each case was taken to be 5% (see description of alternative scenarios in Annexes 6 – 10)

The percentage uncertainty in the average emissions (Scenario 4) presented in Table 13 above is 1.51%.

Detailed description of the uncertainty analysis is presented in Annex 11.

3.8 **Forest Risk Assessment**

For the purpose of RL development, it is important to analyze forest risk to understand potential forest areas that are vulnerable to degradation and even deforestation. The basic principle behind forest risk analysis is that not all forests are under threat of being degraded or deforested. Indeed, two categories are recognized: mosaic-type forests, defined as highly accessible forests with high potential for degradation and/or deforestation; and frontier-type forests, defined as inaccessible forests, with low potential for degradation or deforestation, except near transport corridors. Thus, in determining forest areas under risk versus those not under risk, biophysical and human factors that influence the distribution of biomass or carbon stock are considered. These include elevation/slope, roads, rivers, towns/villages/settlement, logging concessions, post land-use change, pattern of historical deforestation, etc.

In the case of Nepal, the actual procedure employed in risk assessment is elaborated in a separate Working Paper no. 3. As a first step, several documents were reviewed, including Baral *et al* (2012), Mandal *et al* (2012), MoFSC (2009), Paudel *et al* (2013), aiding in contextualizing the application of target factors. Preparation of factor maps was then undertaken. Factors seen to be determining the risk-level of Nepal's forest cover are better contextualized as surface maps, and this may employ different techniques. Heuristic methods assumes that with increasing distance from a determinant feature (e.g. road, settlement, river, etc.), forest degradation and/or deforestation decreases. Empirical methods on the other hand, uses historical evidence (e.g. deforested areas in the first year) to identify whether or not people prefer to deforest.

For each of the determining factors analyzed above, the Heuristic method was employed on raw maps mostly sourced from ICIMOD, while Model Builder in ArcGIS 10.2 was used to prepare raster surfaces for the respective factors.

The working paper presents detailed results of the risk assessment, including maps showing the actual forested areas that are potentially vulnerable to deforestation or forest degradation risk presenting a summary the forest risk level in terms of areal extent (Ha). Generally, moderate and high risk areas (totaling 1,431, 282 Ha) can indeed be considered as vulnerable to forest degradation and /or deforestation. Of these, 555,828 Ha can be assumed to be in critical or perhaps ongoing danger.

The findings of the forest risk analysis highlight that significant forest areas are still at risk; 15% of forests are moderately at risk whilst a further 10% are at high risk of deforestation and forest degradation. These findings broadly corroborate with the data on the historical trends of deforestation and forest degradation i.e. if we assume a timeframe of 10 years in the high risk forest areas, then 1% of the remaining forest would be impacted by deforestation and forest degradation each year during this ten year period, which is line with current trends and would create GHG emission similar to the average from the reference period.

4 HOW NEPAL'S REFERENCE LEVEL MAY BE UPDATED

4.1 Improving data collection, processing and handling

Developing REDD+ forest reference level for REDD+ as a pre-requisite for a payment- based system is an urgent and a challenging task, given the lack of quality data in many participating countries, genuine uncertainties about future rates of deforestation and forest degradation and potential incentives for biasing the estimates. To improve confidence in the RLs presented, countries will need to improve the quality and processes of data collection. This is the case with Nepal at the moment

This is also the basis for a stepwise approach to developing reference levels, which reflects different country circumstances and capacities and will facilitate broad participation, early startup and the motivation for improvements over time, alongside efforts to enhance measurement and monitoring capacities. Hence, as the first iteration of Nepal's RL, proper updates will need to be made as better data becomes available. This section presents recommendations on how the country's RL may be updated. Four key things need to be borne in mind while considering updates to the RL:

i. Establish a protocol (for updating the RL)
ii. Document control procedures including who can make updates and who takes custody of data generated.
iii. Ensure procedures to avoid (1) erroneous changes and (2) loss of information
iv. Establish links with partner organizations that will provide data to improve future iterations of RL

The lack of field plots and ground truth data in the analysis presented in this report is a significant impediment to accurate carbon assessment in Nepal. In order to achieve acceptable levels of accuracy to support carbon transactions with the World Bank and other entities, there is need for extensive data collection in addition to satellite data. As mentioned in the introduction section, some data collection activities that will serve to improve the accuracy of the RL have already been undertaken albeit at small scale. Specifically, in the Terai and a portion of Siwaliks, a cooperative effort of Nepal FRA, WWF, and Arbonaut resulted in the collection of LiDAR data for 5% of the program area and the collection of field data of 738 plots of 12.6-meter radius in 2011 and 46 plots of 30-meter radius in 2013. This process needs to be rolled out gradually to collect national level data.

The following are therefore considered to be the most important areas requiring attention for more accurate updates:

1. Framework

i. More historical time points to improve the trend analysis.
ii. Include other pools such as soil carbon

2. Activity data

i. Higher resolution data
ii. Ground truthing and verification of mapping products
iii. Improved techniques to detect changes in forest carbon stocks (degrade and enhancement)
iv. Resolve issue of apparent discrepancy between gross and net deforestation

v. Mapping of Community Forests

3. *Drivers*

i. Co-ordinated data collection (feeding up from community to district to national level)
ii. More accurate fire data
iii. Timber data has huge inconsistencies

4. *Emission factors*

i. Improved forest inventory data (spatially linked, permanent sampling, consistent, accessible)
ii. Obtain incremental data for reforestation and enhancement / develop more complex growth curves

5. *Capacity building*

i. Focus training on 2 – 4 members of staff (through 1 to 1 training sessions) who would develop the required skills to actually make RL updates

6. *Recommendation for processing satellite images and improving accuracy of generated products*

Two general approaches to constructing change maps may be considered: direct classification which entails the construction of the map directly from a set of change training data and two or more sets of remotely sensed data, and post-classification which entails the construction of the map by comparing two or more separate land cover maps, each constructed using single sets of land cover training data and remotely sensed data. Although direct classification is often preferred, post-classification may be the only option because of factors such as the inability to observe the same sample locations on two occasions, insufficient numbers of change training observations, or a requirement to use an historical baseline map. The post classification approach of creating activity data is marred by inconsistency of the available spatial datasets and scarcity of reference data.

In Nepal, while much effort has gone into harmonizing of these datasets, the propagated error resulting from inconsistencies is potentially large, implying the need for improvement of the approach applied to generate activity data.

The recommended improvement is based on the use of the envisaged FRA dataset. The FRA Project, once complete will generate a comprehensive dataset for 2010 nominal year, yielding a land cover map with detailed land cover categories stratified along physiognomic zones and development regions, forest types based on dominant species, forest management regimes and reachability. Moreover, the data will have rich reference data in addition to plot-level inventory of key variables necessary for quantification of main biomass/carbon pools. This dataset will potentially serve as a key base dataset and would ideally be used to constrain pre-processed satellite data of historical and future reference periods for purpose of generating fairly accurate activity data for any period of interest. The RL was developed with this clear intention in mind.

For a particular historical or future change period, say between 2005 and 2010, a manual procedure of interpretation of satellite data and delineation of change is recommended. The reference data will be the base data (in this case the 2010 FRA dataset). The base dataset (preferably in vector form) together with multi-date comparative images representing the change period, enhanced by appropriate band combination and stretching, are displayed in a good geospatial application software package that allows visual comparison by swiping and flickering. Using swipe and flicker tools, the two images are visually compared, moving systematically over the pixels and making interpretation based on expertise knowledge of the area. Where there is obvious difference between the two images, the base dataset will be activated to qualify the difference in terms of positive or negative land cover change and to allow the change areas to be digitized on-screen. The output of this exercise is a general map highlighting change areas and non-change areas. In reference to the forest cover of the base dataset, the change areas can be positive or negative, and can conveniently be interpreted in terms of the key REDD+ activities. Definition of activity data can be improved when the procedure is implemented over short interval period or time series, enabling clear discrimination of activities such as deforestation, forest harvesting, reforestation/afforestation.

4.2 The step-wise approach to developing an improved reference level

The analysis presented in this and other accompanying reports can be further improved following the step-wise approach as recommended by the UNFCCC Decision 12/CP.17 Guidance on systems for providing information on how safeguards are addressed and respected and modalities relating to forest reference emission levels and forest reference levels as referred to in decision 1/CP.16. This allows the use of available data (even if uncertain) to provide a starting point for RL establishment with simple projections, based on historical data (Step 1), progressively updating the RL based on more robust national datasets for country-appropriate extrapolations and adjustments (Step 2) and ultimately basing the RL on more spatially explicit activity data and driver-specific information support (Step 3). This improvement is necessary in order to achieve acceptable levels of accuracy to allow Nepal to get performance-based payment for REDD activities.

It is therefore recommended to proceed with a step-wise approach towards the National Reference Levels, starting with the large-scale jurisdictional projects at sub-national level. The SMF-Based Emission Reduction Program in Nepal's Terai Arc Landscape is an important step towards that direction. It is possible to improve national reference levels with the LiDAR-Assisted Multi-source Program (LAMP) approach, as it has been implemented for establishing Reference Levels (RLs) in the Terai Arc Landscape (TAL) comprising 12 districts. This approach was welcomed and endorsed by the Forest Carbon Partnership Facility (FCPF) of the World Bank.

If the entire country is covered by a reliable and easily updatable methodology for setting up RLs and subsequent Monitoring, Reporting and Verification (MRV) then domestic leakage will have been addressed at the same time. In case of LAMP only a small sample (less than 2 % coverage) of airborne LiDAR data needs to be acquired once. Then, the reference level can be updated as new satellite data and field surveys (for verification) become available.

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ANNEX 1: APPLICATION OF VEGETATION INDICES TO GENERATE FRACTIONAL VEGETATION COVER USED TO MAP DEGRADATION AND STRATIFY CARBON DENSITY

Fractional cover (FC) is the percentage of vegetative cover on the ground. In the context of a remotely-sensed image, the FC values represent the percentage of vegetative cover present in each pixel. The Landsat vegetation index-based approach of generating fractional vegetation cover as applied by Xiao and Moody (2005) and Wang et al (2005) was followed. According to Wang et al (ibid), using multiple Landsat reflectance images to assess forest degradation is on one hand time consuming as it requires intensive computation, but also prone to some external factors such as sun-target-sensor geometry on the other hand. When vegetation indices are used, they can suppress the spectral variation of reflectances resulting from these external influences and make the mixture model less sensitive to those factors. Mixture model based on vegetation index (VI) is based on the assumption that the vegetation index value of a given pixel is the linear combination of the VI value of green vegetation and bare soil, weighed by their relative proportions, (Xiao and Moody, 2005). The following formulation was thus followed to generate surface map of fractional vegetation cover (*fc*) (Wang *et al*, 2005):

$$\mathrm{fc} = \frac{\mathrm{VI} - \mathrm{VI}_{\mathrm{open}}}{\mathrm{VI}_{\mathrm{canopy}} - \mathrm{VI}_{\mathrm{open}}},$$

Where VI_{canopy} and VI_{open} are two end members empirically obtained from the ETM+ image using a statistical analysis. VI_{open} is the VI value of a pixel containing 0% vegetative cover, and VI_{canopy} is the VI value of a pixel containing 100% vegetative cover. A modified soil adjusted vegetation index (MSAVI) was employed to make mixture model that would be run to generate fractional vegetation cover. Wang et al (2005) had demonstrated that MSAVI, in comparison to other indices, is more sensitive and thus suitable for tropical forests with high vegetation abundance.

Once a value had been determined for each of the two variables, the *fc* formula was then applied to the MSAVI image on a scene-by-scene to generate a preliminary *fc* image (fc_{prelim}). The table below summarizes these values for each target scene. This preliminary image was then modified, to have values ranging from 0 to 1. Due to the well-documented nature of vegetation indices saturating at the upper end in tropical environments, it is quite common to end up with fc_{prelim} values greater than 1. It is also common to have fc_{prelim} values below 0, as the vegetation index value of water can be less than bare soil. Therefore, we were working under the assumption that our VI_{open} and VI_{canopy} values were accurate. So rather than stretching the values to fit between 0 and 1, we simply changed all negative fc_{prelim} values to 0 and all fc_{prelim} values greater than 1 to 1. This way, fractional cover was generated for every target Landsat scene.

Table 14: Parameters used to generate MSAVI on scene-by-scene basis for 2000 nominal year

Path/row	**Date of acquisition**	**MSAVI:** VI_{canopy}	**MSAVI:** VI_{open}
139/041	2001/Dec/26	0.79	-0.53
139/042	2001/Oct/26	0.74	-1.30
140/041	2000/Oct/30	0.84	-0.42

Path/row	**Date of acquisition**	**MSAVI:** VI $_{canopy}$	**MSAVI:** VI $_{open}$
140/042	1999/Oct/28	0.83	-0.32
141/040	2000/Nov/22	0.77	-0.28
141/041	2001/Dec/27	0.76	-0.28
141/042	2001/Oct/24	0.86	-1.33
142/040	1999/Dec/13	0.80	-0.45
142/041	1999/Dec/13	0.84	-0.24
143/039	2000/Oct/03	0.70	-0.73
143/040	2001/Dec/25	0.82	-0.23
143/041	1999/Oct/17	0.83	-0.22
144/039	2001/Oct/13	0.82	-0.30
144/040	1999/Nov/09	0.81	-0.19

ANNEX 2: LAND COVER MAPS FOR THREE REFERENCE TIME POINTS (1990, 2000 AND 2010)

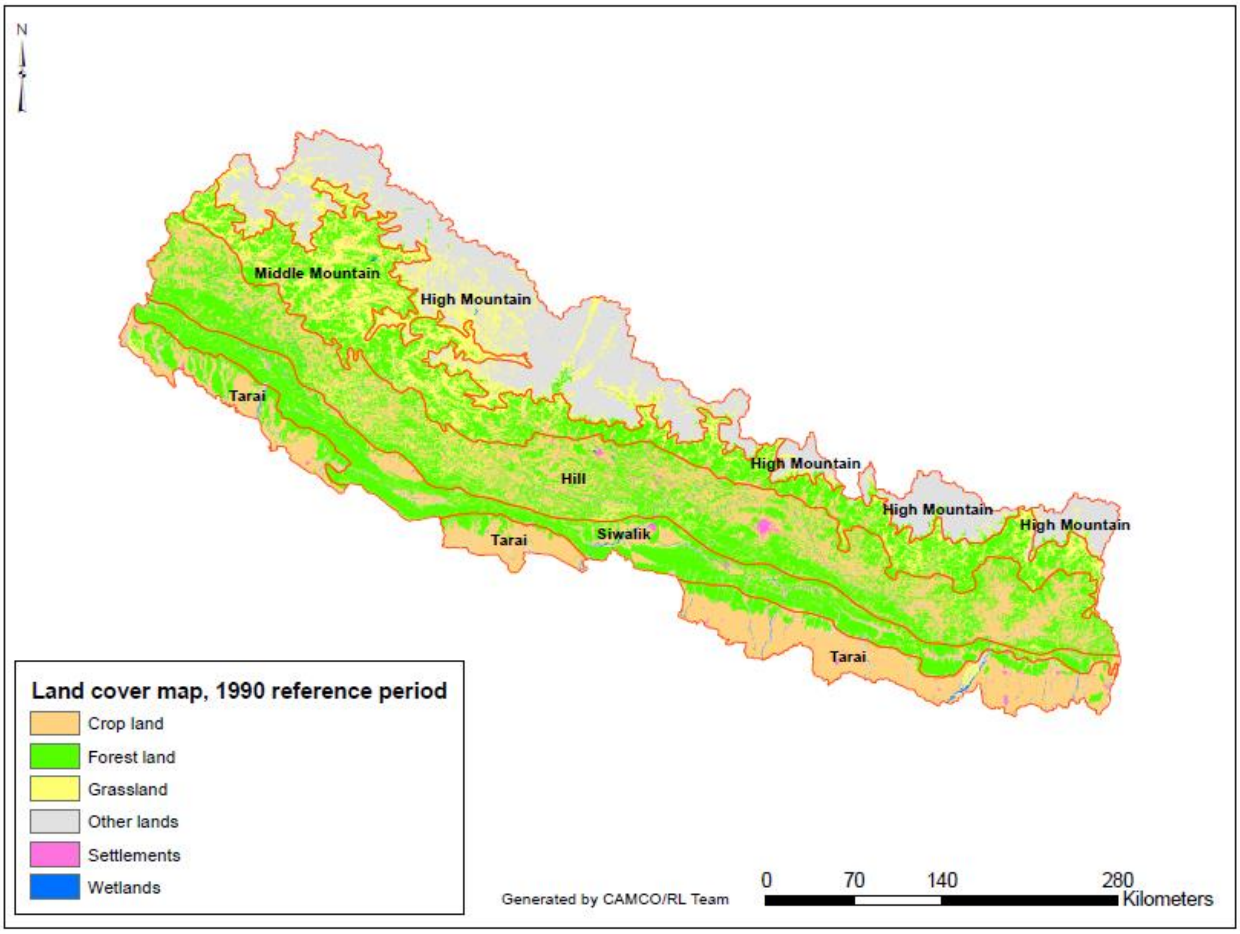

Figure 2: Land Cover Map for 1990

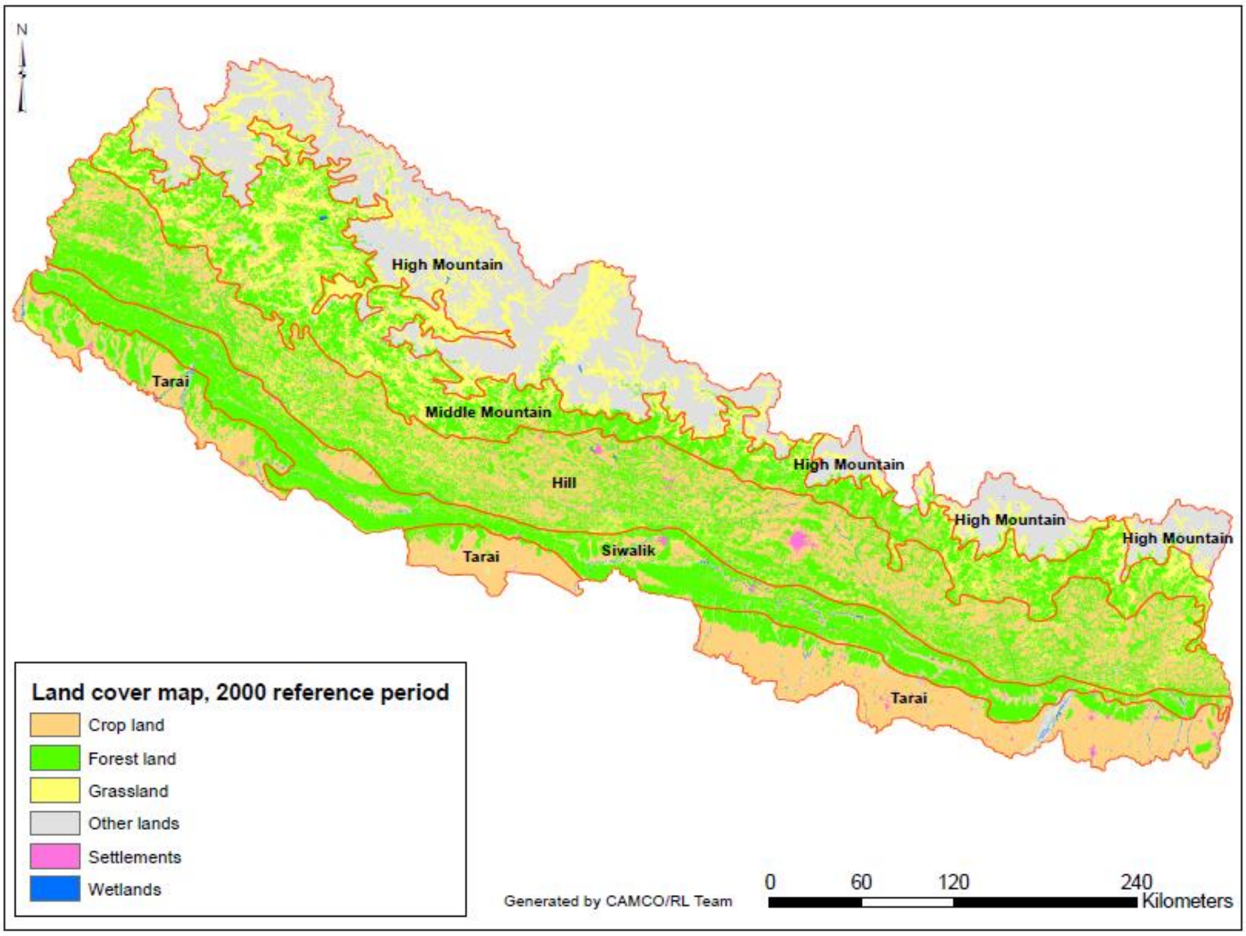

Figure 3: Land Cover Map for 2000

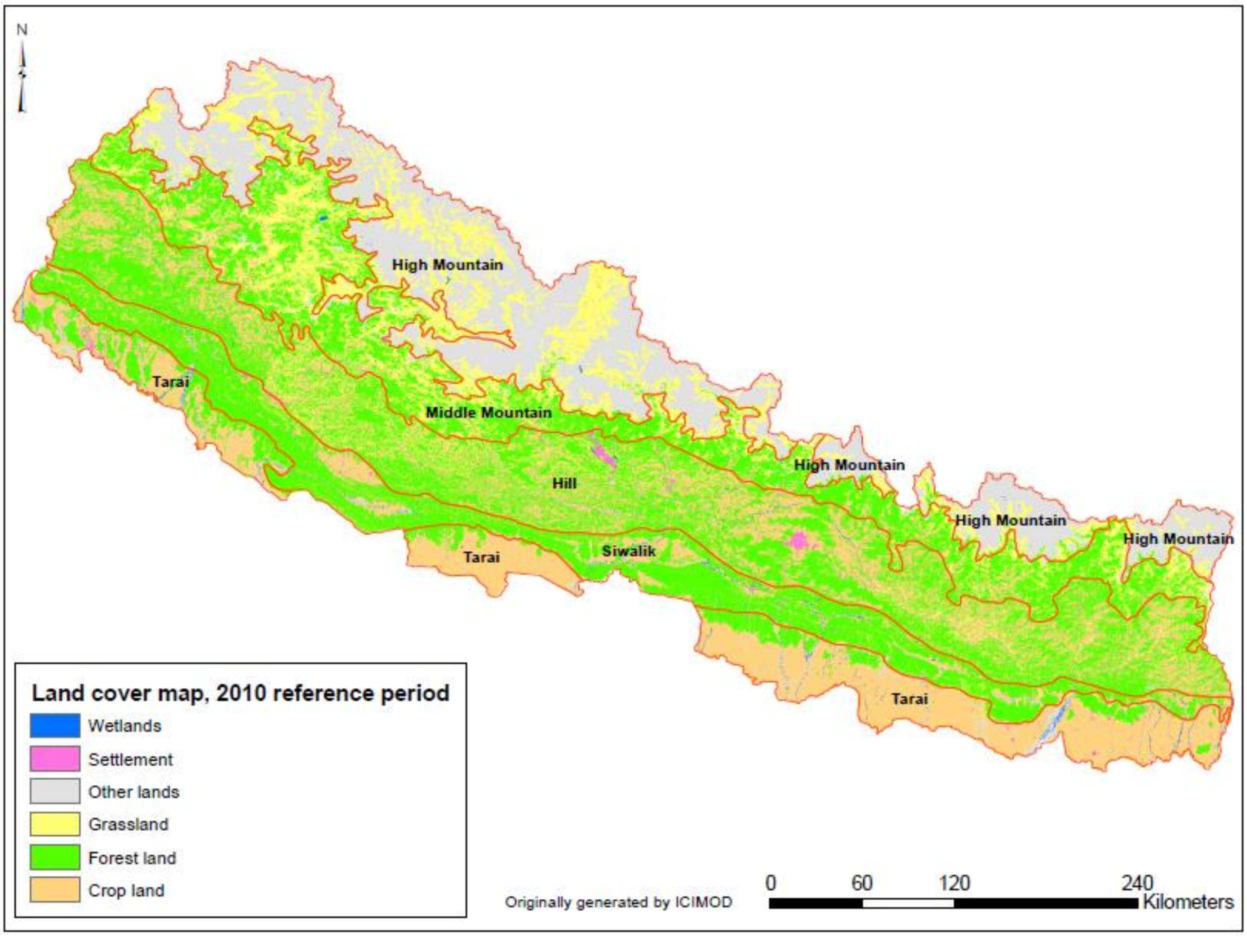

Figure 4: Land Cover Map for 2010

ANNEX 3: FOREST CANOPY DENSITY MAPS FOR THREE REFERENCE TIME POINTS (1990, 2000 AND 2010)

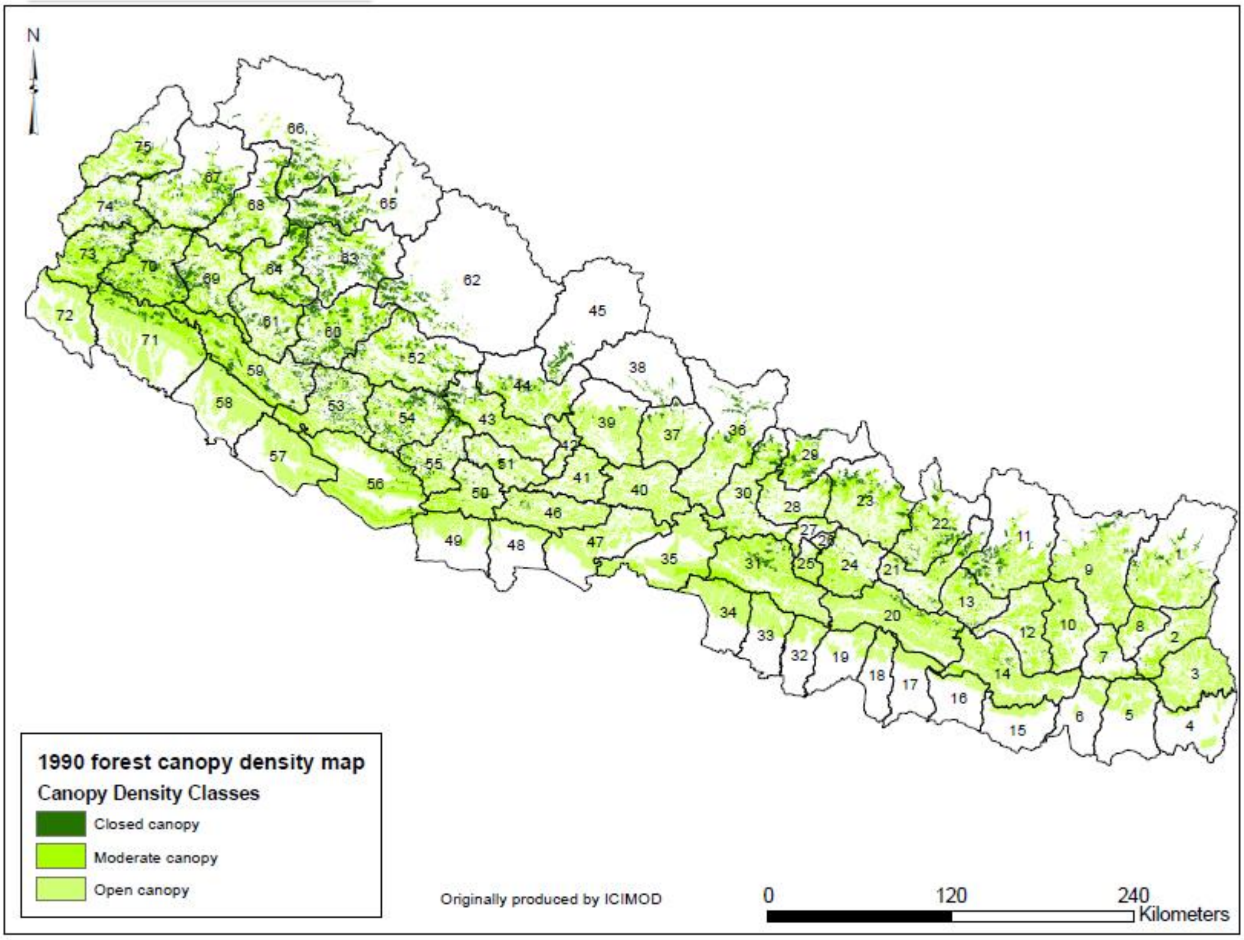

Figure 5: Forest Canopy Density Map for 1990

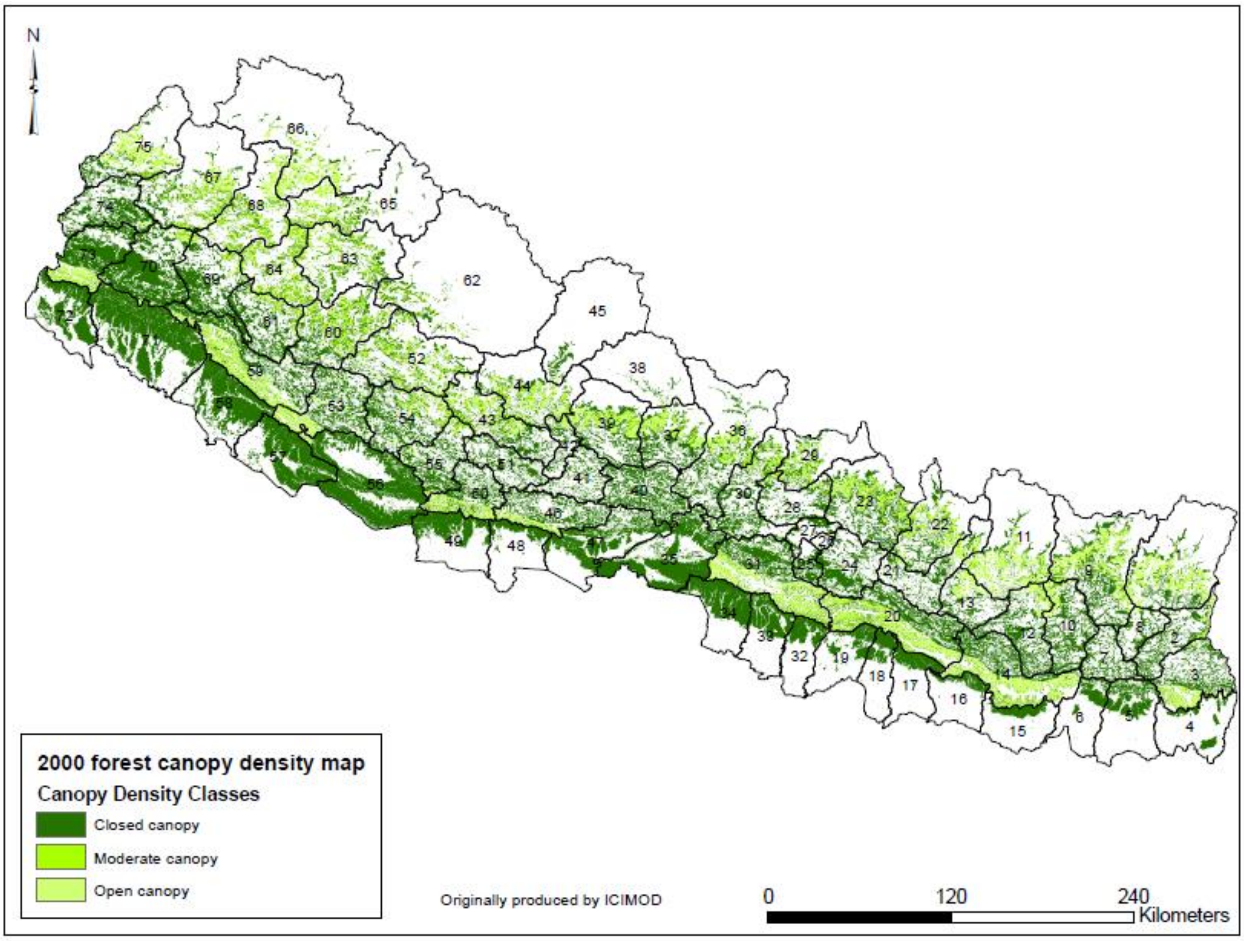

Figure 6: Forest Canopy Density Map for 2000

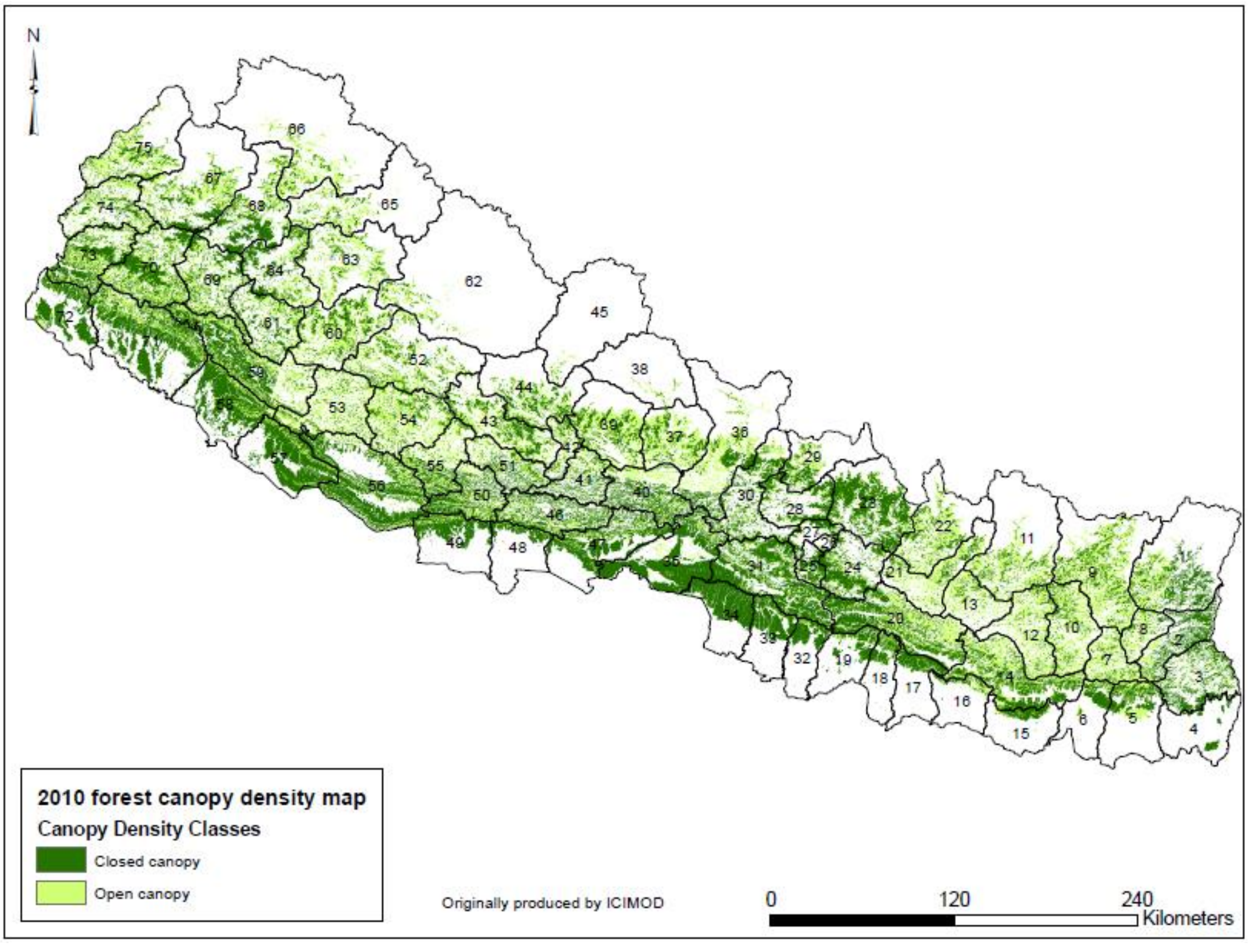

Figure 7: Forest Canopy Density Map for 2010

ANNEX 4: LAND COVER CHANGE OR TRANSITION MAPS ASSOCIATED WITH THE SPATIAL CHANGE MATRICES

1990-2000 Overall Land Cover Transition Map

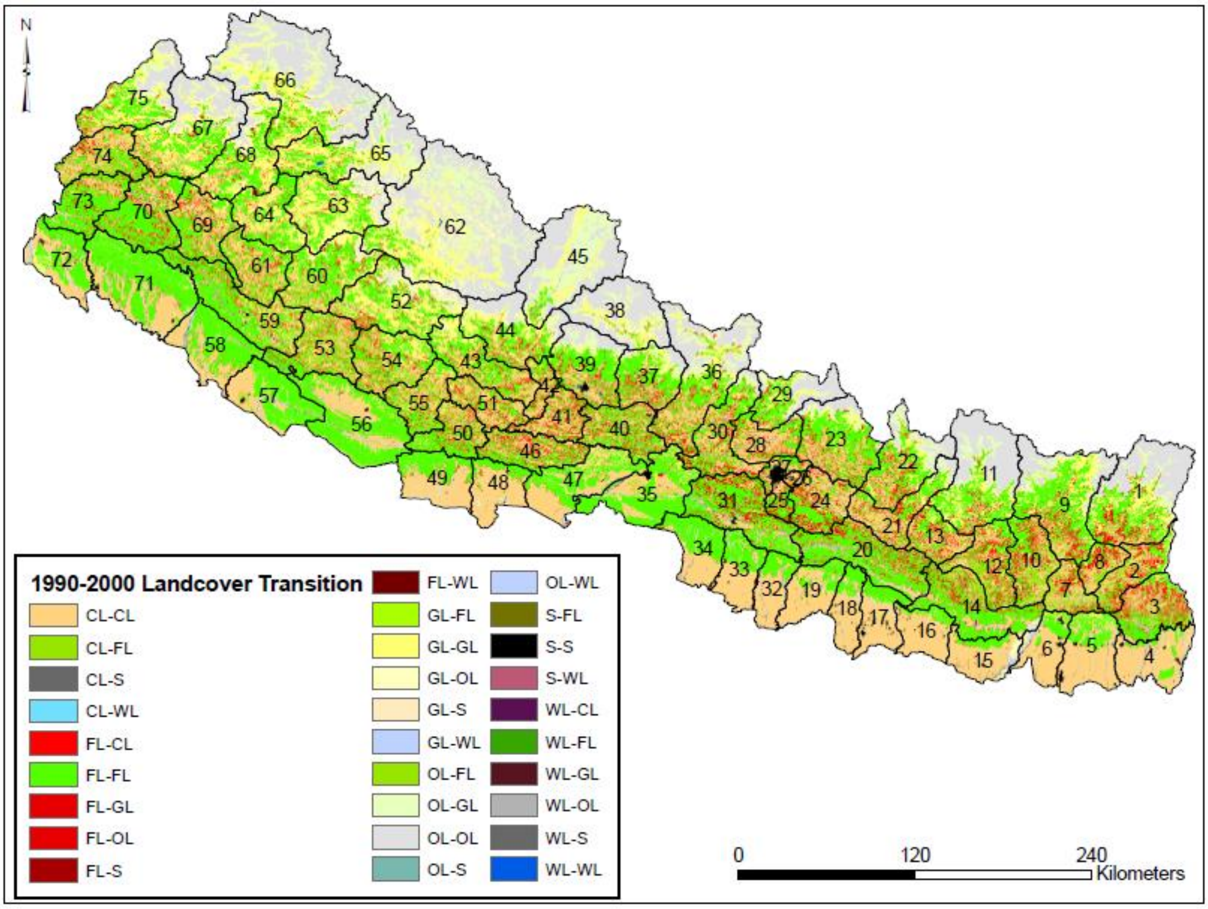

Figure 8: Overall Land Cover Transition (1990-2000)

2000-2010 Overall Land Cover Transition Map

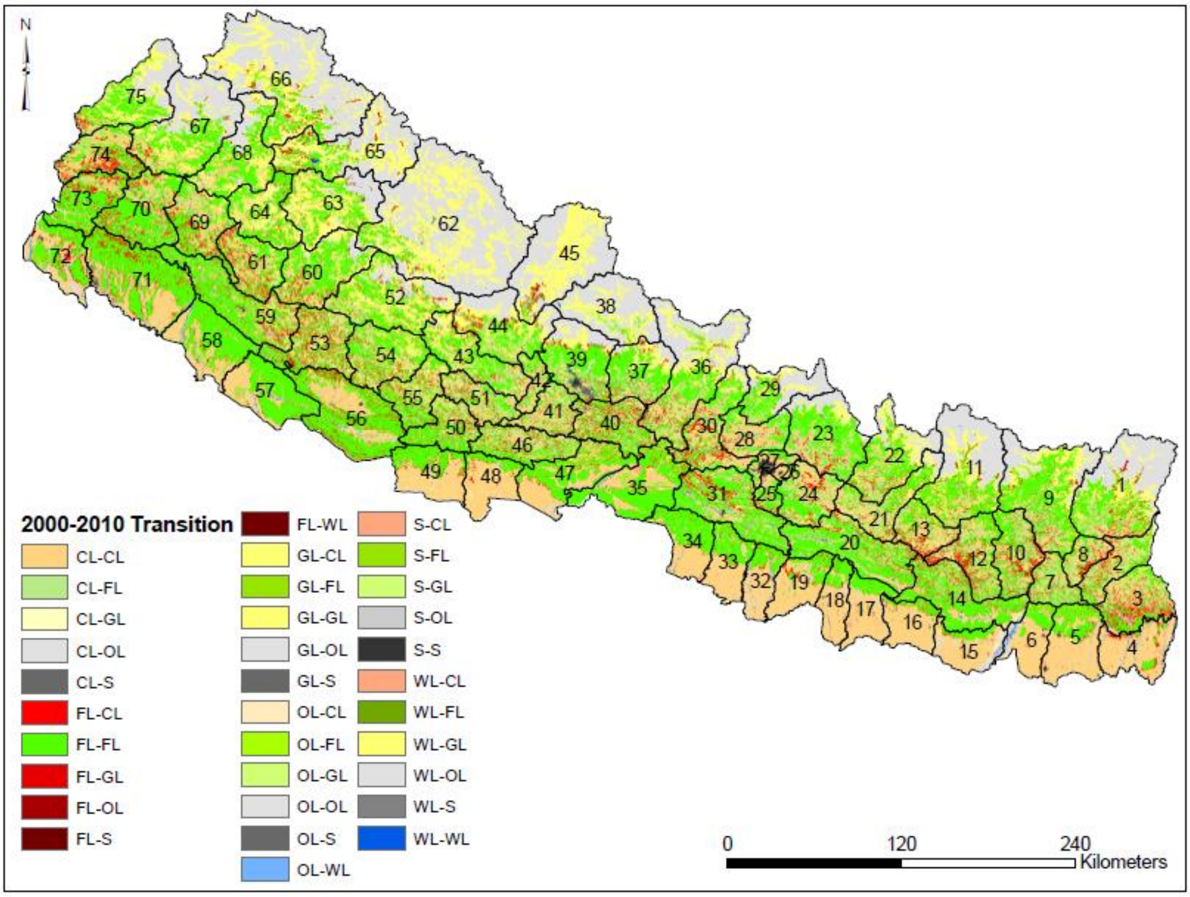

Figure 9: Overall Land Cover Transition Map (2000-2010)

1990-2010 Overall Land Cover Transition Map

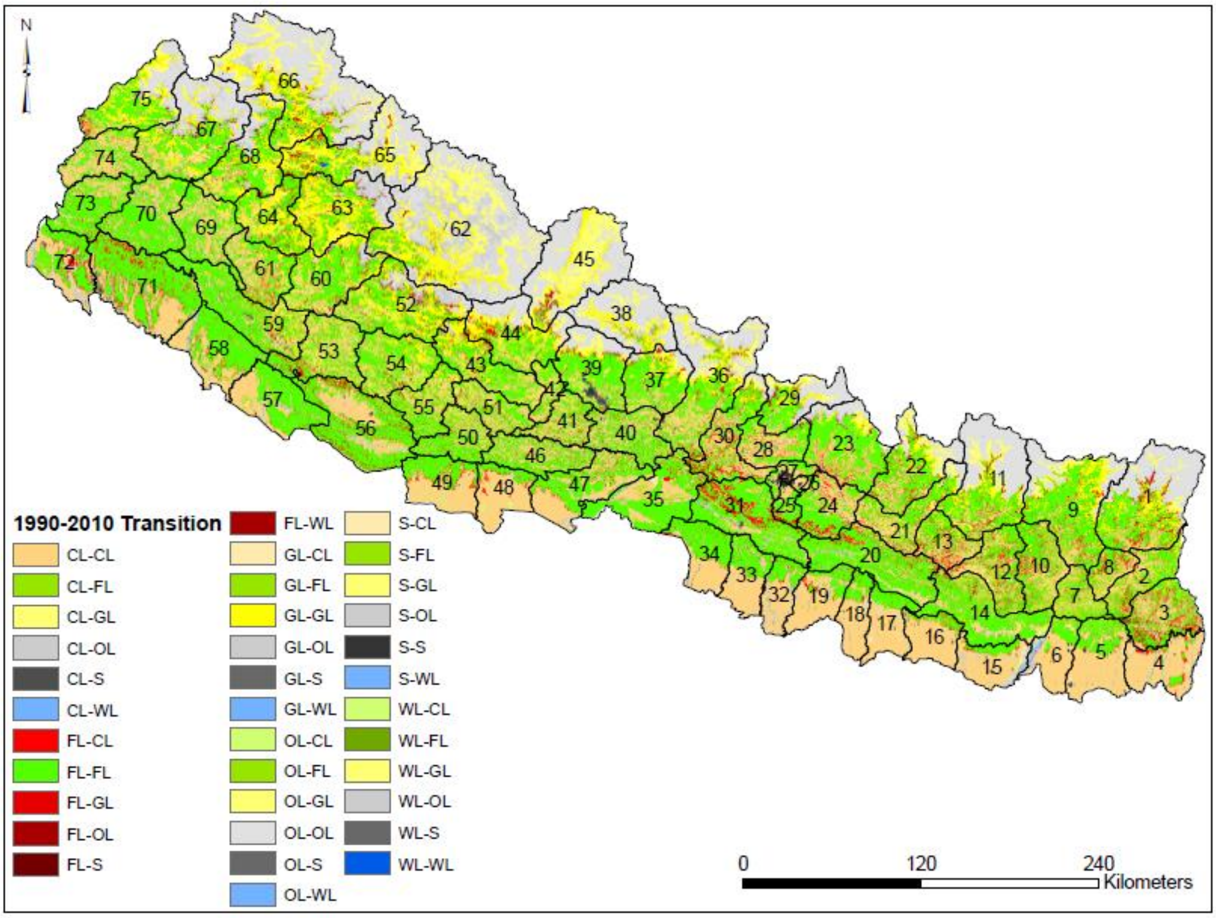

Figure 10: Overall Land Cover Transition Map(1990-2010)

1990-2000 FOREST TRANSITION (ACROSS CANOPY CLASSES)

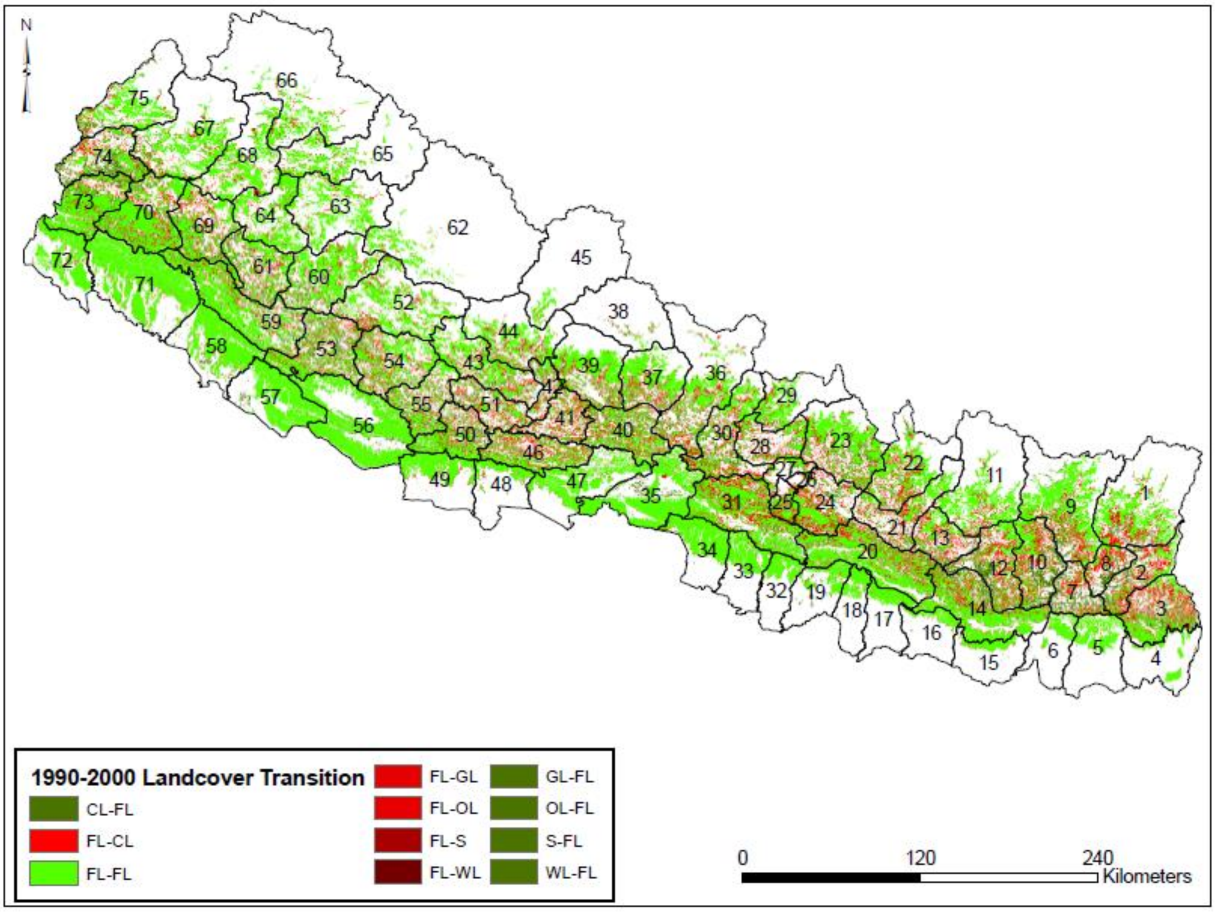

Figure 11: Land Cover Transition across Canopy Classes (1990-2000)

2000-2010 FOREST TRANSITION (ACROSS CANOPY CLASSES)

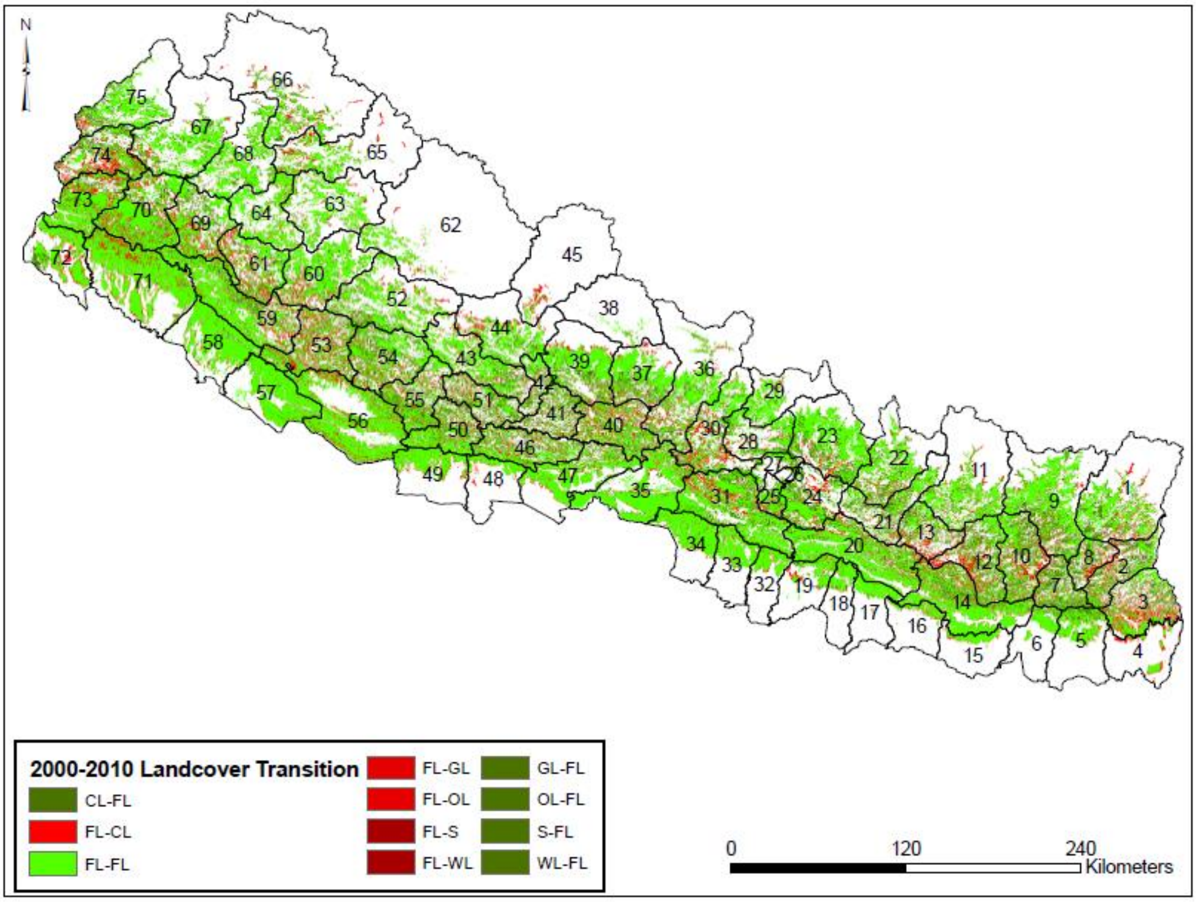

Figure 12: Land Cover Transition across Canopy Classes (2000-2010)

ANNEX 5: ACCURACY ASSESSMENT OF LAND COVER/FOREST COVER CHANGE ANALYSIS

INTRODUCTION

Before advancing the data processing to 'Land-cover change analysis and generation of activity data' stage, it is critical to assess the quality of geographical datasets that goes into the process. In this case, quality of the benchmark land-cover maps corresponding to the three reference periods were assessed, using different approaches depending on the availability of ancillary data for the respective reference period. Accuracy assessment was carried out in both qualitative and quantitative.

- Qualitatively, the products have been compared with existing maps/spatial data. This check forms a general control on the spatial distribution and class labels of the maps.

- Quantitatively, available reference data was used to evaluate the accuracy of the land cover maps.

With respect to quantitative accuracy assessment, effort was made to construct the confidence intervals for the key accuracy measures. This was meant to give an idea of these accuracies estimates. The following sub-sections elaborate on the procedure applied and the results generated.

1. Accuracy assessment of land cover map for 2010 time point

For the purpose of accuracy assessment of ICIMOD generated land cover map (2010), available FRA dataset was used as a reference, since it has been prepared using very high resolution satellite images (Rapid Eye) and complimented by extensive field survey. This dataset was a land cover map showing distribution of three major land cover types, namely forest, other wooded land, and non-forest as well as ground-based reference data. Subsequent accuracy assessment followed three approaches described below with their respective results. The fourth approach used the WWF field survey data as the reference data.

a) In the first approach, a mask of the 2010 land cover map generated by ICIMOD was extracted over Terai and Siwalik, corresponding to the extent of the reference data. For comparison, the mask was reclassified for purpose of matching the classified categories with those of reference FRA dataset. Comparative analysis was implemented, where the extent of the three major land cover types (forest, other wooded land, and non-forest) were compared between the reference FRA dataset and the corresponding ICIMOD 2010 dataset. Comparison was only performed over Terai and Siwalik physiognomic zones, as summarized in Table 15 below.

Table 15: Comparative analysis of the extent of land-cover distribution between FRA dataset and ICIMOD 2010 dataset

	FRA Reference dataset	Corresponding FINAL 2010 Mask Dataset
Comparison over Terai physiognomic zone		
Forest	411,580	401,384
Shrub	9,502	9,166
Non-forest	1,595,916	1,592,221
Comparison over Siwalik physiognomic zone		
	FRA Reference dataset over Siwalik	Corresponding FINAL 2010 Mask Dataset
Forest	1,315,532	1,369,778
Shrub	52,566	7,579
Non-forest	533,657	517,456

In Terai, there is a good match between data generated by ICIMOD compared to the final map generated by FRA. For Siwalik, the reference dataset provided by FRA was then provisional and therefore not much could be inferred regarding accuracy of the data. Nonetheless, the ICIMOD dataset underestimated the shrub cover and overestimated the forest cover in Siwalik. The non-forest cover was comparable between the two datasets.

b) The second approach was a comparative analysis similar to the first approach. Here, forest cover estimated by WWF in Terai Arc Landscape and the corresponding ICIMOD 2010 dataset were compared. Initial estimate of forest cover by WWF was only within the boundary of the forest mask defined by the Topographic Base Maps (1998) of the Department of Survey. Therefore, for comparison purpose, the 2010 ICIMOD dataset had to be clipped to the extent of the Topographic Base Maps (1998), especially the estimated forest cover, to allow comparison with WWF dataset. For this reason, the comparison was only possible between the forest estimates. The summary in Table 7 below shows that apart from the district of Rautahat where estimates of the two datasets are closely matching (27,667 ha versus 25,659 ha respectively), the estimates for the other districts exhibit great variation existing between ICIMOD 2010 dataset and WWF dataset by over 25% difference, the former yielding higher estimates that the latter. This difference is highest in Kapilbastu (134%), Dang (78%), Rupandehi (-56%), Bardiya (44%), Bara (43%), Nawalparasi (42%), Kailali (41%), Parsa (31%), Kanchanpur (26%), Banke (25%), and Chitawan (23%).

To check the divergence observed between the two datasets in Rupandehi and Kapilbastu districts, FRA dataset for Terai and Siwalik (provisional) were used. The forest cover estimated by FRA was clipped to the extent of the forest mask defined by Topographic Base Maps (1998) in order to allow for comparison with the above two datasets since both had the same constraint. As shown in Table 16 below, in Rupandehi district, the forest cover within the forest mask previously defined by Topographic Base Maps (1998) was 21,716 ha, while that of Kapilbastu district was 53,430 ha. These estimates were closely matching those by estimated by ICIMOD 2010, further validating the plausibility of the latter dataset.

Table 16: Comparative analysis of the extent of forest cover between WWF dataset and ICIMOD 2010 dataset

District Name	2010 ICIMOD forest cover estimate over corresponding area	WWF 2011 estimate (within forest mask delineated by Topographic Base Maps)	Variation between ICIMOD map and WWF map	% variation
RAUTAHAT	27,667	25,659	2,008	8
BARA	46,961	32,933	14,028	43
PARSA	74,436	56,891	17,545	31
CHITAWAN	143,182	115,969	27,213	23
NAWALPARASI	100,962	71,280	29,682	42
RUPANDEHI	22,477	50,544	-28,067	-56
KAPILBASTU	56,349	24,040	32,309	134
DANG	181,022	101,711	79,311	78
BANKE	117,293	93,979	23,314	25
BARDIYA	117,720	81,544	36,176	44
KAILALI	185,799	131,845	53,954	41
KANCHANPUR	71,282	56,360	14,922	26
Total Forest Cover (Ha)	1,145,150	842,755	302,395	36

Table 17: Estimates of FRA dataset over Rupandehi and Kapilbastu districts (only within the forest mask previously defined by Topographic Base Maps (1998))

	Terai Forest	Siwalik Forest	Total
RUPANDEHI	4,702	17,014	**21,716**
KAPILBASTU	34,966	18,464	**53,430**

c) In the third approach, the FRA biomass-plot data (over Terai) was used as reference to assess the accuracy the ICIMOD 2010 data (over Terai and corresponding to the reference data). The 355 biomass plots buffered by 20 m linear distance round the point, this corresponding to the largest concentric circular plot laid by FRA. The attributed dataset (LRMP-based attributes) was first reclassified into three main land cover classes namely ‘forest land’, ‘shrubs’ and ‘non forestland’ and the cross-tabulated with the ICIMOD 2010 data yielding a confusion matrix (showing producer’s, user’s and overall accuracy) of summarized in Table 18 below.

For Terai zone, the overall accuracy of ICIMOD 2010 is about 90%, with both forest and non-forest yielding high user’s and producer’s accuracies. However, the accuracies of ‘Shrubs’ is very poor, perhaps because of the low coverage of this category in Terai as well as the proportion of reference data representing this category. Generally, the result of the accuracy assessment over Terai was consistent with the results based on comparative statistics that had indicated good match between the reference FRA dataset and the corresponding ICIMOD 2010 dataset.

Table 18: Accuracy assessment of ICIMOD 2010 dataset (over Sub-National Jurisdiction - Terai zone) using FRA dataset as reference data and based on three main land cover classes

		REFERENCE DATA				
		Forest land	**Shrubs**	**Non-forest**	**Total Classified areas**	**User's accuracy (percent correct)**
CLASSIFIED IN SATELLITE IMAGE AS:	**Forest land**	**18.1**	0.18	0.9	19.89	94.6
	Shrubs	0	**0**	0.27	0.27	0.0
	Non-forest	1.8	0.09	**9.36**	11.25	83.2
	Total Reference Areas	20.61	0.27	10.53	31.41	
	Producer's accuracy (percent correct)	91.3	0.0	88.9		
	Overall accuracy					**89.7**

d) The fourth approach was applied at national scale, assessing the accuracy of ICIMOD generated land cover (2010) using the FRA sample plots as reference data. Over 2000 sample plots were systematically distributed across Nepal as part of FRA Project. Of this plots, 1949 had information regarding land cover types where key attributes namely ‘FAO-Land use Class 2’ and ‘LRMP Land use Class’ had been populated.

For purpose of accuracy assessment, the ‘LRMP Land use Class’ attribute of the sample plots was first re-classified into three corresponding sub-categories, namely ‘Forest’, ‘Shrubs’ and ‘Non-forestland’. Further reclassification matched the records in the ‘LRMP Land use Class’ attribute into the corresponding six ‘IPCC Classes’ namely ‘Forest land’, ‘Cropland’, ‘Settlement’, ‘Grassland’, ‘Wetland’, and ‘Other lands’. Tables 19 and 20 below show the proportion of observations corresponding to each reclassified land cover category.

Table 19: No. of observations in the in the FRA reference data among the three main land cover classes

Classes	No. of observations
Forests	1374
Shrubs	100
Non-forest	475

Table 20: No. of observations in the in the FRA reference data among the six IPCC land cover/land use classes

IPCC Classes	No. of observations
Forest land	1374
Crop land	368
Settlement	22
Grassland	129
Wetlands	25
Other lands	31

Since each sample plot was represented by coordinates of the cluster-point, then each point was buffered by 20m linear distance round the point, this corresponding to the largest concentric circular plot laid by FRA. Implementation of the national-scale accuracy assessment proceeded, first based on the three land use/land cover categories (forest land, shrubs and non-forest) similar to (b) above. Subsequent accuracy assessment was based on the six IPCC classes. For each of these accuracy assessment, the corresponding confusion matrices representing the measures of accuracy is summarized in Tables 21 and 22 below.

Table 21: National-scale accuracy assessment of ICIMOD 2010 dataset using FRA dataset as reference data and based on the three main classes (forest, shrubs, non-forest)

	REFERENCE DATA					
		Forest land	**Shrubs**	**Non-forest**	**Total Classified areas**	**User's accuracy (% correct)**
CLASSIFIED IN SATELLITE IMAGE AS:	**Forest land**	**139.32**	6.03	16.83	162.18	85.9
	Shrubs	3.24	**0.27**	1.53	5.04	5.4
	Non-forest	23.04	5.31	**37.26**	65.61	56.8
	Total Reference Areas	165.6	11.61	55.62		148.1
	Producer's accuracy (percent correct)	84.1	2.3	67.0	232.83	
	Overall accuracy					**76.0**

Table 22: National-scale accuracy assessment of ICIMOD 2010 dataset using FRA dataset as reference data and based on the six IPCC land cover classes

	REFERENCE DATA								
		Forest land	**Crop land**	**Settle-ment**	**Grass - land**	**Wet-land**	**Other lands**	Total Classified areas	**User's accuracy (percent correct)**
	Forest land	**139.32**	13.68	0.54	7.2	0.63	0.81	162	85.9
CLASSIFIED IN SATELLITE IMAGE AS:	**Crop land**	21.42	**26.82**	1.89	6.39	1.53	2.16	60	44.5
	Settlement	0.09	0.81	**0**	0	0	0	1	0.0
	Grassland	3.69	1.17	0	**0.9**	0.18	0.18	6	14.7
	Wetlands	0.27	0	0	0	**0.81**	0	1	75.0
	Other lands	0.81	0.45	0	0.36	0.18	**0.54**	2	23.1
	Total Reference Areas	165.6	42.93	2.43	14.85	3.33	3.69	232.83	
	Producer's accuracy (percent correct)	84.1	62.5	0.0	6.1	24.3	14.6		
	Overall accuracy								**72.3**

In the first instance where accuracy of ICIMOD 2010 data is assessed based on the three main classes (forest, shrubs, and non-forest), the overall accuracy is about 76%. Forest has the highest producer's and user's accuracies (84% and 86% respectively) while corresponding accuracies for non-forest is moderate (67% and 57% respectively). 'Shrubs' has the lowest accuracy level. In the second instance where accuracy of ICIMOD 2010 data is based on the six IPCC land-use classes, the pattern is similar to the first instance as noted in Table 6, with slightly lower overall accuracy of about 72%. Again, forest land has the highest accuracy level while that of crop land is moderate.

Analysis of confidence intervals of the key measures of accuracies related to ICIMOD 2010 data based on the six IPCC land-cover classes (summarized in Table 23) is corresponding with measured values of accuracies, with forest class trailed by crop land class yielding the highest confidence interval, a pattern that can be explained by the theory confidence interval. The width of these confidence intervals is influenced by the sample size and by the size of the accuracy measures themselves, explaining the reason why forest class has high confidence interval (74.8% to 97%), given that it has large sample size (1374) and high user's accuracy measure (85.9%). By extension, this implies higher precision of the estimated accuracy measure of the forest class in comparison to other classes.

Table 23: Confidence intervals of accuracies estimates related to ICIMOD 2010 data based on the six IPCC land cover classes.

Land cover category	Confidence interval of user's accuracy measure
Forest	74.77% to 97.03%
Crop land	34.98% to 54.10%
Grassland	2.06% to 27.34%
Other lands	-100.03% to 146.19%

2. Land Cover Map for 2000

Quality assessment of the 2000 land cover map was accomplished in two ways. First, the forest extent estimated by RL Team was compared with forest mask defined in the Topographic Base Maps of 1998. The second approach entailed comparing forest extent in High Mountain Regions of Nepal estimated by RL Team against those corresponding estimates recorded in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012".

a. The GoN Survey Department employed the criterion of 10% as the minimum canopy cover in defining the forest mask, captured in the Topographic Base Maps of 1998. This forest mask was compared with corresponding estimate generated by RL Team for 2000 and the result shown in Table 24 indicate a close match, both on wall-to-wall basis but also per physiognomic zone.

Table 24: Comparison of the forest mask defined by Topographic Base Maps of 1998 and the by RL Team Product for 2000

Product	2000 RL Team Product (Ha)	Survey Department 1998 Topographic Base Maps (Ha)
Wall-to-wall		
Nepal	5,356,414	5,583,878
Physiographic zones		
Terai	435,857	427,997
Siwalik	1,373,700	1,341,806
Hills	1,936,241	1,930,956
Mid Mountain	1,462,309	1,675,151
High Mountain	147,739	181,574

b. In the second approach, the estimated extent of land cover distribution sourced from Department of Survey, TIPS/DoF, Ecological Maps 2002 and cited in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012" were considered for comparison with corresponding estimates generated by RL Team for 2000. Table 2.4 of the former study summarized the land cover distribution of 25 district considered as High Mountain Region. The estimates from that table was re-coded into 3 categories namely forest, other wooded land and non-forests and then compared with corresponding estimates generated by RL Team for 2000 reference period. The results are shown in Table 25 below.

NB: The list of exact 25 districts considered as High Mountain Region is needed for accurate comparison and subsequent interpretation.

Table 25: Comparison of forest mask (over High Mountain Region) estimated by RL Team for 2000 reference period against estimates reported in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012, Table 2.

	2002 Ecological Maps, Department of Survey, TIPS/DoF (Ha)	2000 RL Team Product (Ha)
High Himal		
Forest	178,200	147,245
Shrubs	102,410	53,308
Non Forest	3,222,720	3,341,669
Total	**3,503,330**	**3,542,222**
High Mountain		
Forest	1,383,370	1,462,270
Shrubs	236,370	147,748
Non Forest	709,270	1,407,652
Total	**2,329,010**	**3,017,669**

In the High Himal zone, forest and non-forest estimates by the RL Team are closely matching the estimates by the 2002 Ecological Maps, Department of Survey, TIPS/DoF. 2000 RL Team product, however, seem to underestimate the shrubs cover. In the High Mountain zone, the 2000 RL Team seems to over-estimate the non-forest cover and underestimate the shrubs cover in comparison to the estimate recorded by 2002 Ecological Maps, Department of Survey, TIPS/DoF. Nonetheless, forest estimates based on the two products are fairly corresponding.

c. The FRA inventory-plots data (spread across the country) were also used as reference data, (in particular the 1,949 data-plots that had been re-organized and applied for accuracy assessment of 2010 ICIMOD land cover map). For accuracy assessment, the 2000 data (based on the six IPCC land-use classes) was cross-tabulated with the buffered dataset (of the 1,949 data-plots) which was based on the field bearing the aggregated "Forest land" class. The result is summarized in Table 10 below. The overall accuracy is 68.5%. Forest land has the highest producer's accuracy (84%) followed by crop land (63%). Again, forest land has the highest user's accuracy (84%) at a confidence interval of 73% to 95% while crop land has 42% user's accuracy at 32% to 51% confidence interval. The other classes have very low producer's and user's accuracies and equally low confidence intervals. Similar to the analysis undertaken to support accuracy assessment of ICIMOD 2010 data based on the six IPCC land-cover classes, confidence intervals of the key measures of accuracies related to 2000 RL Team Product based on the six IPCC land-cover classes was also implemented, (results summarized in Table 26).

Table 26: Accuracy assessment of 2000 RL Team Product (land cover map)

	REFERENCE DATA								
		Forest land	**Crop land**	**Settle-ment**	**Grass-land**	**Wet-land**	**Other lands**	Total Classified areas	**User's accuracy (percent correct)**
	Forest land	**132.8**	14.9	0.99	6.57	0.99	1.17	157	84.3
CLASSIFIED IN SATELLITE IMAGE AS:	**Crop land**	23.31	**24.0**	1.35	6.39	0.45	1.44	57	42.2
	Settlement	0	0.81	**0**	0	0	0	1	0.0
	Grassland	8.37	2.61	0.09	**1.71**	0.54	0.81	14	12.1
	Wetlands	0.27	0	0	0	**0.72**	0	1	72.7
	Other lands	0.99	0.54	0	0.18	0.63	**0.27**	3	10.3
	Total Reference Areas	165.7	42.9	2.43	14.85	3.33	3.69	232.9	
	Producer's accuracy (percent correct)	84.1	62.5	0.0	6.1	24.3	14.6		
	Overall accuracy								**68.5**

Table 27: Confidence intervals of accuracies estimates related to 2000 RL Team Product based on the six IPCC land cover classes.

Land cover category	**Confidence interval of user's accuracy measure**
Forest	73.24% to 95.42%
Crop land	32.87% to 51.48%
Grassland	5.65% to 18.54%
Other lands	-38.58% to 59.27%

As observed in Table 26 and 27, the measured values of accuracies are corresponding with the derived confidence intervals. For example, with forest class trailed by crop land class have the highest confidence interval (73% to 95% for forest and 32.9% to 51.5% for crop land) while grassland and other lands have the lowest. This pattern is matching with pattern of accuracies assessment, implying higher precision of the estimated accuracy measure of the forest class in comparison to other classes.

3. Accuracy assessment of land cover map for 1990 time point

For purpose of assessment of quality of the 1990 land cover data, the estimated extent of land cover distribution sourced from Master Plan for Forestry Sector (MPFS, 1988) and cited in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012" were considered for comparison with corresponding estimates generated by ICIMOD for 1990. Table 2.1 of the former study summarized the land cover distribution of 25 districts considered as High Mountain Region. The estimates from that table was re-coded into 3 categories namely forest, other wooded land and non-forests and then compared with corresponding estimates generated by ICIMOD for. The results are summarized in Table 28 below and show good correspondence between the two datasets.

NB: The list of exact 25 districts considered as High Mountain Region is needed for accurate comparison and subsequent interpretation.

Table 28: Comparison of forest mask (over High Mountain Region) estimated by ICIMOD for 1990 against estimates reported in the report "Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012, Table 2.1"

	MPFS, 1988 (Ha)	1990 ICIMOD Product (Ha)
High Himal		
Forest	155,000	152,763
Shrubs	67,000	93,624
Non Forest	3,128,000	3,280,836
Total	**3,350,000**	**3,527,223**
High Mountain		
Forest	1,639,000	1,562,584
Shrubs	176,000	194,447
Non Forest	1,145,000	1,217,728
Total	**2,960,000**	**2,974,758**

In both High Himal and High Mountain, the estimates are fairly corresponding. However, RL Team product seems to have over-estimated the shrubs cover in High Himal.

Like the other two land cover maps (i.e. maps representing 2010 and 2000), FRA inventory-plots data (spread across the country) was used as reference data, in particular the 1,949 data-plots that had been re-organized. For accuracy assessment, the 1990 data (based on the six IPCC land-use classes) was cross-tabulated with the buffered dataset (of the 1,949 data-plots) which was based on the field bearing the aggregated "Forest" class. The results are summarized in Table 29 below. The overall accuracy is 69.8%. Forest land has the highest producer's accuracy (82%) followed by crop land (57%). Again, forest land has the highest user's accuracy (85%) at a confidence interval of 73% to 95% while crop land has 43% user's accuracy at 33% to 52% confidence interval. The other classes have very low producer's and user's accuracies and equally low confidence intervals.

Table 29: Accuracy assessment of 1990 ICIMOD land cover map

	REFERENCE DATA								
		Forest land	**Crop land**	**Settlement**	**Grass-land**	**Wet-land**	**Other lands**	Total Classified areas	**User's accuracy (percent correct)**
	Forest land	**133.02**	14.94	0.72	7.11	0.54	1.17	158	84.5
CLASSIFIED IN SATELLITE IMAGE AS:	**Crop land**	21.42	**23.76**	1.62	5.76	0.81	1.71	55	43.1
	Settlement	0	0.81	**0**	0	0	0	1	0.0
	Grassland	7.2	1.71	0.09	**1.71**	0.18	0.27	11	15.3
	Wetlands	0	0	0	0.09	**0.63**	0	1	87.5
	Other lands	0.99	0.63	0	0	1.17	**0.54**	3	16.2
	Total Reference Areas	162.63	41.85	2.43	14.67	3.33	3.69	228.6	
	Producer's accuracy (percent correct)	81.8	56.8	0.0	11.7	18.9	14.6		
	Overall accuracy								**69.8**

Recommendations for uncertainty analysis of activity data

Uncertainty analysis is important for purpose of assessing the quality of the activity data, providing opportunity of quantifying and correcting possible errors. Availability or lack of reference data dictates the level as to which uncertainty analysis can be performed. Where reference data is not available, then consistency assessment would be recommended. On the other hand, where reference data is available, comprehensive uncertainty analysis is recommended.

1. Consistency Assessment

Consistency assessment is recommended to be employed to qualify and quantify errors related to the activity data. The procedure elaborated in this section heavily borrows from the work by the TREES-II Research Programme of European Union in 2002 about determination of deforestation rates for the world's humid tropical forests (European Commission, 2002). The method employed in that work can potentially be adapted for the case of historical change-periods in Nepal where availability of reference data is very limited.

According to the report, consistency assessment was based on the re-interpretation of spatial subsets (blocks) extracted from original datasets. From each full Landsat scene two blocks of 30km by 30km were systematically selected and extracted. From each Landsat sub-scene, 1 block of 20km by 20km was also extracted. A systematic dot grid was used for re-interpretation within the blocks. Each block (30km by 30km) contained 225 (15 *15) dots and the 20km by 20km block contained 100 (10*10) dots. The input data sets for each blocks included: i) the digital sub-sets (blocks) of pairs of geometrically corrected satellite images, and ii) the digital sub-sets of land cover interpretation maps (one historical and one recent) produced from the respective satellite images.

The main task was to interpret the sub-sets (blocks) based on the dot grids and on a simplified legend. For each subset, the dots were re-interpreted in an independent and consistent way. Each block was analyzed in its specific geographic, ecological and floristic context systematic references (pan-tropical vegetation, maps, etc.) as well as location-specific references available were used to understand the characteristics of the study sites.

Re-interpretation was done in two steps as follows.

i. Assessing the vegetation class covered by specific dot

For each dot of the grids, a point interpretation was done on-screen, applying the simplified TREES classification scheme. In order to classify the land cover at point location below the minimum mapping level defined by the study, the scale of interpretation was generally larger than the standard 1: 100000. Being point classification, composite classes were not used.

ii. Assessing the whole polygon a dot would fall in

For all grid dots, the polygons (of respective previous interpretation/ land cover maps) that contained the dots were assessed thematically and geometrically. The assessment was done on-screen, using a 1:100000 equivalent scales and applying the simplified TREES classification scheme. Being an area classification, composite classes were also used. The original class label and geometric accuracy of the 'dot polygon' (i.e. polygon containing the dot) were assessed and these "accuracy" codes were assigned per 'dot polygon': agreement/debatable/disagreement.
The result of consistency assessment with respect to the land cover map was measured as the fraction of agreed dot interpretation to the total number of dots.

For consistency assessment of change estimation, change matrices were produced by simple aggregation of the blocks studied. It follows that for every dot location, the class legend/value from the original interpretation/land cover maps – historical/date 1 and recent/date 2 – are extracted and used to construct a change matrix. Similarly, again for every dot location, the values got from re-interpretation of historical/date 1 and recent/date 2 images are used to construct re-interpretation based change matrix. The two matrices are differenced, case-by-case and the difference value for each respective transition (or potential activity data reported as the error measure.

2. Implementing comprehensive analysis of uncertainty and statistical inference of activity data

For key activity data (e.g. deforestation), comprehensive uncertainty analysis is recommended. Here, the procedure elaborated in Methods and Guidance from the Global Forests Observations Initiative (GFOI, 2013).

Estimating uncertainty is via comparisons of map classifications and reference observations for an accuracy assessment sample. Factors that affect satisfaction of the two criteria are the sampling design and sample size for the accuracy assessment sample and map accuracy. The sampling design selected should yield sample size for each activity that is large enough to produce sufficiently precise estimates of the area of the activity. Given the likely rarity of some activities and the large costs associated with large samples, serious consideration should be given to stratified sampling for which the strata correspond to map activity classes. Map accuracy assessments are often summarized in the form of error or confusion matrices that summarize results and facilitate estimation of accuracies, activity areas, and uncertainties. Although an error matrix does not directly provide estimates of activity areas or their uncertainties, the information in an error matrix can be used to do so.

An error matrix was constructed based on a pixel-by-pixel comparison of the map and reference classifications for the accuracy assessment sample. The cell entries of the error matrix are all based on the accuracy assessment sample. The sample-based estimator (statistical formula) for the area proportion ρ_{ij} is denoted as $\hat{\rho}_{ij}$, where i denote the row and j denotes the column in the error matrix. Once $\hat{\rho}_{ij}$ is estimated for each element of the error matrix, accuracies, activity areas and standard errors of estimated areas can be estimated. The procedure to implement uncertainty analysis and statistical inference of activity data is elaborated in Methods and Guidance from the Global Forests Observations Initiative (GFOI, 2013).

Conclusions

Generally, land cover maps for the three reference periods (1990, 2000 and 2010) have provided fairly accurate forest cover estimates as implied by the respective high user's and producer's as well as high confidence intervals at both national scale and sub-national jurisdictions that were assessed either quantitatively. On the other hand, estimates of non-forest cover types are associated with low measures of accuracies/confidence intervals especially at national scale. Quality of the land cover mapping from one physiognomic zone to another can only be scantly discussed, given that accuracy assessment was only conducted over limited zones depending on available comparative datasets. For Terai zone, the results of the assessment implies that the ICIMOD 2010 product discriminated forest from non-forest cover types fairly well over Terai but a bit poorer over Siwalik, when compared with similar estimates generated by FRA Project. Perhaps the flat terrain over Terai may explain the discrimination between cover types, apparently better than in Siwalik. This notwithstanding, comparison with WWF estimates over Terai Arc Landscape shows large divergence from corresponding estimates generated by ICIMOD 2010 dataset. With respect to forest cover generated by 2000 RL Team Product, qualitative comparison with 1998 Topographic base map sourced from Survey Department yield good correspondence over the five physiognomic zones. However, estimates of non-forest cover types over High Mountain Regions generated by RL Team Product shows divergence from similar estimates recorded in 2002 Ecological Maps, Department of Survey. As for the ICIMOD 1990 land cover map, the forest cover estimates over High Mountain Region are fairly corresponding with similar estimates sourced from Master Plan for Forestry Sector (MPFS, 1988) and cited in the report “Study on Drivers of Deforestation and Degradation of Forests in High Mountain Region of Nepal, 2012. However, there is an apparent over-estimation of the shrubs cover in High Himal in this exercise.

The observed pattern above may partially be attributed to the proportion of reference data associated with respective cover type besides the inherent accuracy of the particular cover type. The sample size (per stratum) has great influence to the level of accuracy and the related confidence interval and this may explain the high level of accuracy recorded for forest cover category while other classes recorded very low accuracies measures. The sample reference data is large for forest class where out of the 1949 reference data used for quantitative accuracy assessment at national scale, 1,374 were collected over forest cover category. Thus in future, the envisaged Measurement, Reporting and Verification (MRV) System should aim to be collecting adequate reference data for each of the land cover category. For historical land cover maps, the FRA dataset will form a critical base reference data as well as the WWF field survey data. RL Team also recommends that effort be put towards reconstructing the historical reference data that have been collected in the past. In particular, the current form and /or organization of the 1994 NFI sample plot-data limits its use for purpose of assessing the quality of land cover map for 1990 reference period. The use of 1994 NFI sample plot-data as reference data need sufficient assurance that the original location of the plot center have been reconstructed and respective coordinates provided. While MRV Team has made progress towards this objective, further effort is needed from government agencies to reconstruct the data and validate it for use.

In conclusion, in light of the preceding quality analysis of the land cover maps meant to enable creation of activity data, it is the considered opinion of the RL Team that the land cover maps for the respective three reference periods are adequate to be used subsequent processing stage of activity data creation. Within the framework of step-wise approach of developing Nepal National Reference Scenario, it is expected that iterative implementation of the recommendations set forth along with efforts to improve the land cover maps will yield improved versions of the reference scenario.

ANNEX 6: SCENARIO 1 FOR CONSTRUCTING THE RL

File name: Nepal RL – Workbook 9a – Scenario 1.

Historical reference period for AD: 1990 - 2010

Table 30: Historical reference period for AD: 1990 - 2010

Scenario	Description	Camco comments	Impact on RL
1	In this scenario we use the gross area figures for defor and refor. Carbon stock changes are measured using emission factors for all transitions except refor where carbon increases are measured using annual increment data	Although this is the approach that most closely follows good practice guidance, there are two reasons why we don't think it best represents Nepal's RL (1) using emission factors to measure enhancement clearly overestimates C stock increases in period 1 and provides no incremental data in following periods and (2) although the overall (NET) forest cover data appears to be accurate it reports significant deforestation and reforestation transitions which are not supported by other data sources	This approach to the RL (1) overestimates gross emissions and (2) overestimates removals in period 1 and underestimates removals in period 2. The result of this is that the projection overestimates net emissions and the projection shows an increase in annual emissions beyond expectations

Gross historical emissions from deforestation (tCO_2): 620,473,428
Gross historical emissions from degradation (tCO_2): 349,983,750
Gross historical emissions (tCO_2) = 970,457,179

Gross historical removals due to enhancement (tCO_2): 726,216,210
Gross historical removals due to AR (tCO_2): 52,788,103
Gross historical removals (tCO_2) = 191,452,866

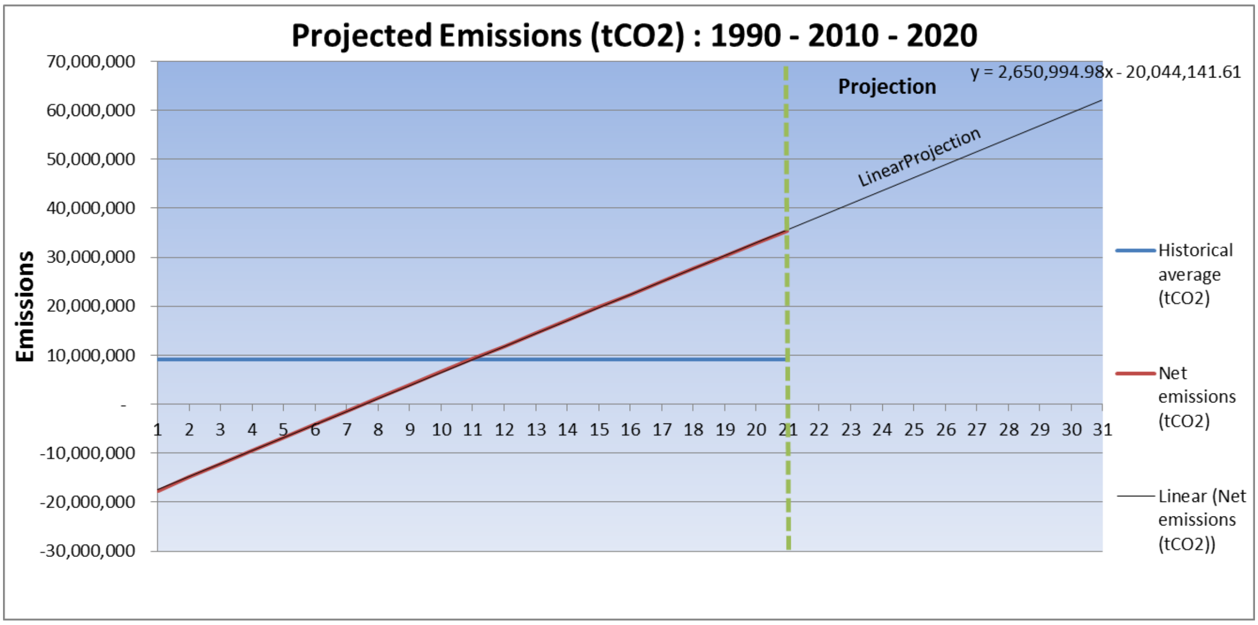

Figure 13: Projected emissions in Scenario 1

Table 31: Projection of emissions for Scenario 1 (2010 - 2020

Projection of emissions										
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Projected emissions (tCO2)	38,277,748	40,928,743	43,579,738	46,230,733	48,881,728	51,532,723	54,183,718	56,834,713	59,485,708	62,136,703

ANNEX 7: SCENARIO 2 FOR CONSTRUCTING THE RL

File name: Nepal RL – Workbook 9b – Scenario 2.

Historical reference period for AD: 1990 - 2010

Table 32: Historical reference period for AD: 1990 - 2010

Scenario	Description	Camco comments	Impact on RL
2	In this scenario we use the gross area figures for defor and refor. Carbon stock changes are measured using emission factors for deforestation and degradation whilst all removals (refor and enhancement) are measured using annual increment data	Although this method of quantifying net GHG emissions / removals appears logical the result does not corroborate with other sources. The reason for this is that the activity data reports very significant levels of defor and refor during both historical periods.	This approach to the RL grossly overestimates GHG emissions

Gross historical emissions from deforestation (tCO_2): 620,473,428
Gross historical emissions from degradation (tCO_2): 349,983,750
Gross historical emissions (tCO_2) = 970,457,179

Gross historical removals due to enhancement (tCO_2):113,089,199
Gross historical removals due to AR (tCO_2):52,788,103
Gross historical removals (tCO_2) = 804,579,877

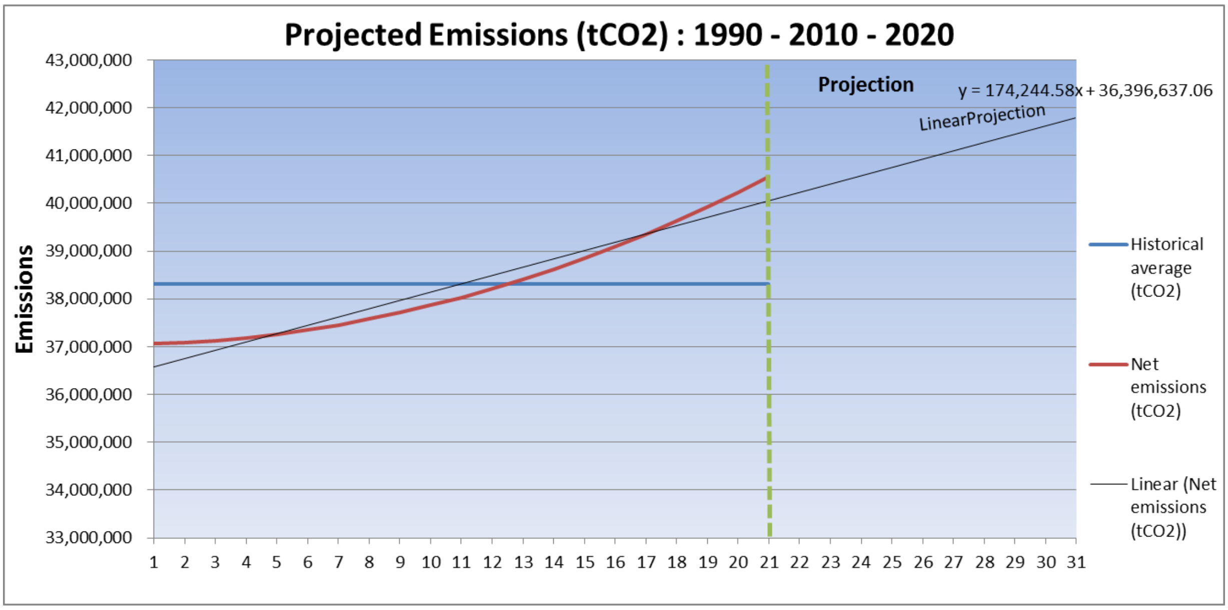

Figure 14: Projected emissions in Scenario 2

Table 33: Projection of emissions for Scenario 2 (2010 - 2020

Projection of emissions										
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Projected emissions (tCO2)	40,230,018	40,404,262	40,578,507	40,752,752	40,926,996	41,101,241	41,275,485	41,449,730	41,623,974	41,798,219

ANNEX 8: SCENARIO 3 FOR CONSTRUCTING THE RL

File name: Nepal RL – Workbook 9c – Scenario 3.

Historical reference period for AD: 1990 - 2010

Table 34: Historical reference period for AD: 1990 - 2010

Scenario	Description	Camco comments	Impact on RL
3	In this scenario we have modelled defor and refor based on NET values rather than GROSS values. Carbon stock changes are measured using emission factors for deforestation and degradation whilst all removals (refor and enhancement) are measured using annual increment data	Although this method does not follow the prescribed methods for developing RLs we think it is the most accurate measure of the RL. If we include the very high rates of deforestation and reforestation (as indicated by the activity data) net GHGs are most likely over estimated.	This approach to the RL avoids the inclusion of defor and refor data which does not corroborate with other sources. The RL is therefore based on inputs that are largely corroborated and the projection is therefore more in line with expectations,

Gross historical emissions from deforestation (tCO_2):97,289,516
Gross historical emissions from degradation (tCO_2):349,983,750
Gross historical emissions (tCO_2) = 447,273,266

Gross historical removals due to enhancement (tCO_2):113,089,199
Gross historical removals due to AR (tCO_2):10,790,533
Gross historical removals (tCO_2) = 323,393,535

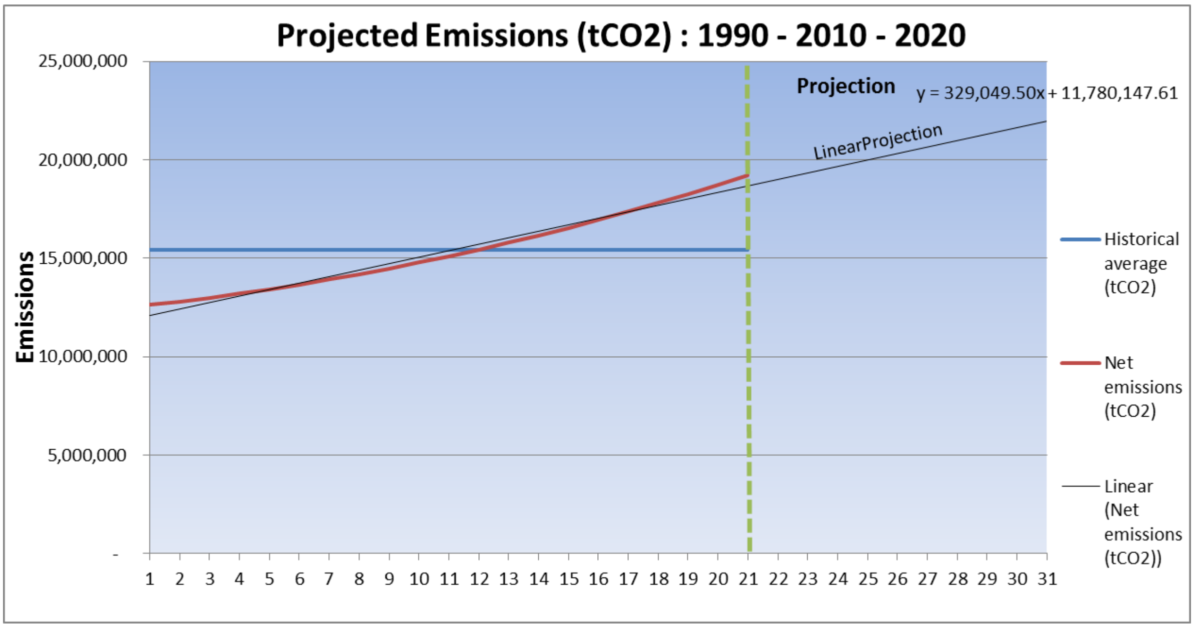

Figure 15: Projected emissions in Scenario 3

Table 35: Projection of emissions for Scenario 3 (2010 - 2020

Projection of emissions										
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Projected emissions (tCO2)	19,019,237	19,348,286	19,677,336	20,006,385	20,335,435	20,664,484	20,993,534	21,322,583	21,651,633	21,980,682

ANNEX 9: SCENARIO 4 FOR CONSTRUCTING THE RL

File name: Nepal RL – Workbook 9d – Scenario 4.

Historical reference period for AD: 2000 - 2010

Table 36: Historical reference period for AD: 2000 - 2010

Scenario	Description	Camco comments	Impact on RL
4	In this scenario we have modeled for and refor based on NET values rather than GROSS values. Carbon stock changes are measured using emission factors for deforestation and degradation whilst all removals (refor and enhancement) are measured using annual increment data. The reference period only covers 2000 - 2010. No projections have been made - only used to calculate average emissions during this period.	This scenario was introduced to calculate average emissions over the period 2000 - 2010.	The result of this scenario is dominated by degradation emissions. The average for this period is even higher than emissions based on a projection of historical trends from 1990 - 2010 periods.

Gross historical emissions from deforestation (tCO_2):22,852,865
Gross historical emissions from degradation (tCO_2):270,378,779
Gross historical emissions (tCO_2) = 293,231,645

Gross historical removals due to enhancement (tCO_2):11,345,746
Gross historical removals due to AR (tCO_2):8,047,194
Gross historical removals (tCO_2) = 273,838,705

Annual average during the period 2000 – 2010 (tCO_2): 24,894,428

ANNEX 10: SCENARIO 5 FOR CONSTRUCTING THE RL

File name: Nepal RL – Workbook 9e – Scenario 5.

Historical reference period for AD: 1990 - 2010

Table 37: Historical reference period for AD: 1990 - 2010

Scenario	Description	Camco comments	Impact on RL
5	In this scenario we have modelled defor and refor based on NET values rather than GROSS values. Carbon stock changes are measured using emission factors for deforestation and degradation whilst all removals (refor and enhancement) are measured using annual increment data. The reference period AD covers the period 1990 - 2010. No projections have been made - only used to calculate average emissions during this period.	This scenario introduced to calculate average emissions over the period 1990 - 2010 (in order to compare with the outputs from other scenarios)	The average for the period 1990 - 2010 is slightly lower than for the period 2000 - 2010 as would be expected in a situation where the impact of degradation is estimated to have increased significantly.

Gross historical emissions from deforestation (tCO_2):92,656,682
Gross historical emissions from degradation (tCO_2):333,317,857
Gross historical emissions (tCO_2) = 425,974,539

Gross historical removals due to enhancement (tCO_2):110,880,886
Gross historical removals due to AR (tCO_2):8,692,286
Gross historical removals (tCO_2) = 119,573,172

Annual average during the period 1990 – 2010 (tCO_2): 14,590,541

ANNEX 11: UNCERTAINTY ANALYSIS

Uncertainty estimates are an essential element of a complete inventory of greenhouse gas emission and removals (IPCC, 2006). The estimates of emissions and removals from each source are based on an assumption about the relationship between a certain activity and emissions generated. Uncertainties in emission inventories may have various origins. Many emission-generating processes are, by nature, variable in space and time, and it is difficult to develop appropriate estimation models and estimation data. Some processes may also be poorly understood, and perhaps not even recognised as an important emission source. For other sources, good models may be available, but appropriate data is missing to fill the models and the estimates rely on approximations. Finally, there may be human errors in data processing of the inventory or in the data used (Rypdal and Winiwarter, 2001)

In this assignment the propagation of error technique was used to compute the uncertainties by category to estimate overall uncertainty for one year and the uncertainty in the trend. The uncertainties for the activity data and emission factors were combined and obtained as half the 95 percent confidence interval divided by the mean and expressed as a percentage. The computations followed the "*2006 Guidelines for Gas National Greenhouse Gas Inventories-General Guidance and Reporting*"

The following assumptions and considerations were made when calculating the uncertainties:

- Emission factor and activity data uncertainties were combined
- Correlations occur between some of the activity data sets, emission factors, or both
- The distributions of the uncertainties are Gaussian
- The relative ranges of uncertainty in the emission and activity factors are the same in the base year and in year *t*.

The results are as follows:

Scenario 1:
The result indicates that the percentage uncertainty in the total inventory is 3.67%. It also shows that the trend uncertainty is 796.86%. Although the uncertainty in the total inventory is small, the one of trend is extremely large. This arises from the emission data that ranges from -17,627,799.9 tCO_2 in 1990 to 35,392,099.65 tCO_2 in 2010 (See table 38).

Scenario 2:
The result indicates that the percentage uncertainty in the total inventory is 0.06%. It also shows that the trend uncertainty is 0.00%. The data indicates that there are low variations in the data from 37,063,368.51 in 1990 to 40,548,260.19 in 2010 (See table 39).

Scenario 3:
The result indicates that the percentage uncertainty in the total inventory is 0.27%. It also shows that the trend uncertainty is 0.23%. In 1990 the net emission was 12,628,654.19 while in 2010 it was 19,209,644.22 (See table 40

Scenario 4:
The net emission is a constant value of 27,560,169.96 between 2000 and 2010. The percentage uncertainty in the total inventory is 1.51% (See table 41).

Scenario 5:
The net emission is 14,590,541. The uncertainty level is 5% (See table 42).

Scenario 6:
The net emissions are computed by region for 2010. The percentage uncertainty in the total inventory is 3.09% (See table 43).

Table 38: Uncertainty analysis for scenario 1 of the RL presentation

	Year	Base year emissions or removals	Year t emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter v	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions
	1990	-17627799.9	-17627799.9	0.00%	8.71%	8.71%	0.01%	445.34%	4.76%	38.79%	0.00%	15.04%
	1991	-17627799.9	-14906408.94	0.00%	10.30%	10.30%	0.01%	445.36%	4.03%	45.87%	0.00%	21.04%
	1992	-17627799.9	-12192428.08	0.00%	12.59%	12.59%	0.01%	445.37%	3.29%	56.08%	0.00%	31.45%
	1993	-17627799.9	-9485857.332	0.00%	16.18%	16.18%	0.01%	445.39%	2.56%	72.09%	0.00%	51.96%
	1994	-17627799.9	-6786696.684	0.00%	22.62%	22.62%	0.01%	445.40%	1.83%	100.76%	0.00%	101.52%
	1995	-17627799.9	-4094946.139	0.00%	37.49%	37.49%	0.01%	445.41%	1.11%	167.00%	0.00%	278.87%
	1996	-17627799.9	-1410605.697	0.00%	108.84%	108.84%	0.01%	445.43%	0.38%	484.80%	0.00%	2350.29%
	1997	-17627799.9	1266324.642	0.00%	121.24%	121.24%	0.01%	445.44%	-0.34%	540.05%	0.00%	2916.55%
	1998	-17627799.9	3935844.877	0.00%	39.01%	39.01%	0.01%	445.46%	-1.06%	173.76%	0.00%	301.93%
	1999	-17627799.9	6597955.01	0.00%	23.27%	23.27%	0.01%	445.47%	-1.78%	103.66%	0.00%	107.45%
	2000	-17627799.9	9252655.039	0.00%	16.59%	16.59%	0.01%	445.48%	-2.50%	73.92%	0.00%	54.64%
	2001	-17627799.9	11899944.96	0.00%	12.90%	12.90%	0.01%	445.50%	-3.21%	57.48%	0.00%	33.04%
	2002	-17627799.9	14539824.79	0.00%	10.56%	10.56%	0.01%	445.51%	-3.93%	47.04%	0.00%	22.13%
	2003	-17627799.9	17172294.51	0.00%	8.94%	8.94%	0.01%	445.53%	-4.64%	39.83%	0.00%	15.87%
	2004	-17627799.9	19797354.12	0.00%	7.75%	7.75%	0.01%	445.54%	-5.35%	34.55%	0.00%	11.94%
	2005	-17627799.9	22415003.64	0.00%	6.85%	6.85%	0.01%	445.55%	-6.06%	30.52%	0.00%	9.31%
	2006	-17627799.9	25025243.05	0.00%	6.13%	6.13%	0.01%	445.57%	-6.76%	27.34%	0.00%	7.47%
	2007	-17627799.9	27628072.35	0.00%	5.56%	5.56%	0.01%	445.58%	-7.46%	24.76%	0.00%	6.13%
	2008	-17627799.9	30223491.56	0.00%	5.08%	5.08%	0.01%	445.59%	-8.16%	22.64%	0.00%	5.12%
	2009	-17627799.9	32811500.66	0.00%	4.68%	4.68%	0.01%	445.61%	-8.86%	20.85%	0.00%	4.35%
	2010	-17627799.9	35392099.65	0.00%	4.34%	4.34%	0.01%	445.62%	-9.56%	19.33%	0.00%	3.74%
Total		-370183797.8	191452866.1				0.14%					6349.85%
Percentage uncertainty in total inventory:							**3.67%**	**Trend uncertainty:**				**796.86%**

Table 39: Uncertainty analysis for scenario 2 of the RL presentation

	Year	Base year emissions or removals	Year t emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter v	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions
	1990	37063368.51	37063368.51	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.76%	0.000312%	0.000000%	0.000000%
	1991	37063368.51	37089867.03	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.77%	0.000312%	0.000000%	0.000000%
	1992	37063368.51	37131917.78	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.77%	0.000312%	0.000000%	0.000000%
	1993	37063368.51	37189520.74	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.78%	0.000311%	0.000000%	0.000000%
	1994	37063368.51	37262675.91	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.79%	0.000310%	0.000000%	0.000000%
	1995	37063368.51	37351383.3	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.80%	0.000309%	0.000000%	0.000000%
	1996	37063368.51	37455642.91	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.81%	0.000308%	0.000000%	0.000000%
	1997	37063368.51	37575454.74	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.83%	0.000306%	0.000000%	0.000000%
	1998	37063368.51	37710818.78	0.00%	0.28%	0.28%	0.00000166%	0.11%	4.85%	0.000305%	0.000000%	0.000000%
	1999	37063368.51	37861735.04	0.00%	0.27%	0.27%	0.00000166%	0.11%	4.86%	0.000303%	0.000000%	0.000000%
	2000	37063368.51	38028203.52	0.00%	0.27%	0.27%	0.00000166%	0.11%	4.89%	0.000301%	0.000000%	0.000000%
	2001	37063368.51	38210224.21	0.00%	0.27%	0.27%	0.00000166%	0.11%	4.91%	0.000299%	0.000000%	0.000000%
	2002	37063368.51	38407797.12	0.00%	0.27%	0.27%	0.00000166%	0.11%	4.93%	0.000297%	0.000000%	0.000000%
	2003	37063368.51	38620922.24	0.00%	0.27%	0.27%	0.00000166%	0.11%	4.96%	0.000295%	0.000000%	0.000000%
	2004	37063368.51	38849599.59	0.00%	0.27%	0.27%	0.00000166%	0.11%	4.99%	0.000292%	0.000000%	0.000000%
	2005	37063368.51	39093829.14	0.00%	0.27%	0.27%	0.00000166%	0.11%	5.02%	0.000289%	0.000000%	0.000000%
	2006	37063368.51	39353610.92	0.00%	0.26%	0.26%	0.00000166%	0.11%	5.06%	0.000287%	0.000000%	0.000000%
	2007	37063368.51	39628944.91	0.00%	0.26%	0.26%	0.00000166%	0.11%	5.09%	0.000284%	0.000000%	0.000000%
	2008	37063368.51	39919831.12	0.00%	0.26%	0.26%	0.00000166%	0.11%	5.13%	0.000281%	0.000000%	0.000000%
	2009	37063368.51	40226269.55	0.00%	0.26%	0.26%	0.00000166%	0.11%	5.17%	0.000278%	0.000000%	0.000000%
	2010	37063368.51	40548260.19	0.00%	0.26%	0.26%	0.00000166%	0.11%	5.21%	0.000274%	0.000000%	0.000000%
Total		778330738.7	804579877.3				0.00003495%					0.000000%
Percentage uncertainty in total inventory:							**0.06%**	**Trend uncertainty:**				**0.00%**

Table 40: Uncertainty analysis for scenario 3 of the RL presentation

	Year	Base year emissions or removals	Year t emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter v	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions
	1990	12628654.19	12628654.19	0.00%	1.52%	1.52%	0.000035%	3.96%	4.76%	0.0602%	0.000000%	0.000036%
	1991	12628654.19	12801866.57	0.00%	1.50%	1.50%	0.000035%	3.95%	4.83%	0.0594%	0.000000%	0.000035%
	1992	12628654.19	12991482.85	0.00%	1.48%	1.48%	0.000035%	3.95%	4.90%	0.0585%	0.000000%	0.000034%
	1993	12628654.19	13197503.05	0.00%	1.46%	1.46%	0.000035%	3.95%	4.98%	0.0576%	0.000000%	0.000033%
	1994	12628654.19	13419927.15	0.00%	1.43%	1.43%	0.000035%	3.95%	5.06%	0.0566%	0.000000%	0.000032%
	1995	12628654.19	13658755.16	0.00%	1.41%	1.41%	0.000035%	3.95%	5.15%	0.0556%	0.000000%	0.000031%
	1996	12628654.19	13913987.07	0.00%	1.38%	1.38%	0.000035%	3.95%	5.25%	0.0546%	0.000000%	0.000030%
	1997	12628654.19	14185622.9	0.00%	1.36%	1.36%	0.000035%	3.95%	5.35%	0.0535%	0.000000%	0.000029%
	1998	12628654.19	14473662.63	0.00%	1.33%	1.33%	0.000035%	3.95%	5.46%	0.0525%	0.000000%	0.000028%
	1999	12628654.19	14778106.27	0.00%	1.30%	1.30%	0.000035%	3.95%	5.57%	0.0514%	0.000000%	0.000026%
	2000	12628654.19	15098953.82	0.00%	1.27%	1.27%	0.000035%	3.95%	5.69%	0.0503%	0.000000%	0.000025%
	2001	12628654.19	15436205.27	0.00%	1.25%	1.25%	0.000035%	3.95%	5.82%	0.0492%	0.000000%	0.000024%
	2002	12628654.19	15789860.64	0.00%	1.22%	1.22%	0.000035%	3.95%	5.95%	0.0480%	0.000000%	0.000023%
	2003	12628654.19	16159919.91	0.00%	1.19%	1.19%	0.000035%	3.94%	6.09%	0.0469%	0.000000%	0.000022%
	2004	12628654.19	16546383.09	0.00%	1.16%	1.16%	0.000035%	3.94%	6.24%	0.0458%	0.000000%	0.000021%
	2005	12628654.19	16949250.17	0.00%	1.13%	1.13%	0.000035%	3.94%	6.39%	0.0447%	0.000000%	0.000020%
	2006	12628654.19	17368521.17	0.00%	1.11%	1.11%	0.000035%	3.94%	6.55%	0.0436%	0.000000%	0.000019%
	2007	12628654.19	17804196.07	0.00%	1.08%	1.08%	0.000035%	3.94%	6.71%	0.0425%	0.000000%	0.000018%
	2008	12628654.19	18256274.88	0.00%	1.05%	1.05%	0.000035%	3.94%	6.88%	0.0415%	0.000000%	0.000017%
	2009	12628654.19	18724757.59	0.00%	1.03%	1.03%	0.000035%	3.94%	7.06%	0.0404%	0.000000%	0.000016%
	2010	12628654.19	19209644.22	0.00%	1.00%	1.00%	0.000035%	3.94%	7.24%	0.0394%	0.000000%	0.000016%
Total		265201738	323393534.7				0.000742%					0.000536%
Percentage uncertainty in total inventory:							**0.27%**	**Trend uncertainty:**				**0.23%**

Table 41: Uncertainty analysis for scenario 4 of the RL presentation

	Year	Base year emissions or removals	Year t emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter v	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions
	2000	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2001	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2002	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2003	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2004	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2005	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2006	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2007	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2008	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2009	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
	2010	27560169.96	27560169.96	0.00%	5.00%	5.0000%	0.0021%	0.0000%	9.0909%	0.0000%	0.0000%	0.0000%
Total		303161869.6	303161869.6				0.02%					0.00%
Percentage uncertainty in total inventory:							**1.51%**	**Trend uncertainty:**				**0.00%**

Table 42: Uncertainty analysis for scenario 5 of the RL presentation

	Year	Base year emissions or removals	Year t emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter v	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions
	2010	14590541	14590541	0.00%	5.00%	5.0000%	0.2500%	0.0000%	100.0000%	0.0000%	0.0000%	0.0000%
Total		14590541	14590541				0.25%					0.00%
Percentage uncertainty in total inventory:							**5.00%**	**Trend uncertainty:**				**0.00%**

Table 43: Uncertainty analysis for scenario 6 of the RL presentation

Physiographic Region	Year	Base year emissions or removals	Year t emissions or removals	Activity data uncertainty	Emission factor / estimation parameter uncertainty	Combined uncertainty	Contribution to Variance by Category in Year t	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor / estimation parameter v	Uncertainty in trend introduced by activity data uncertainty	Uncertainty introduced into the trend in total emissions
Terai	2010	10151880.44	10151880.44	0.00%	5.00%	5.0000%	0.0006%	0.0000%	4.8980%	0.0000%	0.0000%	0.0000%
Siwalik	2010	19304179.82	19304179.82	0.00%	5.00%	5.0000%	0.0022%	0.0000%	9.3137%	0.0000%	0.0000%	0.0000%
Hills	2010	117279747.1	117279747.1	0.00%	5.00%	5.0000%	0.0800%	0.0000%	56.5839%	0.0000%	0.0000%	0.0000%
Mid Mountain	2010	43085231.73	43085231.73	0.00%	5.00%	5.0000%	0.0108%	0.0000%	20.7873%	0.0000%	0.0000%	0.0000%
High Mountain	2010	17445993.83	17445993.83	0.00%	5.00%	5.0000%	0.0018%	0.0000%	8.4172%	0.0000%	0.0000%	0.0000%
Total		207267032.9	207267032.9				0.10%					0.00%
Percentage uncertainty in total inventory:							**3.09%**	**Trend uncertainty:**				**0.00%**