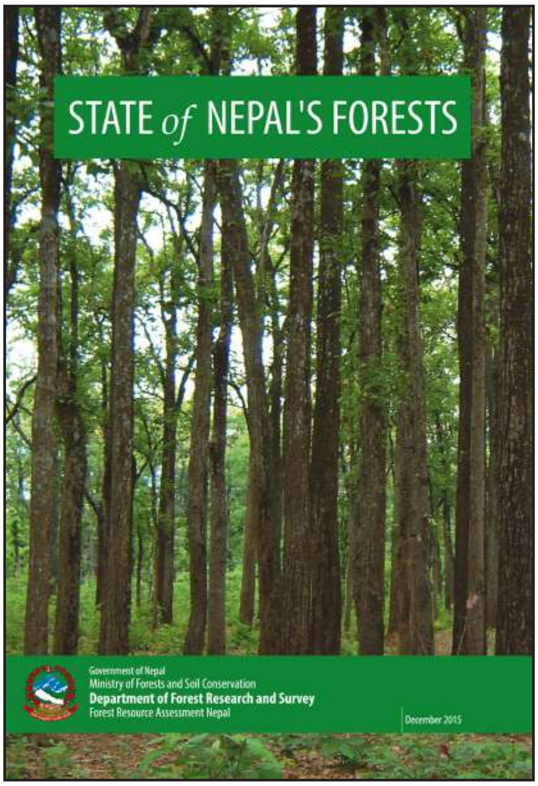
STATE OF NEPAL'S FORESTS

GOVERNMENT OF NEPAL
MINISTRY OF FORESTS AND SOIL CONSERVATION
DEPARTMENT OF FOREST RESEARCH AND SURVEY
FOREST RESOURCE ASSESSMENT NEPAL

Publication No. 5

December 2015



Citation

DFRS, 2015. State of Nepal's Forests. Forest Resource Assessment (FRA) Nepal, Department of Forest Research and Survey (DFRS). Kathmandu, Nepal.

ISBN: 978-9937-8896-3-6

Published by

Department of Forest Research and Survey
P.O. Box: 3339, Babarmahal
Kathmandu, Nepal
Tel: 977 1 4220482, Fax: 977 1 4220159
Email: info@dfrs.gov.np
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Cover Photographs

Front cover: Terai Sal forest of Rautahat District, Nepal

Back cover: High altitude forest of Kalikot District, Nepal

MESSAGE

The contribution of forests to the well-being of humankind is enormous and wide-ranging. Forests play an important role in ensuring food security, combating rural poverty and providing decent livelihoods to the people. Forests also offer green growth opportunities and provide vital environmental services such as cleaning air and water, conserving biodiversity and watersheds and addressing climate change impacts. By providing essential goods and services, sustainably managed forests ultimately contribute to sustainable development. Therefore, forests and their role have also been recognised in the United Nation's sustainable development goals.

Reliable and up-to-date information on the state of forest resources is crucial for supporting policy formulation, strategic planning, financial investment and sustainable forest management. The current forest policy of Nepal also recognises the need for updating the information of the country's forest resources. Forest Resource Assessment (FRA) Nepal project was a bilateral cooperation between the Governments of Nepal and Finland. The project aimed to conduct the national level forest assessment for updating information on forest resources of Nepal.

While this report summarises the results of the FRA project, greater details are provided in physiographic region-wise reports. I believe that the implementation of national FRA and production of all these reports are the major steps forward in the forestry sector of Nepal.

On behalf of the Government of Nepal, I am thankful to the Government of Finland for providing financial and technical support to implement the FRA Nepal project. I would also like to acknowledge the efforts of the Department of Forest Research and Survey in implementing the project and all the stakeholders contributing for the successful completion of the project.

Finally, I would like to assure that the Ministry of Forests and Soil Conservation is committed to institutionalise periodic FRA system and utilise the updated forest resource information for forestry sector policy-making, planning and sustainable forest management. I hope the information disseminated by this report will be beneficial in full extent to all decision makers, planners, academicians, students and other professionals working in the field of natural resource management.

Thank you.

Agni Prasad Sapkota

Minister

Ministry of Forests and Soil Conservation

FOREWORD

National level forest resource information is important for policy-making, strategic level planning, and international reporting by government. To generate this information, the Government of Nepal implemented the Forest Resource Assessment Nepal (FRA Nepal) project from 2010 to 2014 with support from the Government of Finland.

This national report presents the results of the forest resource assessment of the entire country. It provides a wide range of information including forest cover, growing stock, biomass, and forest carbon. In addition, there are separate physiographic region-wise detailed reports for Terai, Churia, and Middle Mountains, and a combined report for High Mountains and High Himal physiographic regions.

I would like to acknowledge the efforts of the Department of Forest Research and Survey for executing the Forest Resource Assessment project. I appreciate the hard work of all those involved in planning, field inventory, data analysis, mapping, report writing and other supportive work related to the implementation of FRA Nepal project.

I would also like to take this opportunity to express my sincere gratitude to the Government of Finland for providing technical and financial support to accomplish this important work.

I am confident that the capacity enhancement of our institutions and personnel during the FRA Nepal project would be useful for undertaking forest resource assessments in future.

I believe that the results of this study will be useful not only in policy-making, strategic planning and international reporting but will also serve as baseline information for future forest resource assessments of the country.

Uday Chandra Thakur

Secretary

Ministry of Forests and Soil Conservation

ACKNOWLEDGEMENTS

Like any major undertaking, the Forest Resource Assessment Nepal project was the collective effort of many. In particular, I appreciate the efforts of the following people who, in their various capacities, contributed in the implementation of the project. Some names are repeated to recognise the person's role in various capacities.

Project Steering Committee: Yuvaraj Bhusal, Chhabi R. Pant, Keshab P. Bhattarai, Naveen K. Ghimire, Krishna C. Paudel, Ganesh R. Joshi, Sharad C. Poudel, Madhav P. Acharya, Gopal K. Shrestha, Harihar Sigdel, Annapurna N. Das, Sahas M. Shrestha, Biswo N. Oli, Braj K. Yadav, Gopal K. Upadhyaya, Megh B. Pandey, Krishna P. Acharya, Bharat P. Pudasaini, Yam B. Thapa, Tika R. Adhikari, Pem N. Kandel, Mukunda P. Ghimire, Kiran R. Sharma, Ramesh Shakya, Hasta B. Thapa, Deepak K. Kharal, Yam P. Pokharel, Kailash Pokharel, Abhoy K. Das, Chudamani Joshi, Kari Leppanen, Pekka Seppala, Tuomo A. Kotimaki, Micheal D. Hawkes.

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Support Staff: Shyam Sangachhe, Purna B. Karki, Krishna B. Tamang, Om Timilsina, Hari Pokharel, Padam Tamang, Ramesh Khadgi, Arun Karki, Kumar Gurung, Ram Lama, Mohan Shrestha, Prabhuram Thapa Magar, Rameshwor Ranabhat, Nar B. Rai, Dhan B. Thing, Nanda B. Rai, Talak B. Mahat, Shree K. Khadka, Govinda Suwal, Jeetlal Suwal, Uday B. Shrestha, Laxmi Nepal, Bishal Thapa, Rekha Thapa, Premkumari Ranabhat, Tunakumari Giri, Ram G. Maharjan, Yuvraj Thapa, Laxman Kandel.

I am thankful to MFSC task force team—Man B. Khadka, Yam P. Pokharel, Sagar Rimal, Mohan Poudel, and Bijaya R. Subedi—for their validation checks during the report approval process. I acknowledge the hardwork of Deepak K. Kharal, Yam P. Pokharel, Keshab R. Goutam, Buddi S. Poudel, Shiva Khanal, Amul K. Acharya, and Kiran K. Pokharel in finalising this report.

I am thankful to Indufor Oy, the Finnish Forest Research Institute (Metla), Arbonaut, and Genesis Consultancy for their support to the department in implementing the project.

I am grateful to the Ministry of Forests and Soil Conservation; Department of Forests; Department of Soil Conservation and Watershed Management; Department of National Parks and Wildlife Conservation; Department of Plant Resources; Regional Forest Directorates; District Forest Offices; District Soil Conservation Offices; District Plant Resource Offices; Offices of National Parks, Wildlife Reserves, and Conservation Area; Nepal Foresters' Association; office bearers and members of Community Forest User Groups, Leasehold Forest User Groups, Collaborative Forest and Buffer Zone Community Forest User Groups, and others for their contributions.

Prakash Mathema

Director General

Department of Forest Research and Survey

ACRONYMS AND ABBREVIATIONS

BRDF	Bidirectional Reflectance Distribution Function
CBS	Central Bureau of Statistics
CCSP	Concentric Circular Sample Plot
CDR	Central Development Region
cm	Centimetre
DBH	Diameter at Breast Height (1.3 m)
DEM	Digital Elevation Model
DFRS	Department of Forest Research and Survey
DHM	Department of Hydrology and Meteorology
DoF	Department of Forests
DoS	Department of Survey
EDR	Eastern Development Region
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resource Assessment
FWDR	Far-Western Development Region
GIS	Geographic Information System
GOFC-GOLD	Global Observation of Forest and Land Cover Dynamics
ha	Hectare
HH	High Himal
HM	High Mountains
IPCC	Intergovernmental Panel on Climate Change
LMH	Lower Mixed Hardwood
LRMP	Land Resources Mapping Project
m^3/ha	Cubic metre per hectare
MFSC	Ministry of Forests and Soil Conservation
mm	Millimetre
MM	Middle Mountains
MPFS	Master Plan for the Forestry Sector
MSS	Multi-Spectral Scanner
MWDR	Mid-Western Development Region
NFI	National Forest Inventory
NTFPs	Non-Timber Forest Products

OC	Organic Carbon
OL	Other Land
OWL	Other Wooded Land
PA	Protected Area
PSP	Permanent Sample Plot
RMSE	Root Mean Square Error
RS	Remote Sensing
SD	Standard Deviation
SOC	Soil Organic Carbon
t/ha	tonne per hectare
TMH	Terai Mixed Hardwood
UMH	Upper Mixed Hardwood
USAID	United States Agency for International Development
WDR	Western Development Region

GLOSSARY

Above-ground biomass	It refers to the biomass of trees (≥10 cm DBH) above the soil; it includes dead wood but not stumps.
Below-ground biomass	It refers to the biomass of trees (≥10 cm DBH) contained within live roots and stumps.
Biomass	The biological material derived from living or recently living organisms. It includes both the above- and below-ground biomass of trees and saplings.
Bulk density	Soil mass per unit volume, expressed in g/cm^3.
Carbon stock	Carbon content in above-ground and below-ground biomass, and soil.
Cull tree	A malformed tree that does not meet, and cannot be expected to meet regional merchantability standards.
Debris	Fallen dead trees and the remains of large branches (<10 cm diameter) on the forest floor.
Forest	An area of land at least 0.5 ha and a minimum width/length of 20 m with a tree crown cover of more than 10% and tree heights of 5 m at maturity.
Forest type	The species which has more than 60% basal area is defined as that forest type.
Growing stock	The sum of all trees by number or volume or biomass growing in a unit area.
High-quality sound tree	A live tree which will yield at least a 6 m long saw log.
Land cover	The bio-physical material covering the surface of the earth.
Litter	Dead plant materials such as leaves, bark, needles, and twigs that have fallen to the ground.
Lower Mixed Hard-wood (LMH)	Mixed hardwood forests generally found between 1,000–2,000 m altitude.
Non-reachability	A plot is regarded as non-reachable if the slope within the plot is more than 45 degrees (100 %).
Other Land	All land that is not classified as Forest or Other Wooded Land.

Other Wooded Land (OWL)	The land not classified as forest spanning more than 0.5 ha, having at least 20 m width and a tree canopy cover of trees between 5% and 10%. or The canopy cover of trees less than 5% but the combined cover of shrubs, bushes and trees more than 10%; includes area of shrubs and bushes where no trees are present.
Shrub	An area occupied by woody perennial plants, generally 0.5–5.0 m height at maturity, and often without definite stems or crowns.
Sound tree	A live tree not qualified as class 1 but able to produce at least one 3 m saw log or two 1.8 m saw logs.
Terai Mixed Hardwood (TMH)	A low-altitude, broadleaved forest in which no species constitutes 60% of the total basal area.
Upper Mixed Hardwood (UMH)	Mixed hardwood forests generally found above 2,000 m.
Wall-to-wall mapping	Mapping that covers an entire area.

MAIN RESULTS

Forest Cover

1. Forest occupies a total of 5.96 million ha which is 40.36% of the total area of the country. Other Wooded Land (OWL) covers 0.65 million ha (4.38%). Forest and OWL together represent 44.74% of the total area of the country.

2. Out of the total area of Forest, 82.68% (4.93 million ha) lies outside Protected Areas and 17.32% (1.03 million ha) inside Protected Areas. Within the Protected Areas, Core Areas and Buffer Zone contain 0.79 and 0.24 million ha of Forest, respectively.

3. Out of the total area of Forest, 37.80% lies in Middle Mountains physiographic region, 32.25% in High Mountains and High Himal, 23.04% in Churia and 6.90% in Terai. In case of OWL, Terai, Churia, Middle Mountains, and High Mountains and High Himal physiographic regions share 1.47%, 3.50%, 9.61% and 85.42%, respectively.

Growing Stock

4. The total number of stems with Diameter at Breast Height (DBH) ≥10 cm estimated in the Forest of Nepal is 2,563.27 million (429.93/ha). The estimated total stem volume is 982.33 million m^3 (164.76 m^3/ha).

5. High Mountains and High Himal physiographic regions together has the highest stem volume per hectare (225.24 m^3/ha) whereas Middle Mountains has the lowest stem volume per hectare (124.26 m^3/ha). Terai and Churia regions have 161.66 m^3/ha and 147.49 m^3/ha, respectively.

6. The total above-ground air-dried biomass in the Forest of Nepal is 1,159.65 million tonnes (194.51 t/ha).

Carbon Stock

7. The total carbon stock in Nepal's Forest has been estimated as 1,054.97 million tonnes (176.95 t/ha). Out of this total, tree component (live, dead standing, dead wood and below-ground biomass), forest soils, and litter and debris constitute 61.53%, 37.80 %, and 0.67%, respectively.

Biodiversity

8. A total of 443 tree species belonging to 239 genera and 99 families were identified in the sample plots. The number of tree species identified in the sample plots of Middle Mountains, Churia, High Mountains along with High Himal and Terai regions were 326, 281, 275 and 164, respectively.

Forest Disturbance

9. Among all physiographic regions, Churia was observed to have the highest occurrence of forest disturbance particularly grazing, forest fire, landslide and bush cutting.

प्रमुख नतिजाहरू

वन क्षेत्र

१. नेपालमा वनले ५९ लाख ६२ हजार हेक्टर भू-भाग ओगटेको छ, जुन नेपालको कुल क्षेत्रफलको ४०.३६% हुन आउँछ। अन्य काष्ठ तथा बुट्यान क्षेत्र (Other Wooded Land) ६ लाख ४८ हजार हेक्टर (४.३८%) रहेको छ। नेपालको कुल क्षेत्रफलमध्ये वन क्षेत्र र अन्य काष्ठ तथा बुट्यान क्षेत्र दुबैले गरी ४४.७४% भू-भाग ओगटेको छ।

२. कुल वन क्षेत्रफलमध्ये संरक्षित क्षेत्र भन्दा बाहिरको भागमा ४९ लाख २९ हजार हेक्टर (८२.६८ %) र संरक्षित क्षेत्रमा १० लाख ३३ हजार हेक्टर (१७.३२%) वन रहेको पाइएको छ। संरक्षित क्षेत्रको भित्री भाग (Core Area) मा ७ लाख ९३ हजार हेक्टर र मध्यवर्ती क्षेत्रमा २ लाख ४० हजार हेक्टर वन रहेको पाइएको छ।

३. कुल वन क्षेत्रफलको ३७.८०% मध्यपहाडी भौगोलिक क्षेत्रमा, ३२.२५% उच्चपहाडी तथा उच्चहिमाली क्षेत्रमा, २३.०४% चुरे क्षेत्रमा र ६.९०% तराई क्षेत्रमा अवस्थित छ। यसैगरी अन्य काष्ठ तथा बुट्यान क्षेत्र मध्ये तराई, चुरे, मध्यपहाडी र उच्चपहाडी तथा उच्चहिमाली भौगोलिक क्षेत्रहरुमा क्रमशः १.४७%, ३.५०%, ९.६१%, र ८५.४२% रहेको छ।

रुखको मौज्दात

४. नेपालको वन क्षेत्रमा १० से.मि. भन्दा बढि व्यास भएका रुखको संख्या २ अर्ब ५६ करोड ३३ लाख (४२९.९३ प्रति हेक्टर) र कुल काण्ड आयतन ९८ करोड २३ लाख ३२ हजार घन मिटर (१६४.७६ घन मिटर प्रति हेक्टर) अनुमान गरिएको छ।

५. काण्डको औसत आयतन (mean stem volume) सबैभन्दा बढि (२२५.२४ घन मिटर प्रति हेक्टर) उच्चपहाडी तथा उच्चहिमाली भौगोलिक क्षेत्रमा पाइएको छ भने मध्यपहाडी क्षेत्रमा सबैभन्दा कम (१२४.२६ घन मिटर प्रति हेक्टर) पाइएको छ। तराई र चुरे भौगोलिक क्षेत्रहरुमा क्रमशः १६१.६६ र १४७.४९ घन मिटर प्रति हेक्टर काण्ड आयतन रहेको पाइयो।

६. नेपालको वन क्षेत्रमा रुखको कुल जैविक पिण्ड (air-dried biomass) १ अर्ब १५ करोड ९७ लाख टन (१९४.५१ टन प्रति हेक्टर) रहेको छ।

कार्वनको संचिति

७. नेपालको वन क्षेत्रमा कुल कार्बन संचिति १ अर्ब ५ करोड ५० लाख टन (१७६.९५ टन प्रति हेक्टर) रहेको अनुमान गरिएको छ जसमध्ये ६१.५३% भाग रुखमा (जीवित, सुखड खडा, ढलापडा र सतह मुनिको भाग समेत), ३७.८०% माटोमा र ०.६७% पातपतिंगर (litter and debris) मा रहेको पाइयो।

जैविक विविधता

८. मापन गरिएका वन क्षेत्रमा ९९ परिवार (families) अन्तर्गत २३९ जाति (genera) का कुल ४४३ वटा रुख प्रजाति (species) पहिचान गरिएका छन्। मध्यपहाडी, चुरे, उच्चपहाडी तथा उच्चहिमाली र तराई भौगोलिक क्षेत्रहरुमा क्रमशः ३२६, २८१, २७५ र १६४ वटा रुख प्रजातिहरु नमुना प्लटमा भेटिएका थिए।

प्रतिकूल प्रभावहरु

९. अन्य भौगोलिक क्षेत्रहरुको तुलनामा चुरे भौगोलिक क्षेत्रको वनमा सबैभन्दा बढि प्रतिकूल प्रभावहरु भएको पाइयो जसमध्ये चरिचरन, वन डढेलो, पहिरो र झाडी कटानी प्रमुख हुन्।

EXECUTIVE SUMMARY

The Department of Forest Research and Survey (DFRS) implemented Forest Resource Assessment (FRA) Nepal Project (2010–2014) with financial and technical assistance from the Government of Finland. The project was designed to carry out national-level forest resource assessment, with an overall objective of providing comprehensive and up-to-date national-level forest resource information to support forest policy formulation, forestry sector decision-making and international reporting. The report presents information primarily on forest cover, growing stock, biomass, carbon stock, biodiversity and forest disturbances.

Forest cover maps were prepared and classified as Forest, Other Wooded Land (OWL) and Other Land (non-forest) using RapidEye MSS satellite imagery, secondary images (Google Earth images, Landsat), ancillary maps (LRMP and topographical maps) and the FRA Nepal field inventory data. Images were classified by applying an automated method of object-based image analysis method on segmented images using eCognition software. In order to conduct the forest inventory, a two-phased stratified systematic cluster sampling design was adopted. Five physiographic regions—Terai, Churia, Middle Mountains, High Mountains and High Himal—were considered as strata. At the first phase, a total of 9,230 clusters (55,358 plots) were laid out systematically at the nodes of 4 km × 4 km square grids placed across the country. These plots were interpreted by using high-resolution RapidEye imagery and Google Earth. At the second phase, a total of 2,544 sample plots (Forest: 1,553; OWL: 105; OL: 886) were measured in the field. Each sample plot consisted of four concentric circular sample plots (CCSP) of different radii, four vegetation sub-plots, four shrubs and seedlings sub-plots, and four soil pits.

As per this assessment, Forest covers 5.96 million ha (40.36%), Other Wooded Land covers 0.65 million ha (4.38%) and Other Land covers 8.16 million ha (55.26%). Forest and OWL together comprise 44.74% of the total area of the country. Out of the total forest area of Nepal, 37.80% lies in Middle Mountains region, 32.25% in High Mountains and High Himal, 23.04% in Churia and 6.90 in the Terai. The Mid-Western Development Region has the highest (26.68 %) forest cover of Nepal, whereas Far-Western Development Region has the lowest (16.94 %) of the total forest area. Out of the total forest area of the country, 4.93 million ha (82.68%) lies outside Protected Areas and 1.03 million ha (17.32%) inside Protected Areas.

The estimated total number of stems with Diameter at Breast Height (DBH) ≥10 cm is 3,112.28 million, of which 2,563.27 million (429.93/ha) is in Forest. The total estimated stem volume with DBH ≥10 cm is 1,063.56 million m^3; out of which 982.33 million m^3 (164.76 m^3/ha) is in Forest, 4.58 million m^3 (7.91 m^3/ha) in OWL and 76.65 million m^3 (14.49 m^3/ha) in Other Land. High Mountains and High Himal physiographic regions together has the highest stem volume per hectare (225.24 m^3/ha) whereas Middle Mountains has the lowest (124.26 m^3/ha) in Forest. Terai and Churia regions have 161.66 m^3/ha and 147.49 m^3/ha, respectively. Of the total stem volume in Forest, *Shorea robusta* has the highest stem volume (31.76 m^3/ha) followed by *Quercus* spp. (24.39 m^3/ha) and *Pinus roxburghii* (11.62 m^3/ha). The average above-ground air-dried biomass in Forest is 194.51 t/ha. The assessment showed an increase in the number of stems from 408/ha in NFI 1987–98 to 430/ha in FRA 2010–2014. However, the mean stem volume per hectare was found to be less in FRA 2010–2014 (164.76 m^3/ha) than in NFI 1987–98 (178 m^3/ha).

The total carbon stock in Nepal is estimated to be 1,157.37 million tonnes, out of which Forest, OWL and OL constitute 1,054.97 million tonnes (176.95 t/ha), 60.92 million tonnes (105.24 t/ha) and 41.48 million tonnes (7.84 t/ha), respectively. Out of the total forest carbon stock, tree, soil and litter/debris components contribute 61.53%, 37.80 %, and 0.67% of carbon, respectively.

Altogether, 443 tree species belonging to 239 genera and 99 families were recorded in the sample plots. The highest number of taxa was found in Middle Mountains region (326 species) and the lowest in Terai region (164 species). Nearly two-thirds of the total forest area in the country was affected by grazing. Tree cutting, bush cutting, *lathra* cutting, lopping and forest fire were also common.

The results reported here provide an important insight into the forests of Nepal which will help the Government and concerned stakeholders in decision-making towards sustainable forest management. Sample plots selected for this assessment were permanently established for regular monitoring. This, together with the institutional capacity strengthened during the project, will help to conduct periodic forest resource assessment in the future.

सारांश

वन अनुसन्धान तथा सर्वेक्षण विभागले संचालन गरेको वन स्रोत सर्वेक्षण आयोजना नेपाल सरकार र फिनल्याण्ड सरकारको द्विपक्षीय सहयोगमा संचालित आयोजना हो । यो आयोजनाको मुख्य उद्देश्य राष्ट्रिय स्तरमा नेपालको वन स्रोतको सर्वेक्षण गरी उपयुक्त नीति रणनीति तर्जुमा गर्न सहयोग पुऱ्याउनुको साथै वन सम्बन्धी विस्तृत र आवधिक तथ्यांक तथा सूचनाहरु प्रदान गर्नु रहेको थियो । यस राष्ट्रिय प्रतिवेदनमा मुख्यतया वन क्षेत्र, वनको मौज्दात, जैविकपिण्ड, कार्बन संचिति, जैविक विविधता र वनमा हुने प्रतिकूल प्रभावहरु सम्बन्धी नतिजाहरु प्रस्तुत गरिएको छ ।

नेपालको सम्पूर्ण भू-भागलाई भू-उपग्रह चित्रहरुको साथै अन्य नक्साहरु अध्ययन गरी फिल्ड कार्य समेतको आधारमा वन (Forest), बुट्यान (Other Wooded Land) र अन्य क्षेत्र (Other Land) गरी तीन भागमा वर्गिकरण गरी नक्सांकन गरिएको थियो । वनस्रोत सर्वेक्षणको लागि पहिलो चरणमा पाँच वटै भौगोलिक क्षेत्रहरुमा चार कि. मि. को वर्गाकार ग्रिड बनाई ९,२३० ठाउँमा जम्मा ५५,३५८ प्लटहरु राखी अध्ययन गरिएको थियो भने दोस्रो चरणमा वनमा १,५५३, बुट्यानमा १०५ र अन्य क्षेत्रमा ८८६ गरी जम्मा २,५४४ नमुना प्लटहरु फिल्डमा गई नाँपजाँच गरिएको थियो । प्रत्येक नमुना प्लटमा चार वृत्तीय घेराहरु बनाई रुखको साईज अनुसार मापन गरिएको थियो । सोहि प्लटभित्र अरु सानो साइजका सब-प्लटहरु बनाई घाँस/झार, बुट्यान/बिरुवा/लाथ्राको तथ्यांक संकलन गरिएको थियो । यसको अतिरिक्त माटोमा रहेको कार्बन आंकलन गर्न प्लटको बाहिरपट्टि चारवटा कुनाबाट माटोको नमुना संकलन समेत गरिएको थियो ।

नेपालमा वनले करिब ५९ लाख ६२ हजार हेक्टर भू-भाग ओगटेको छ जुन नेपालको कुल क्षेत्रफलको ४०.३६% हुन आउँछ । बुट्यान क्षेत्र ६ लाख ४८ हजार हेक्टर (४.३८%) रहेको छ । यसरी नेपालको कुल क्षेत्रफल मध्ये वन तथा बुट्यान क्षेत्रले गरी जम्मा ४४.७४% भू-भाग ओगटेको छ । कुल वन क्षेत्रको ३७.८०% मध्यपहाडी भौगोलिक क्षेत्रमा, ३२.२५% उच्चपहाडी तथा उच्चहिमाली क्षेत्रमा, २३.०४% चुरे क्षेत्रमा र ६.९०% तराई क्षेत्रमा अवस्थित छ । कुल वन क्षेत्र मध्ये संरक्षित क्षेत्रमा १० लाख ३३ हजार हेक्टर (१७.३२%) र संरक्षित क्षेत्र भन्दा बाहिर ४९ लाख २९ हजार हेक्टर (८२.६८%) वन रहेको छ ।

नेपालमा १० से.मि. भन्दा बढि व्यास भएका रुखहरुको कुल संख्या ३ अर्ब ११ करोड २३ लाख छ जसमध्ये वन क्षेत्रमा २ अर्ब ५६ करोड ३३ लाख (४२९.९३ प्रति हेक्टर) छन् । नेपालमा काण्डको कुल आयतन करिब १ अर्ब ६ करोड ३६ लाख घन मिटर रहेको छ जसमध्ये करिब ९८ करोड २३ लाख घन मिटर (१६४.७६ घन मिटर प्रति हेक्टर) वन क्षेत्रमा पाइयो । उच्चपहाडी तथा उच्चहिमाली भौगोलिक क्षेत्रको वनमा सबैभन्दा बढि आयतन (२२५.२४ घन मिटर प्रति हेक्टर) र मध्यपहाडी क्षेत्रमा सबैभन्दा कम (१२४.२६ घन मिटर प्रति हेक्टर) पाइएको छ । तराई र चुरे क्षेत्रमा क्रमशः १६१.६६ र १४७.४९ घन मिटर प्रति हेक्टर आयतन पाइयो । रुख प्रजातिको आधारमा हेर्दा वनक्षेत्रको औसत आयतन मध्ये साल प्रजातिको सबैभन्दा बढि (३१.७६ घन मिटर प्रति हेक्टर) पाइएको छ भने त्यसपछि क्रमशः खस्रु (२४.३९ घन मिटर प्रति हेक्टर) र खोटे सल्ला (११.६२ घन मिटर प्रति हेक्टर) प्रजातिको रहेको पाइयो । वन क्षेत्रमा रुखको जमिन माथिको औसत जैविकपिण्ड १९४.५१ टन प्रति हेक्टर रहेको पाइयो । करिब बीस वर्ष अगाडि गरिएको राष्ट्रिय वन सर्वेक्षणको

तुलनामा हाल प्रति हेक्टर रुखको संख्यामा केहि वृद्धि भएको (४०८ बाट ४३०) र काण्डको आयतन मौज्दातमा केहि गिरावट (१७८ बाट १६५ घन मिटर) आएको पाइएको छ ।

नेपालमा कुल कार्बन संचिति करिब १ अर्ब १५ करोड ७४ लाख टन भएको अनुमान गरिएको छ जसमध्ये वनमा करिब १ अर्ब ५ करोड ५० लाख (औसतः १७६.९५ टन प्रति हेक्टर), बुट्यानमा करिब ६ करोड ९ लाख (औसतः १०५.२४ टन प्रति हेक्टर) र अन्य क्षेत्रमा करिब ४ करोड १५ लाख टन (औसतः ७.८४ टन प्रति हेक्टर) रहेको पाइयो । वन क्षेत्रको कुल कार्बन संचिति मध्ये ६१.५३% रुखमा, ३७.८०% माटोमा र ०.६७% पातपतिंगर (litter and debris) मा रहेको पाइयो ।

यस सर्वेक्षणको क्रममा मापन गरिएका नमुना प्लटहरुमा कुल ४४३ प्रकारको रुखको प्रजातिहरु (२३९ जाति र ९९ परिवार) पाइएको छ। सबैभन्दा बढि रुखका प्रजातिहरु मध्यपहाडी क्षेत्रमा (३२६ प्रजाति) र सबैभन्दा कम तराइ क्षेत्रमा (१६४ प्रजाति) पाइएका छन् । नेपालको करिब दुई-तिहाइ वन क्षेत्रमा चरिचरनको प्रभाव रहेको पाइयो । त्यसैगरी अन्य प्रभावहरुमा रुख, लाथ्रा र बिरुवा कटानी तथा वन डढेलो उल्लेख्य मात्रामा पाइयो ।

यस सर्वेक्षणबाट नेपालको वन क्षेत्रको विविध विषयहरुमा जानकारी प्राप्त भएको र यसरी प्राप्त नतिजाहरु नेपाल सरकार र अन्य सरोकारवालाहरुलाई वन स्रोतको दिगो व्यवस्थापनमा आवश्यक निर्णय लिन सहयोग पुग्ने अपेक्षा गरिएको छ। सर्वेक्षणको क्रममा मापन गरिएका प्लटहरुलाई स्थायी नमुना प्लटको रुपमा स्थापना गरिएको छ । यसका साथै वन स्रोत सर्वेक्षणको लागि आवश्यक संस्थागत क्षमतामा समेत अभिवृद्धि भएको छ, यसबाट भविष्यमा वन स्रोत सर्वेक्षण कार्यलाई आवधिक रुपमा संचालन गरी वन तथा कार्बन सम्बन्धी सूचना तथा तथ्यांकहरु अध्यावधिक गर्नमा सहयोग पुग्ने विश्वास लिइएको छ ।

Contents

LIST OF FIGURES

LIST OF TABLES

1

INTRODUCTION

1.1 Background

Department of Forest Research and Survey (DFRS) under the Ministry of Forests and Soil Conservation (MFSC) executed Forest Resource Assessment (FRA) Nepal Project (2010–2014), under the bilateral agreement between the Government of Nepal and the Government of Finland. The project was designed to carry out national level forest resource assessment for providing comprehensive and up-to-date national-level forest resource information to support forest policy formulation, national-level forestry sector decision-making and international reporting.

This report presents the findings of FRA 2010–2014. It summarises the results of the forest resource assessment of physiographic regions of Nepal presented in the region-specific reports *viz*. "Terai Forests of Nepal", "Churia Forests of Nepal", "Middle Mountains Forests of Nepal", and "High Mountains and High Himal Forests of Nepal". This report presents information primarily on land cover, forest cover, growing stock, structural composition of tree species, biomass, carbon stock and forest disturbance. It attempts to address the demand for forest resource information at national and international levels.

The forest resource assessment made use of high-resolution satellite imagery, precise measurement devices, advanced computer systems, and trained human resources to obtain reliable output.

1.2 Physiographic Setting

1.2.1 Geography

Nepal is located between 26^0 22' N and 30^0 27' N latitude and 80^0 04' E and 88^0 12' E longitude. There are five physiographic regions in Nepal (Figure 1) based on geology and geomorphology (LRMP, 1986).

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

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

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

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

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

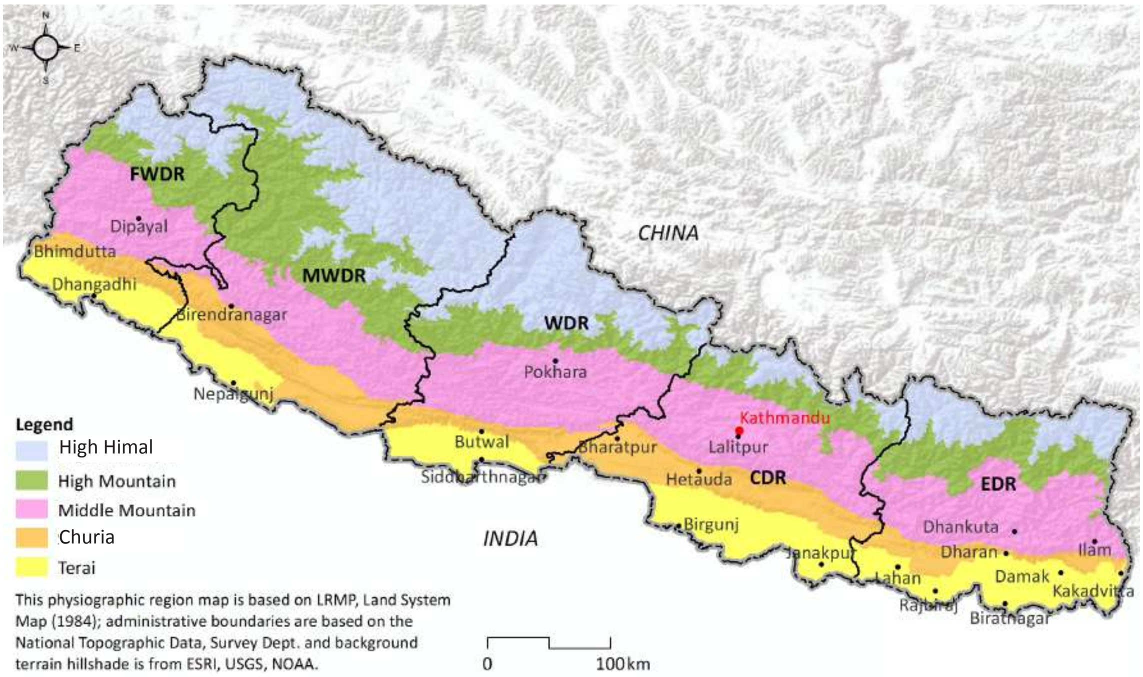

Figure 1: *Physiographic regions of Nepal*

1.2.2 Soils

Terai region consists of recent and post-Pleistocene alluvial deposits that form a piedmont plain (Carson *et al.,* 1986). The lower Churia is largely composed of very fine-grained sediments such as variegated mudstone, siltstone and shale with smaller amounts of fine-grained sandstone (Upreti, 1999). The middle Churia has thick beds of multi-storied sandstones alternating with subordinate beds of mudstone. The upper Churia is characterised by very coarse sediments such as loose boulder conglomerates. Dominant soil texture found in Middle Mountains region ranges from fragmented sandy to loamly/boulderly, loamy, loamy skeletal as per the diverse land forms. High Mountains soils are rocky mostly derived from phyllite, schist, gneiss and quartzite of different ages. High Himal physiographic region is characterised by rocky soils originated from gneiss, schist, limestone and shale of different ages (Pariyar, 2008).

1.2.3 Climate

The climate of Nepal greatly varies from north to south and east to west. In general, climatic zones in Nepal are categorised by temperature regimes based on altitudinal ranges. These climatic zones are sub-tropical (<1,000 m elevation), warm-temperate (1,000–2,000 m elevation), cool-temperate (2,000–3,000 m elevation), alpine (3,000–4,000 m elevation) and arctic (>4,500 m elevation).

Terai region is located in sub-tropical climatic zone characterised by hot and humid summers, intense monsoon rain, and dry winters. The annual rainfall decreases gradually from the Eastern to the Western Terai. The annual total rainfall in this region varies from 1,138 mm to 2,680 mm, and the mean monthly precipitation ranges from 8 mm to 535 mm.

The climate of Churia region ranges from sub-tropical to warm-temperate and is characterised by hot and sub-humid summers, intense monsoon rain, and cold dry winters. The precipitation pattern in Churia is variable, with the highest annual rainfall in the Eastern and Central Development Regions. The total annual rainfall varies from a minimum of 1,138 mm to the maximum of 2,671 mm.

In Middle Mountains, the climate ranges from sub-tropical, sub-humid in river valleys to warm-temperate in valleys to cool-temperate in the high hills. Annual precipitation varies from east to west with the highest in the Western Development Region (1,898 mm).

The climate in High Mountains and High Himal regions ranges from warm-temperate in the valleys to cool-temperate in the higher elevations and arctic in the upper most elevations. Precipitation in the region varies from east to west with the highest in the Central Development Region with a total annual precipitation of 2,185 mm (Figure 2). Trans-Himalayan areas receive very little precipitation, and are also known as cold desert.

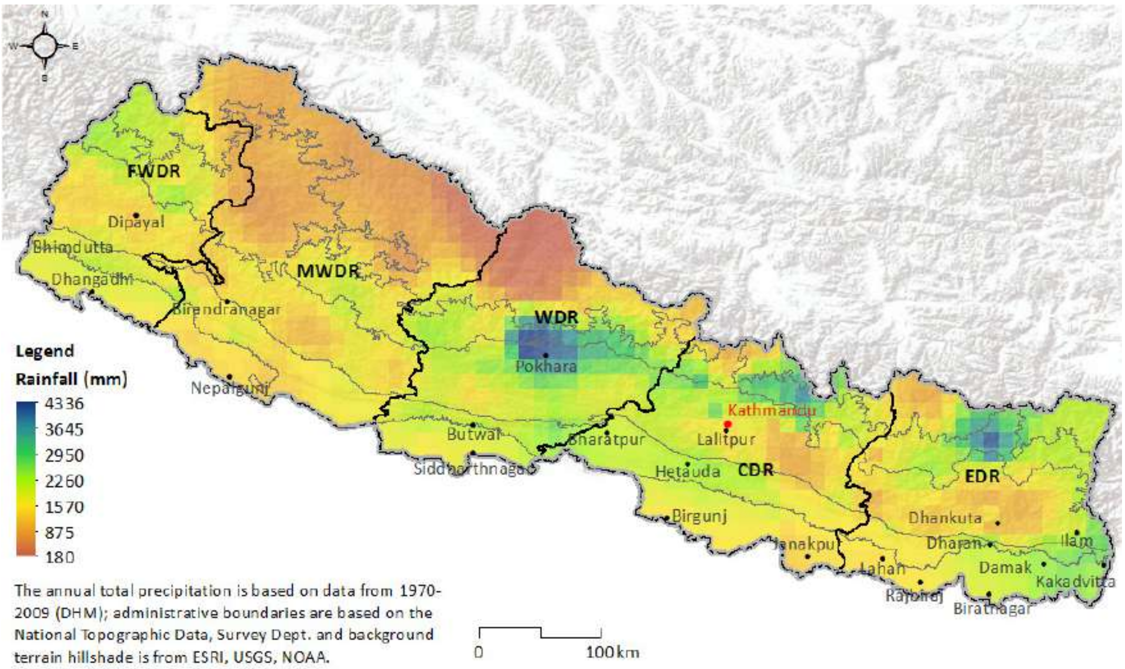

Figure 2: *Annual total precipitation (1970–2009)*

1.2.4 Drainage

Terai region is drained by numerous rivers and rivulets (Figure 3). The largest, among them are Koshi in the east, Gandaki in the centre, and Karnali and Mahakali in the west. These rivers originate from the Himalayan Region and even beyond the Himalayas. As the rivers cross the hills and Churia, they start depositing huge sediments along their banks in the Terai. The deposition process creates multiple channels of the rivers. Every year during monsoon season, most of the rivers are swollen up and cause flash floods in the Terai due to their shallow beds. One of the biggest concerns is the tendency of minor and major rivers to change their courses due to flooding events (Carson *et al.,* 1986).

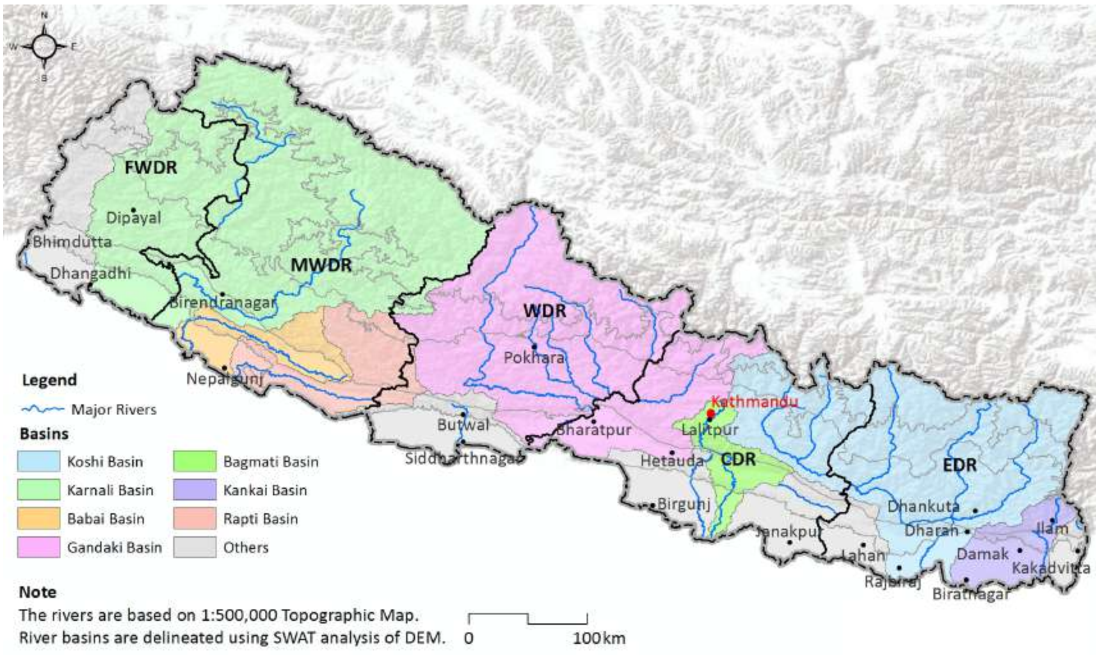

Figure 3*: River basin and drainage of Nepal*

Several large rivers originating in High Himal region cut the east-west Churia chain, while smaller, ephemeral rivers flow only during the monsoon season. Water in the small rivers may dry up totally outside the monsoon season, probably because the soil in the river beds is highly permeable (Shrestha *et al.,* 2008). Churia region is the origin of the third-grade rivers of Nepal. These rivers are characterised by their smaller sizes and low to almost no flow during the dry season.

In Middle Mountains region, rivers originating in the Lesser Himalaya and the Mahabharat Range are called the second-grade rivers. They are fed by precipitation as well as ground water recharge (WECS, 2011). These rivers are perennial and are commonly characterised by wide seasonal fluctuation in discharge. The major river systems in this region are Babai, West Rapti, Tinau, Bagmati, Kamala, Kankai, and Mechi.

High Mountains and High Himal regions are the origin of first-grade rivers of Nepal. These rivers are snow-fed rivers, originate from the Himalayas, and flow across all the physiographic regions. The first-grade rivers that originate from the Himalayas are Mahakali, Karnali, Gandaki and Koshi.

1.3 Vegetation

Nepal occupies about 0.1 percent of the global area but harbours over three percent of the world's known flora. A total of 284 flowering plants are endemic to Nepal. The number of known species in Nepal is: 6,073 angiosperms; 26 gymnosperms; 534 pteridophytes; 1,150 bryophytes; 365 lichens; 1,822 fungi and 1,001 algae (GoN, 2014).

Phyto-geographically, Nepal is located in the Oriental Region (Polunin, 1964). According to the Conservation Science Programme WWF-US (1998), Nepal includes 12 eco-regions (TISC, 2002) as given in Table 1.

Table 1: *Vegetation types and eco-regions in Nepal*

Vegetation type	Eco-region	Altitude
Montane grasslands and shrub lands	Trans-Himalayan alpine shrub/meadow	
	West Himalayan alpine shrub/meadow	3,700–4,400 m
	East Himalayan alpine shrub/meadow	4,000–4,500 m
	North-west Himalayan alpine shrub/meadow	Above 4,000 m
Sub-alpine conifer forest	Trans-Himalayan sub-alpine conifer forest	
	West Himalayan sub-alpine conifer forest	3,000–4,000 m
	East Himalayan sub-alpine conifer forest	3,000–4,000 m
Temperate broadleaved forest	West Himalayan broadleaved forest	1,500–3,000 m
	East Himalayan broadleaved forest	1,500–3,000 m
Tropical forests/sub-tropical conifer forest	Himalayan sub-tropical pine forest	1,000–2,000 m
Sub-tropical broadleaved forest	Himalayan sub-tropical broadleaved forest	500–1,000 m
Grasslands, savannahs and shrub lands	Tarai-Duar savannahs and grassland	Below 500 m

Source: TISC (2002)

According to TISC (2002), Stainton (1972) identified 35 forest types in Nepal, largely based on Champion (1936). These 35 types are often categorised into 10 major groups (GoN, 2014): (i) tropical, (ii) sub-tropical broadleaved, (iii) sub-tropical conifer, (iv) lower temperate broadleaved, (v) lower temperate mixed broadleaved, (vi) upper temperate broadleaved, (vii) upper temperate mixed broadleaved, (viii) temperate coniferous, (ix) sub-alpine and (x) alpine scrub. Similarly, Biodiversity Profile Project (BPP) identified a total of 118 ecosystems in Nepal (BPP, 1995). Table 2 presents distribution of ecosystems in different physiographic regions.

Table 2: *Distribution of ecosystems by physiographic region*

Physiographic region	Ecosystems		
	Number	%	Types
Terai	12	10.2	10 'forest' and two 'cultivated'
Churia	14	11.9	13 'forest' and one cultivated 'Dun'
Middle Mountains	53	44.9	52 'forest', and one 'cultivated'
High Himal and High Mountains	38	32.2	37 'forest' and one 'glacier/snow/ rock'
Others	1	0.8	'Water bodies; found in all zones, except the Siwalik
Total	**118**	**100**	

Source: BPP (1995)

1.4 Forestry Sector Policies

Nepal has well-defined policies and legal framework in the forestry sector. Some key policies and legal instruments are: Nationalisation of Private Forest Act, 1957; National Parks and Wildlife Conservation Act, 1972; National Forest Plan, 1976; Master Plan for Forestry Sector, 1989; Forest Act, 1993; Revised Forestry Sector Policy, 2000; Leasehold Forestry Policy, 2002; Herbs and NTFP Development Policy, 2004; Terai Arc Landscape Strategy, 2004–2014; Gender and Social Inclusion Strategy in the Forestry Sector, 2004-19; Sacred Himalayan Landscape Strategy, 2006-16; National Wetland Policy, 2012; National Biodiversity Strategy and Action Plan, 2014 and Forest Policy, 2015.

Forestry sector development in Nepal has been guided by periodic national plans and, until recently, by the Master Plan for Forestry Sector (MPFS, 1989; NPC, 2013). At present, Forest Policy, 2015 is the main policy document which guides sub-sectoral programmes relating to forests, plant resources, wildlife, biodiversity, medicinal plants, and soil and watershed conservation. Periodic assessment and updating of information on forest resources of the country is also included in the forest policy (GoN, 2015).

1.5 Population

Distribution of population varies among the physiographic regions of Nepal and between rural and urban regions of the country (CBS, 2011; CBS, 2012). Terai region is populated by 41.48% of the nation's population with a population density of 583.46 persons/km^2. Population in the Churia is 12.78% of the total population with a density of 191.56 persons/km^2. In the Middle Mountains region, the proportion of population is 38.17% with a density of 251.99 persons/km^2. Both the High Mountains and High Himal regions are sparsely populated with average population densities of about 65.54 and 4.98 persons/km^2, respectively. High Mountains region has about 6.94% of the total population of the country and High Himal has about 0.62% (Table 3 and Figure 4).

***Table 3:** Population characteristics of Nepal by physiographic region*

Physiographic region	Male	Female	Total population	%	Household	Population density/ km^2
Terai	5,795,762	5,995,930	11,791,691	41.48	2,210,625	583.46
Churia	1,719,994	1,913,707	3,633,701	12.78	783,752	191.56
Middle Mountains	5,128,216	5,722,844	10,851,070	38.17	2,450,369	251.99
High Mountains	946,610	1,025,637	1,972,247	6.94	399,008	65.54
High Himal	86,985	89,004	175,989	0.62	37,571	4.98
Total	**13,677,567**	**14,747,122**	**28,424,698**		**5,881,325**	**192.48**

Adapted from CBS (2011)

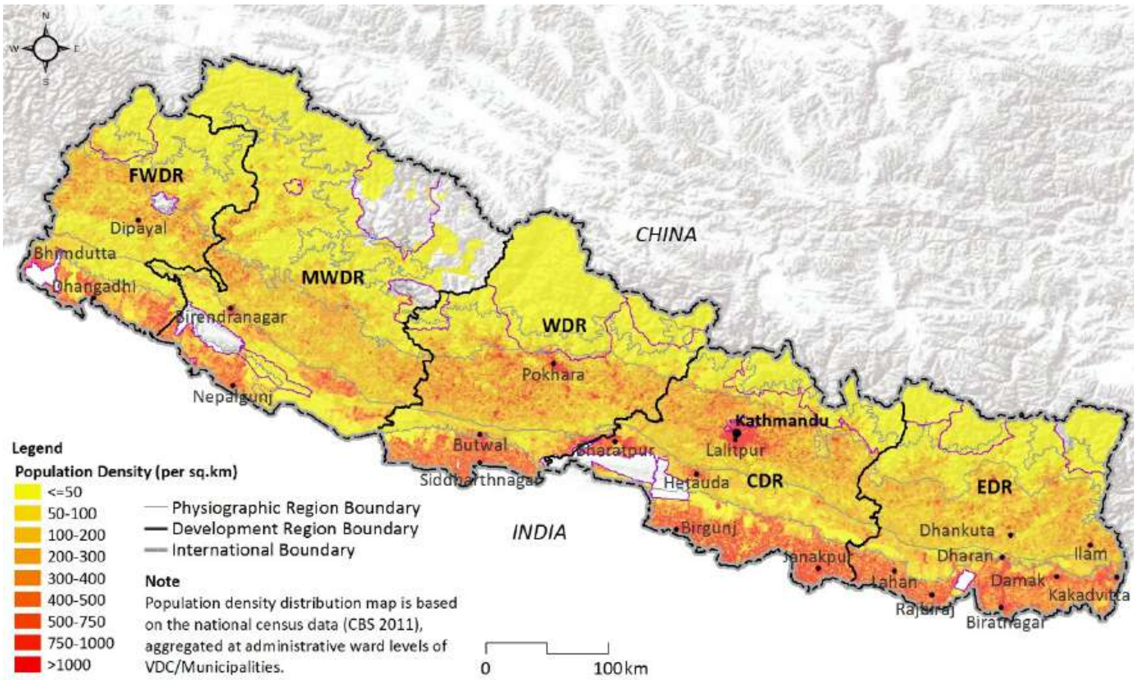

Figure 4: *Population density distribution in Nepal (Adapted from CBS, 2011)*

2

PREVIOUS FOREST RESOURCE ASSESSMENTS

Forests play a vital role in Nepal's socio-economic development. In order to maximise forests' contribution to sustainable development, the forestry sector needs detailed and up-to-date information on the status of the resource and information management systems. This information is obtained by carrying out forest inventories periodically with the goal of recording the current state and changes in the forests.

The first national-level forest inventory was carried out in the 1960s. Since then, several forest resource assessments have been carried out, each different in terms of its purpose, scale, scope, design and technology used. The second national-forest inventory was carried out in the 1990s. FRA Nepal (2010–2014) is the third and most comprehensive national-level forest resource inventory.

2.1 Forest Resources Survey

The first national-level forest inventory was conducted between 1963 and 1967 with support from USAID (FRS, 1967). It covered the Terai, Inner Terai, and Churia Hills, as well as the southern faces of the Mahabharat Range, but excluded most of the then Chitwan Division, which was inventoried separately. The survey classified forests as either commercial or non-commercial, and focused on collecting data from commercial forests, primarily on timber estimates of stock and domestic consumption of wood products. Methodologically, it used visual interpretation of aerial photographs taken in 1953–1958 and 1963–1964, mapping, and field inventory. The inventory provided the first comprehensive assessment of commercial forests in Terai region as well as those in the adjoining areas of the hilly region.

2.2 Land Resources Mapping Project

The Land Resources Mapping Project (LRMP) used a variety of methods for country-wide assessment. It used aerial photographs taken between 1977 and 1979 with ground verification. It focused on mapping of land use; producing forest cover maps; and assessing the type, size and crown cover of forests. Both the high- and low-altitude forests were mapped according to crown cover (0–10%, 10–40%, 40–70%, and 70–100%), and scrubland (degraded forest) was mapped separately. Each forest was defined on the basis of dominant species and its forest type (coniferous, hardwood, or mixed). Land utilisation maps at the scale of 1:50,000 were produced by interpreting aerial photographs of the scale of 1:12,000.

2.3 Forest Resources and Deforestation in the Terai

The then Forest Survey and Statistics Division, a division directly under MFSC, with support from the Government of Finland, assessed forest resources and deforestation in the Terai from 1978/79 to 1990/91 by using 1991 Landsat TM (28.5 m spatial resolution) satellite imagery. It covered all 20 districts in the Terai (3.4 million ha) excluding protected areas (PAs).

2.4 National Forest Inventory

The second National Forest Inventory (NFI) was conducted by DFRS with support from the Government of Finland from 1987 to 1998. Using 1991 Landsat TM satellite images of the Terai and aerial photographs of the hills taken in 1989–1992 (DFRS, 1999), it updated data on forest cover and change, and produced forest statistics for all accessible forests, excluding those in protected areas. The NFI categorised Middle Mountains region as Hilly Area. Three types of inventories were carried out: using Landsat TM satellite imagery for 14 districts, a district-wise forest inventory for 10 districts, and aerial photo interpretation for 51 districts. District-wise forest inventory data was used to estimate the forest and shrub cover in Middle Mountains region. In the hills, photo-point sampling was used to estimate forest area as well as to carry out forest inventory in the field.

2.5 Forest Cover Change Analysis of the Terai Districts

In 2005, Department of Forests (DoF) conducted a study of forest cover change in the 20 Terai districts by using Landsat 1990/91 and Landsat 2000/01 satellite images and classifying land into six main categories (forest, degraded forest, grass land, barren land, water bodies, and other land). Ground verification was conducted between September and November 2004. Although this report focused mainly on Terai forests, it also included certain parts of Churia and Middle Mountains forests.

3

METHODOLOGY

FRA Nepal implemented multi-source forest resources inventory by using high-resolution satellite imagery, field inventory as well as other existing data sources such as digital elevation model and national topographic maps. Categorisation of land cover followed in FRA Nepal is based on current international practices of FAO which is also adopted by IPCC for GHG emission estimation and reporting. The inventory design was largely based on the principle adopted for NFI (1999) developed by Kleinn (1994). The design was tested in the field and subsequently revised to improve its functionality. Two-phase systematic cluster sampling was adopted for field measurement.

3.1 Land Cover Mapping

Land cover maps were prepared by using RapidEye MSS satellite imagery (Level 1b, 48 scenes acquired in February–April 2010/11), secondary images (Google Earth images, Landsat, etc.), ancillary maps (LRMP and topographical maps) and the FRA Nepal field inventory data. The imageries were processed for geometric and atmospheric corrections prior to forest cover analysis and mapping.

Area by land cover classes—Forest, Other Wooded Land (OWL), and Other Land (OL)—was estimated by using the forest cover maps. Also, the results on area by protection category, area by districts, and forest patches were estimated by using the forest cover maps.

Geometric Correction

The RapidEye Level 1b imagery was ortho-rectified by using Toutin's Model (Toutin, 2004), with ground control points and digital elevation model. The ground control points were identified by using road and river features from the National Topographical Map Data. The digital elevation model was also generated from the National Topographical Map Data by using contours and spot levels. Independent check points were fixed to assess the level of accuracy (Figure 5). The planimetric accuracy of the ortho-rectified images was 9.81 m (≈1.96 pixels RMSE) for the 1,355 ground-control points for 48 RapidEye scenes covering the entire country.

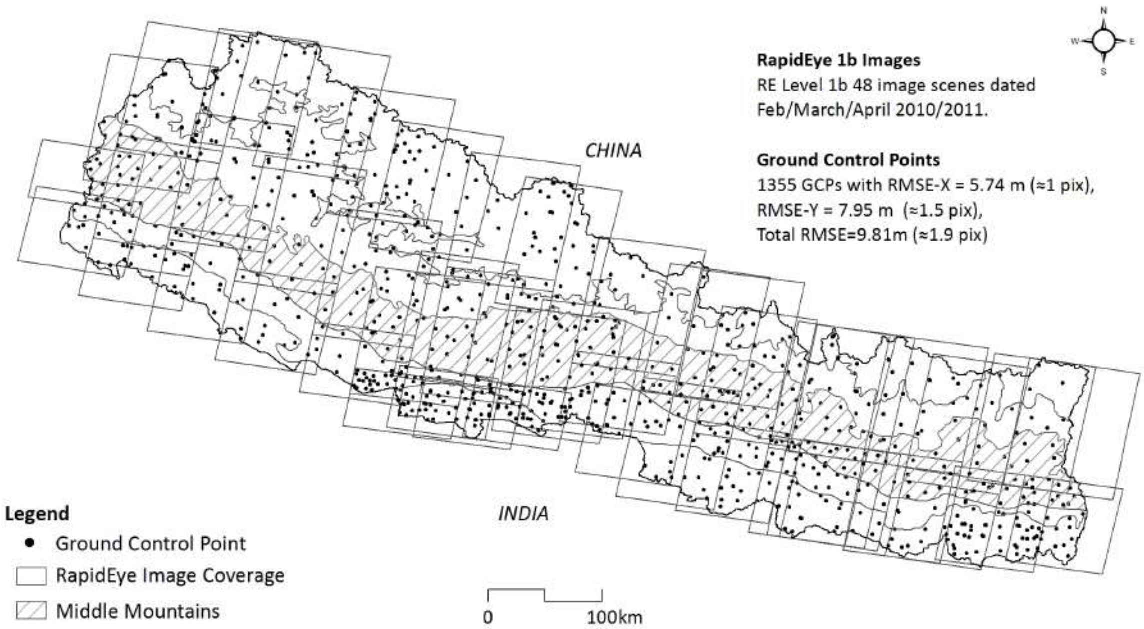

***Figure 5:** RapidEye image tiles and ground control points used for mapping*

Atmospheric Correction

Atmospheric correction was made to minimise the effects of atmospheric haze and terrain shadows by using topographical normalisation and Bidirectional Reflectance Distribution Function (BRDF) correction of the ATCOR3 model defined by Richter (1998) and given in Equation 1. Atmospheric correction was made for cloud and haze removal for the imageries covering Terai region. For the imageries covering Churia, Middle Mountains, High Mountains and High Himal, atmospheric correction was made for haze and cloud removal, and BRDF correction was made to remove terrain shadow.

Equation 1: Bidirectional reflectance distribution function (BRDF)

$G = (\cos \beta_i / \cos \beta_T)^{1/2}$

where,

G = BRDF factor
β_i = incidence angle
β_T = threshold angle

3.1.1 Land Cover Mapping

Land cover was mapped by adopting a hybrid approach using automated image classification system and supported by extensive visual interpretation (GOFC-GOLD, 2013). Images were classified by applying segmentation and automated object-based image analysis method (Baatz and Schape, 2000) using eCognition software (Version 8). Four spectral properties were considered: (i) mean pixel values of green, red, red-edge and near-infrared bands; (ii) a derived Normalised Difference Vegetation Index (NDVI); (iii) principal components; and (iv) the homogeneity texture of the near-infrared band. Randomly sampled reference training sets from the Phase 1 plots were used to classify land as Forest, OWL and Other Land (non-forest) along with additional field observation data for OWL and shrub classification. Forest, OWL and Other Land areas were classified by defining a 'containment membership function' for threshold values for all four properties. In order to improve classification accuracy, on-screen post-classification visual interpretation was carried out on the classified Forest, OWL (including shrub) and Other Land by using high-resolution images in Google Earth. In addition, field verification surveys were undertaken throughout Terai, Churia and Middle Mountains regions, in order to delineate OWL (including shrub) as well as to rectify errors in forest cover classification.

3.1.2 Forest Fragmentation Mapping

Fragmentation of forest patches and the sizes of those patches were analysed and mapped over the classified forest cover for each physiographic region. Spatially contiguous forest patches that fulfilled the criteria for forest were categorised based on their sizes, which ranged from less than 2 ha to greater than 50,000 ha. The frequency of occurrence and total area covered in each size category were analysed to assess the distribution and area of forest fragments. The results of the assessment of forest patches are presented in the reports for physiographic regions.

3.1.3 Forest Type Mapping

An approach based on machine learning and classification was developed for national level wall-to-wall forest type classification and mapping. The approach used Classification and Regression Tree (CART) with threefold cross-validation algorithm. In the CART process, Landsat 8 (acquired during October/November 2013) imagery variables (6 MSS bands, 8-Grey Level Co-occurrence Matrix) along with DEM parameters (elevation range, slope, aspect) were used as predictor variables. The machine learning CART process was trained by using FRA field inventoried forest type data from the PSPs (n = 907) selected randomly (80% intensity with forest types as strata) within individual Landsat 8 scene coverage area. The CART process uses binary regression algorithm to classify each image segment into designated forest types. The classified forest type was cross-validated by using the remaining 20% PSP forest type plots (n = 597).

3.1.4 Accuracy Assessments of Mapping

Accuracy assessment for land/forest cover mapping at each physiographic region was done by comparing randomly sampled cover classes on the maps with independent ground truth data (n = 1,894) of which 1,522 were inventory plots (PSPs) and 372 purposively sampled observation plots for OWL (including shrubs). Additional purposively selected observation plots were used to supplement the limited number of OWL plots in the inventory.

For wall-to-wall forest type classification and mapping, cross validation was done by using the randomly selected inventory plots (n = 597). Error matrices were analysed to assess overall accuracy and kappa statistics were used to test the reliability and standard errors.

3.2 Forest Resource Inventory

3.2.1 Sampling Design

A two-phased stratified systematic cluster sampling design was adopted. The five physiographic regions defined by the Department of Survey—High Himal, High Mountains, Middle Mountains, Churia and Terai—were used as strata. A hybrid approach was adopted in the forest inventory through interpretation of satellite images at the first phase and measurement of forest characteristics in the field at the second phase (Figure 6). Detailed methodology is presented in the respective reports for the physiographic regions.

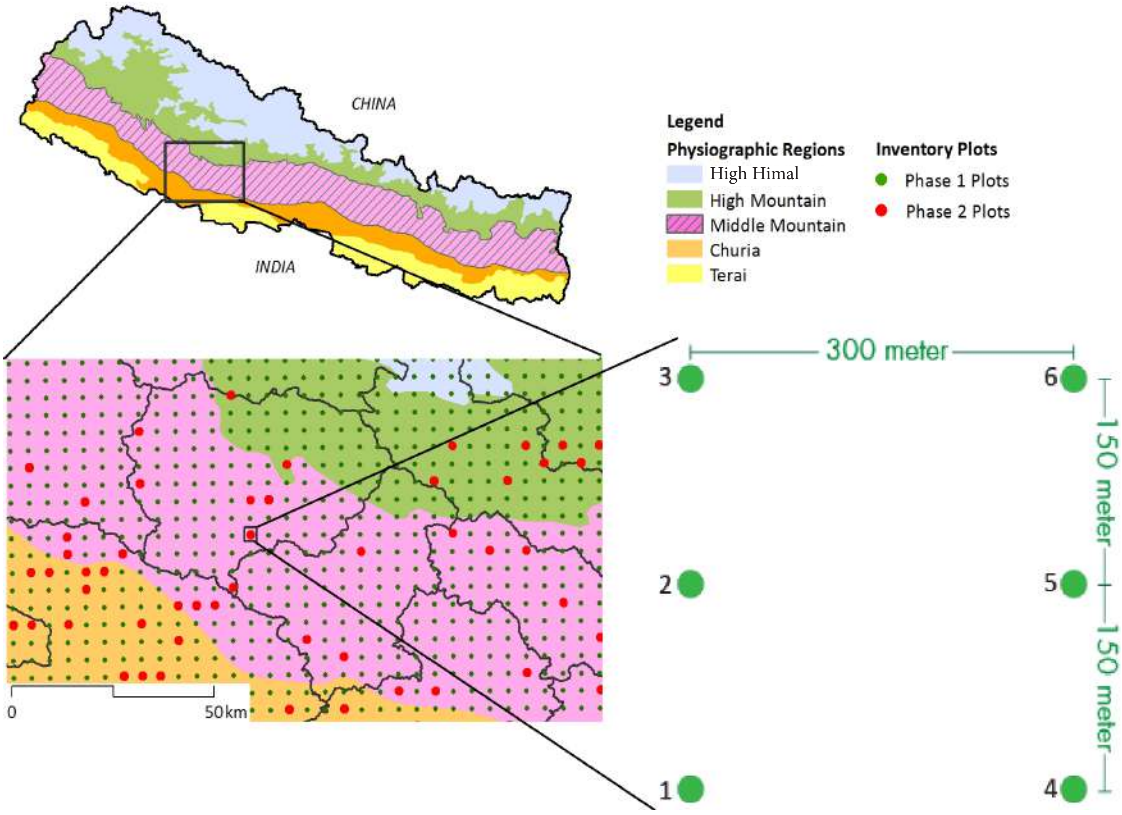

Figure 6: *Layout of sample plot /cluster*

A two-phased sampling method was used in order to concentrate the field measurements on forested clusters and to avoid walking long distances to reach a cluster without forest plots. Whilst a wide variety of biophysical forest parameters were assessed; the 10% accuracy at 95% confidence limit was set for stem volume.

First Phase Sampling

The first phase of sampling was undertaken as a desk study using high-resolution satellite imagery (RapidEye) and Google Earth (along with topographic maps) with a grid of 4 km x 4 km laid over it. The evenly distributed first phase sampling clusters were positioned at the grid nodes and the plots were examined closely on the satellite image, topographic map sheets and digital elevation model. Reachability (defined as altitude <4,000 m and slope <100%) and accessibility were then assessed for each of these first phase sample plots.

The first of the six sample plots in each cluster was situated at a grid node and the two other plots were each mapped an additional 150 m northward of that plot. A parallel set of three plots was situated 300 m east of the first three (Figure 6).

Clusters were numbered by columns from west to east and by rows from south to north across the country. Altogether, 9,230 clusters were identified on the imagery. Within each cluster, plots were numbered from south to north, assigning plot numbers 1, 2 and 3 to the west and 4, 5, and 6 to the east. In some cases, where plots crossed international borders, fewer than six plots were identified. In this way, 55,358 viable plots inside Nepal were identified by column, row and plot number (Table 4).

Table 4: *Distribution of the first phase sample plots by physiographic region*

Physiographic region	1st phase plots
Terai	7,533
Churia	7,132
Middle Mountains	16,139
High Mountains	11,307
High Himal	13,247
Total	55,358

Each plot was classified according to FAO Land Use Classes and reachability through visual interpretation of Google Earth imagery. The nine land use classes of FAO were:

i. Forest
ii. Other wooded area
iii. Agricultural area with tree cover
iv. Agricultural area without tree cover
v. Built-up area with tree cover
vi. Built-up area without tree cover
vii. Roads
viii. Other area
ix. Water

The land use classes (iii) to (ix) were categorised as Other Land in this assessment.

Second Phase Sampling

The second phase sample was a sub-sample of the first phase sample. Clusters selected for the second phase were measured in the field. A total of 450 clusters (1,553 plots) in Forest were measured. Altogether, 2,544 sample plots including 1,553 plots in Forest and 105 plots in OWL were permanently established and assessed whereas 886 plots on Other Land were measured (Table 5 and Figure 7). Details of second phase sampling for each physiographic region can be found in the respective physiographic region reports.

Table 5: *Distribution of permanent sample plots and clusters*

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

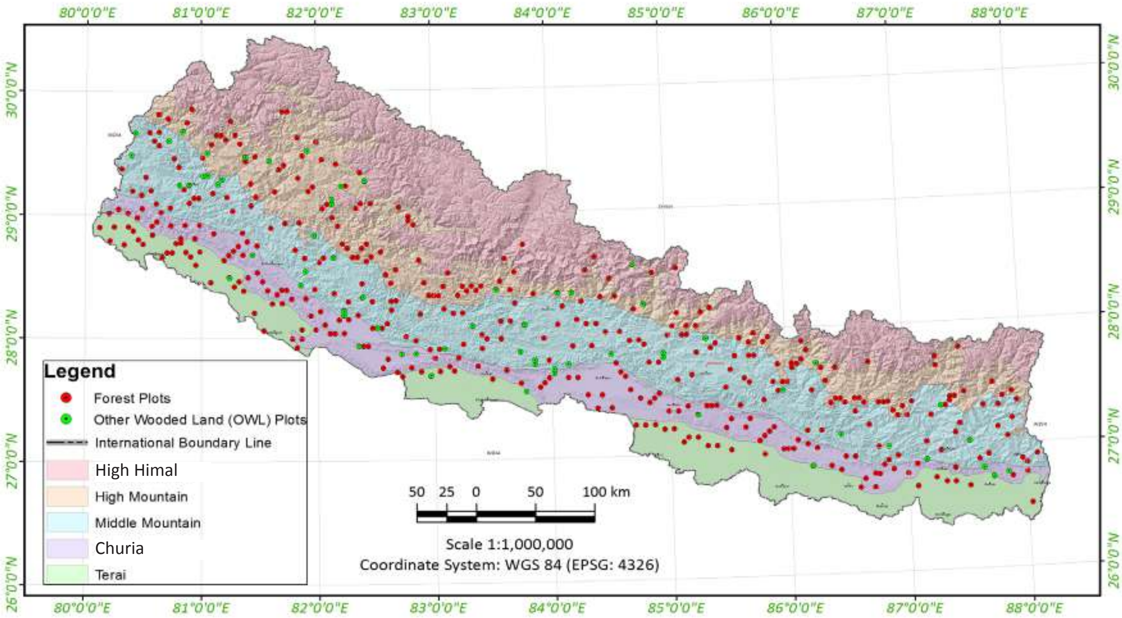

Figure 7: *Distribution of sample plots*

3.3 Sample Plot Design

Each sample plot consisted of four concentric circular sample plots (CCSP) of different radii, four vegetation sub-plots, four shrubs and seedlings sub-plots, and four soil pits. The plot design for tree measurement is given in Table 6 and Figure 8.

Table 6: *Size and area of CCSP of different radii with DBH limits*

S.N.	Plot radius (m)	DBH limit (cm)	Area (m^2)
1	20	>30.0	1,256.63
2	15	20.0–29.9	706.86
3	8	10.0–19.9	201.06
4	4	5.0–9.9	50.27

Other sub-plots were established to assess the status of seedlings, saplings, shrubs and herbs. Seedlings, saplings and shrubs were measured in four circular sub-plots, each with a radius of 2 m, located 10 m away from the centre of the plot in each of the four cardinal directions (North, East, South and West). Species-wise stem counting and mean height estimations were carried out for tree and shrub species having DBH less than 5 cm. Information on non-woody vascular plants was collected from four 1 m^2 plots, each located 5 m away from the centre in the four cardinal directions. Dead wood was assessed in a circular plot with a radius of 10 m from the plot centre.

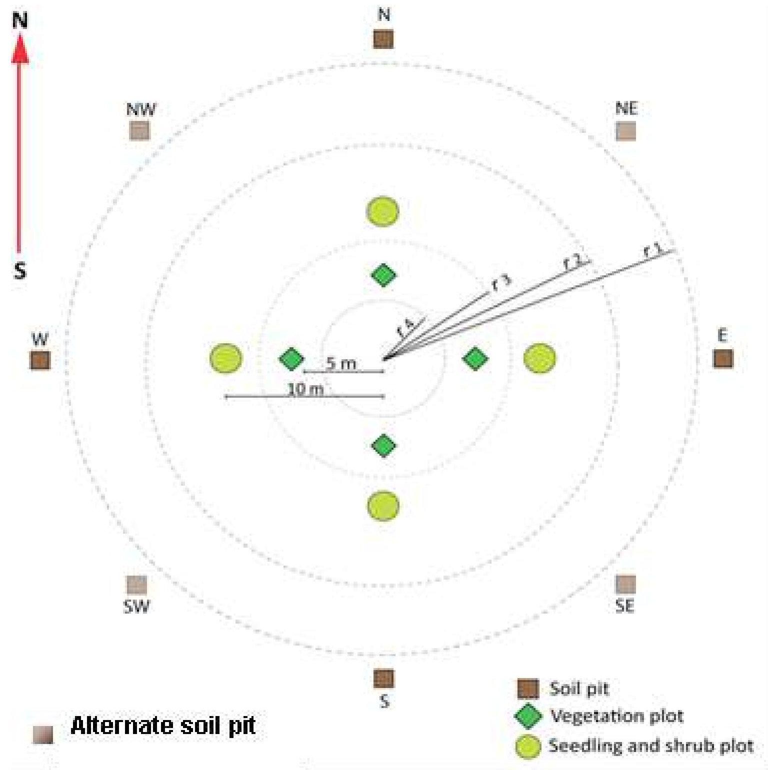

Figure 8: *Layout of concentric circular permanent sample plots and sub-plots*

Fourteen categories of natural and anthropogenic forest disturbances were assessed through field observations of both their occurrence and intensity (severe, moderate, minor) in the 20 m radius plot. Four soil pits per forest stand were prepared in order to identity soil texture and to determine soil stoniness. Soil, litter and debris were collected as composite samples by combining the materials collected at all soil pits.

The sample plots were navigated in the field by using hand-held GPS and located with a differential GPS (DGPS). Height of the sample tree was measured by using Vertex IV and Transponder T3. Crown cover was estimated by using spherical densiometer. Calipers and D-tapes were used to measure diameter.

3.3.1 Volume and Biomass Estimation

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

The volume equations developed by Sharma and Pukkala (1990) and the biomass models prescribed by the MPFS (1989) were used to estimate the volume and biomass of standing trees. The air-dried biomass values obtained using these equations were then converted into oven-dried biomass values using a conversion factor of 0.91 (Chaturvedi, 1982; Kharal and Fujiwara, 2012) and a carbon-ratio factor of 0.47 (IPCC, 2006a, b). The volume and biomass of seedling and sapling having DBH less than 10 cm were not included.

Stem volume estimation

The following allometric equation (Equation 2) developed by Sharma and Pukkala (1990) was used to estimate stem volume over bark:

Equation 2: Stem volume

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

where,

ln = Natural logarithm to the base 2.71828.

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

d = DBH in cm

h = Total tree height in m

a, b and c are coefficients depending on species

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

The volumes of individual broken trees were estimated by using a taper curve equation developed by Heinonen *et al.* (1996).

Tree-stem biomass estimation

Tree-stem biomass was calculated by using Equation 3 and species-specific wood-density values (Sharma and Pukkala, 1990; MPFS, 1989).

***Equation 3:** Tree stems biomass*

Stem biomass = Stem vol. × Density

where,

Stem vol. = Stem volume in m^3

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

Tree-branch and foliage biomass estimation

The separate branch-to-stem and foliage-to-stem biomass ratios prescribed by MPFS (1989) were used to estimate branch and foliage biomass from stem biomass. Dead trees were not taken into account for the estimation of branch and foliage biomass.

The total biomass of individual trees was estimated by using Equation 4.

***Equation 4:** Total biomass of each individual tree*

Total biomass = Stem biomass + Branch biomass + Foliage biomass

Below-ground biomass estimation

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

3.3.2 Reliability of Results

The mean value at national level was estimated by using weighted method considering area and mean value of the physiographic regions. Stem volume per hectare was considered as the main variable while assessing the reliability of the results. Reliability was estimated in terms of standard error of the mean stem volume. The desired accuracy was 10% at 95% confidence level. The variance of mean volume estimate in forest was estimated by using the variance estimator of a ratio estimator:

Equation 5: *Variance of mean volume estimate (for individual physiographic region)*

$$\mathbf{v}(\bar{\mathbf{x}}_{\mathbf{p}}^{(\mathbf{F})}) = \frac{\mathbf{1}}{(\sum^{\mathbf{n_p}} \mathbf{m_i})^2} \frac{\mathbf{n_p}}{\mathbf{n_p} - \mathbf{1}} \sum^{\mathbf{n_p}} \left(\mathbf{x_i} - \bar{\mathbf{x}}_{\mathbf{p}}^{(\mathbf{F})} \cdot \mathbf{m_{p,i}}\right)^2$$

where,

n_p=number of clusters with at least one forest plot

$m_{p,i}$=number of forest plots in cluster i

x_i=sum of plot level volumes in cluster i, m^3/ha

$\bar{x}_n^{(F)}$=mean volume in forest

p refers to physiographic region.

The variance of mean volume estimate in forest at national level was calculated with an estimator of stratified sampling (Cochran, 1977):

Equation 6: *Variance of mean volume estimate (for national level)*

$$v(\bar{x}^{(F)}) = \sum^{n_p} W_p^2 v(\bar{x}_p^{(F)})$$

where,

$W_p = \frac{A_p^{(F)}}{\sum A_p^{(F)}}$ = proportion of physiographic region-wise forest area with respect to total forest area of Nepal.

3.4 Forest Soils

3.4.1 Sampling of Soil

Soil samples were collected from four soil pits dug at each cardinal direction, 21 m away from the CCSP-centre, soil pits were dug within 2 m x 2 m area so as to collect undisturbed soil samples. The samples were collected by using a 100 mm long, slightly conical cylinder corer with a lower diameter of 37 mm (at its cutting edge) and an upper diameter of 40 mm; the volume of each soil sub-sample collected was 107.5 cm^3.

Composite soil samples from three layers i.e., 0–10 cm, 10–20 cm and 20–30 cm depth were collected in separate plastic bags for each layer (Figure 7). The fresh mass of composite sample was determined with the accuracy of 1 g. The samples were brought to DFRS Soil Laboratory and kept separately in order to facilitate assessment of the within-site variability of soil organic carbon (SOC). The relative volume occupied by stones in the soil was estimated occularly by observing the soil pit-walls by using the FAO Guidelines (FAO, 2006).

3.4.2 Sampling of Litter and Woody Debris

Litter and debris fractions were separately collected from the 1 m^2 circular plots at the location of each soil pit before it was dug to make their composite samples (Figure 9). A value of zero was recorded for pits without any litter or woody debris on the surface to ensure that the estimate of average litter and debris mass per unit area would be accurate. The total composite fresh mass of both litter and debris was weighed in the field to an accuracy of 1 g. As the total volume of all 4 m^2 areas (the total of the four 1 m^2 plots) was relatively large, small representative sub-samples were set aside so that their dry mass could be determined in the laboratory.

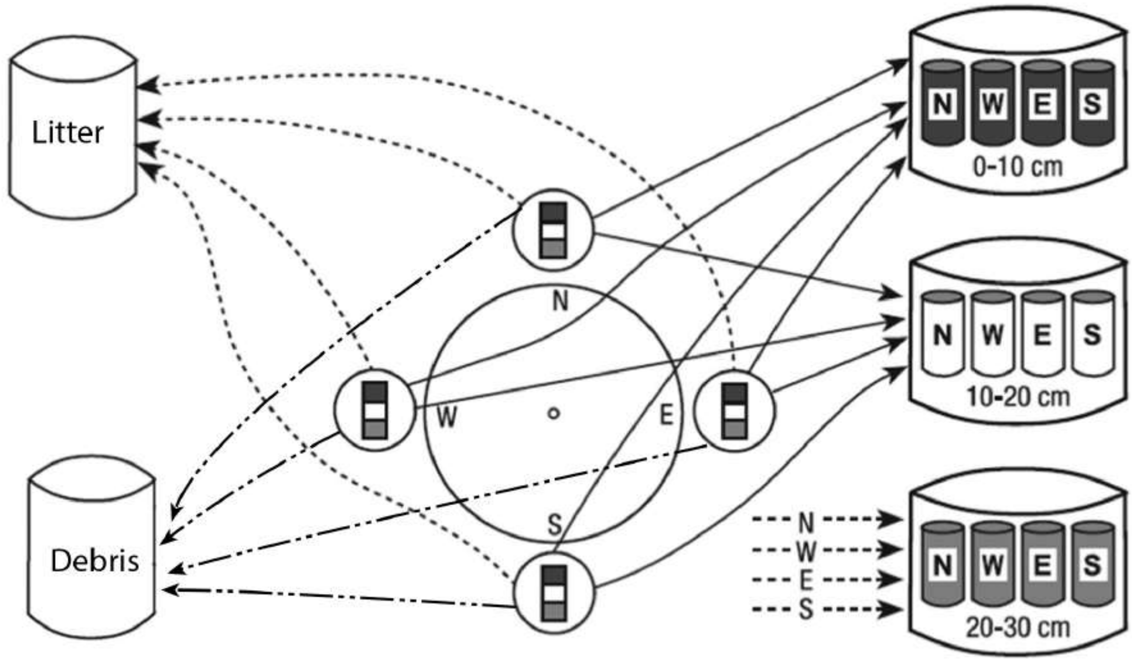

Figure 9: *Collection of composite samples of litter, debris and soil from a plot*

3.4.3 Analyses in the Laboratory

Analysis of soil physical parameters and proportion of Organic Carbon (OC)

For calculation of soil OC stock per volume and area, dry mass of undisturbed soil with known volume is needed. For that purpose, the composite soil samples were first air-dried to stabilise decomposition of organic matter, and later oven-dried to constant weight. The oven-dried sample was immediately weighed for total bulk density and then sieved through a 2 mm sieve, thus the soil fine fraction (FF) was obtained. The volume of coarse fraction (not passing the sieve) was determined from water replacement method. The bulk density of the soil fine fraction was then calculated by eliminating the volume of the coarse fraction, because the stone particles are void of OC. The bulk-density of the fine soil fraction for each soil layer was used to calculate the organic carbon stock in each of the 10 cm soil layers.

Soil organic carbon content was analysed by using the partial wet combustion method (Walkley and Black, 1934), with a correction factor of 1.33 to adjust for the total OC. Prior to analysis, the soil was passed through a 0.5 mm sieve for better homogenisation.

Estimation of soil organic carbon stock

The SOC_{FF} stock was calculated by multiplying the dry soil bulk density (g/cm^3) by the proportion of OC as analysed in the fine fraction (FF) of soil. The final $SOC_{FF, adj}$ value was obtained after adjusting the laboratory results with a consideration of the proportion (Stone%) of stoniness determined in the field:

$SOC_{FF, adj} = (100\text{-Stone}\%/100) * SOC_{FF}$.

This adjustment was needed because no organic carbon is found in stones and because laboratory analyses give the organic carbon content only for the fine soil fraction (SOC_{FF}). After adjustment, the SOC stock results were extrapolated per hectare.

Analysis of organic carbon in litter and woody debris

Organic carbon stock in litter and woody debris fractions was obtained on the basis of the total fresh mass collected from a known area as measured in the field. First, the dry mass of litter and woody debris sub-sample was obtained by oven-drying it to constant weight. Second, the total oven-dried weight of the litter and debris was estimated by multiplying the ratio of oven-dried to fresh weight of the litter and debris sub-samples. The total OC content of litter and woody debris fractions was then obtained by summing the respective dry mass estimates per m^2, multiplied by 0.50, a carbon content constant suggested by Pribyl (2010).

3.5 Forest Biodiversity

The lists of flora species obtained from the field sample plots were verified by using various sources (Edwards, 1996; DPR, 2007; Press *et al*., 2000 and Bhuju *et al*., 2007). Frequency of tree species (the proportion of sampling units containing a given tree species) was calculated by using Equation 7.

Equation 7: *Tree species frequency*

$$f_i = \left(\frac{n_i}{N}\right) \times 100$$

where,

f_i = Frequency of species *i*

n_i = Number of plots on which species *i* occurred

N = Total number of plots studied

3.6 Forest Disturbance

A disturbance is defined as a temporary change in average environmental conditions that cause a pronounced change in an ecosystem. Intensity of each disturbance affecting the growth of vegetation in each sample plot were recorded and analysed at the national level. The types of disturbances were recorded by using the following categories:

No disturbance:	No signs of significant disturbance observed
Landslide:	Signs of landslide and/or flooding observed
Grazing:	Presence of the hoofmarks and dung of animals, broken tops of seedlings and saplings, signs of trampling, disturbed forest litter
Lopping:	Cutting of the side branches of trees for fodder
Leaf litter collection:	Collection of dead leaves on the forest floor
Bush cutting:	Sign of cutting of shrubs, bushes and seedlings
Forest fire:	Sign of forest fire observed caused by natural and human activities
Encroachment:	Encroachment in forest for cultivation and plantation
Resin tapping:	Tapped trees, ordinarily pines, were identified by cuts made in the boles of trees to enable resin to ooze out
Lathra cutting:	Cutting of saplings and poles up to 30 cm DBH

Tree cutting:	Cutting of trees ≥30 cm DBH
Insect attack:	Plant leaves with signs of insect attacks (e.g. holes, nests, etc.)
Plant parasites:	Presence of parasitic plants in trees
Plant disease:	Disease caused mainly by fungi (e.g. black rot) or bacteria (e.g. rotting). If a tree was rotting due to resin-tapping, the disturbance was recorded as resign-tapping, not as plant disease
Wind, storm, hail:	Sign of trees broken and erosion on forest floor caused by wind, storm, hail

Other human-induced disturbances: Disturbances by humans other than those described above (e.g. removing the bark from the base of a tree, snaring, foot trails, forest roads, etc.)

The intensity levels of the above-mentioned disturbances were classified as below:

Intensity level 0:	No significant disturbance
Intensity level 1:	Minor disturbance (little or no effect on trees and regeneration, less than 10% of trees and seedlings affected)
Intensity level 2:	Moderate disturbance (tangible effect on trees and regeneration, 10–25% of trees and seedlings affected)
Intensity level 3:	Severe disturbance (significant effect on trees and regeneration, more than 25% of trees and seedlings affected)

4

LIMITATIONS

4.1 Land Cover Mapping

4.1.1 Visual Interpretation in the First Phase Sampling

On-screen visual interpretation as a pre-processing step makes it possible for an interpreter to easily integrate the different characteristics of objects (e.g. surface texture) visible in an image and benefit from direct knowledge of the context. Unlike digital classification methods, such interpretation does not require specialised software. Some of the images interpreted in 2010 were partly from 2003–2005, and land cover changes in the intervening years could have caused some discrepancies. Google Earth images might have some local geometrical distortions which can lead to misinterpretation of the boundaries between two land cover types, and visual interpretation may be distorted by human error in classifying land cover.

4.1.2 Forest Cover Classification and Analysis

Remote sensing-based mapping of vegetation and its types is a challenging task to begin with and these challenges are exacerbated by the difficult and varied terrain and climate of Nepal. With a scientific and technically sound approach, appropriate remote sensing materials and the support of reliable and extensive ground samples, multi-source mapping of vegetation/forest can be achieved with a good degree of accuracy and reliability. Several technical challenges were faced while mapping forest and non-forest areas in all physiographic regions. These are given below:

- The classification and analysis of forest cover was complicated by the fact that some deciduous trees, e.g., *Shorea robusta, Acacia catechu* and *Anogeissus latifolia* were defoliated during the period of image acquisition. Classification and analysis of such forest cover was challenging (Figure 10).

Figure 10: *Defoliated Acacia catechu forest in Mid-Western Nepal*

- Spatial heterogeneity of forest stands and fuzziness of their boundaries might have introduced errors into their classification and delineation (Figure 11).

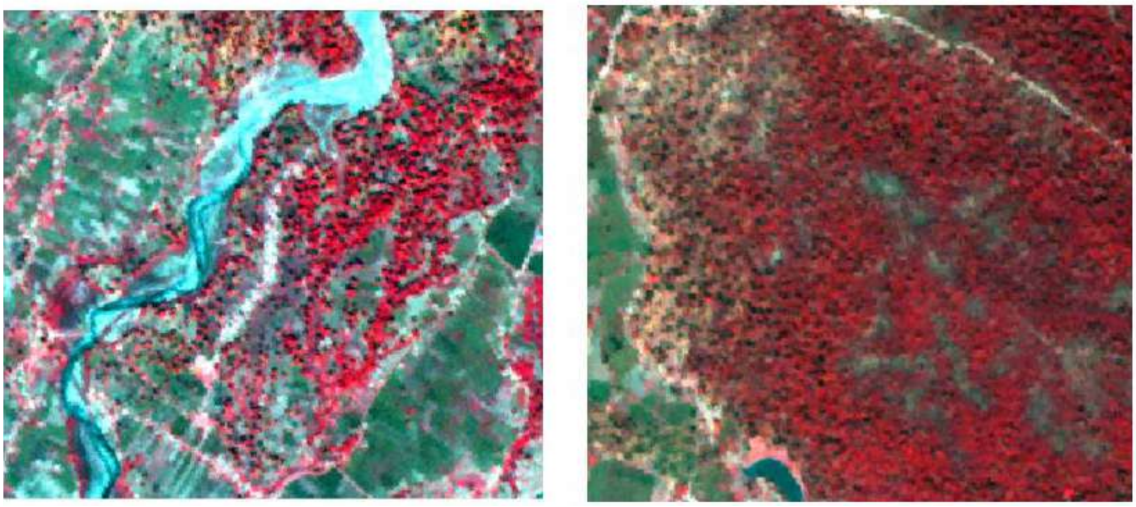

Figure 11: *Undefined (fuzzy) boundaries of forest areas*

- Mapping and delineation of shrub areas was challenging due to the limitations of the images used and reflectance characteristics of different species. Mapping of shrubs had to rely on visual interpretation method with the aid of very high-resolution Google Earth imageries as ancillary data to supplement automatic classification using CART machine learning method adopted in the first phase plots in the High Mountains and High Himal regions.
- Due to the difficult terrain and inaccessibility, independent ground verification for mapping could not be conducted in High Mountains, High Himal and the central part of Middle Mountains. Instead, the validation work had to rely heavily on visual interpretation of Google Earth images and independent assessments using forest inventory plots.
- Young regeneration and recent plantation might have been classified as Other Land because they are not spectrally different from the surrounding land cover.

4.2 Forest Resource Inventory

The methodology was designed to collect national-level data on per hectare stem volume or biomass of forests with 10% accuracy at 95% confidence limit. This is the reason why reliability of other findings (number of stems and volume by species, forest type, quality class; number of seedlings and saplings, biodiversity; soil carbon, etc.) may not be within the target accuracy level, and they are indicative values.

The High Mountains and the High Himal data were combined for analysis and reporting due to insufficient number of sample plots measured in High Himal region because of difficult terrain and weather condition. Moreover, the forest types and species composition of both the regions are similar. The number of measured sample plots in both the physiographic regions is in proportion to their respective total forest area.

The tree attribute figures for physiographic regions were calculated for all stems $\geq$5 cm DBH while national-level calculation considered stems $\geq$10 cm DBH to make the national results comparable with previous assessments and for international reporting. This results in differences between the values calculated for national reporting and for physiographic region-wise reporting.

4.3 Assessment of Forest Soils

4.3.1 Soil Organic Carbon

Soil sampling was done only in the sample plots that were designed for national-level forest inventory. Therefore, it might not have represented all the micro-site variability for all physiographic regions. Seasonal variability in field work and soil sampling might also have affected soil organic carbon estimation. Some level of bias may have occurred when calculating SOC from few accessible plots especially in High Mountains and High Himal and averaging the value for the whole region.

4.3.2 Litter and Woody Debris

Estimation of the litter and debris stock may have been impacted by the time of assessment. The inventory was mostly conducted over the long dry period outside of the monsoon, and there could be seasonal differences in litter-fall between visits to different areas and elevations.

5

RESULTS

5.1 Land Cover

5.1.1 Land Cover by Physiographic Region

According to land cover mapping, Forest covers 5.96 million ha, i.e., 40.36% of total area of Nepal. Similarly, Other Wooded Land (OWL) covers 0.65 million ha (4.38%) and Other Land covers 8.16 million ha (55.26%). Within OWL, shrub covers 0.12 million ha (0.79%) and areas with tree crown cover 5–10% covers 0.53 million ha (3.59% of the total area). Both Forest and OWL together cover 6.61 million ha, 44.74% of total area of the country (Table 7 and Figure 12).

***Table 7:** Land cover area by physiographic region (ha)*

Physiographic region	Forest	Other Wooded Land (OWL)			Other Land	Total[1]
		Tree crown cover 5–10%	Shrub	Total OWL		
Terai	411,580	5,573	3,930	9,502	1,595,916	2,016,998
Churia	1,373,743	22,336	336	22,672	501,848	1,898,263
Middle Mountains	2,253,807	29,308	32,979	62,287	1,993,302	4,309,396
High Mountains and High Himal	1,922,909	473,850	79,581	553,431	4,072,426	6,548,766
National total	**5,962,038**	*531,066*	*116,826*	**647,892**	**8,163,492**	**14,773,423**

Note: For inventory calculation, the area of OWL and OL was considered as the area below 4,000 m altitude in High Mountains and High Himal i.e. 484,357 ha and 1,197,005 ha, respectively. In total, OWL and OL were calculated as 578,818 ha and 5,288,071 ha, respectively.

Due to rounding-off of area figures, there are slight differences in their total.

[1] This area indicates the total mapped area based on the generalised international boundary data from the Department of Survey. The official area of Nepal is 147,181 km^2.

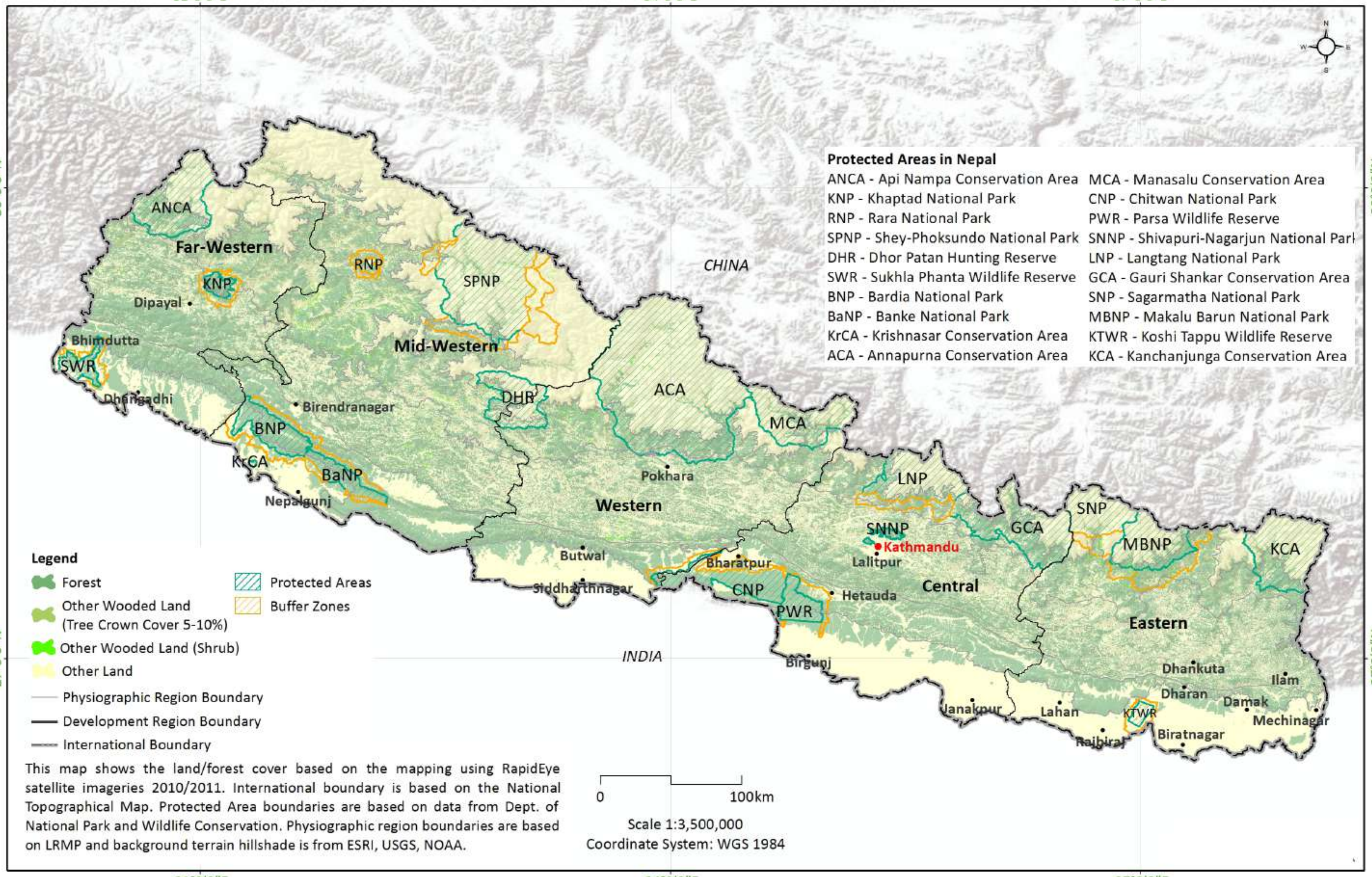

Figure 12: *Land cover map of Nepal*

Out of the total Forest, 37.80% lies in Middle Mountains physiographic region, 32.25% in High Mountains and High Himal, 23.04% in Churia and 6.90% in the Terai. Out of the total OWL, Terai, Churia, Middle Mountains, and High Mountains and High Himal physiographic regions share 1.47%, 3.50%, 9.61% and 85.42%, respectively (Figure 13).

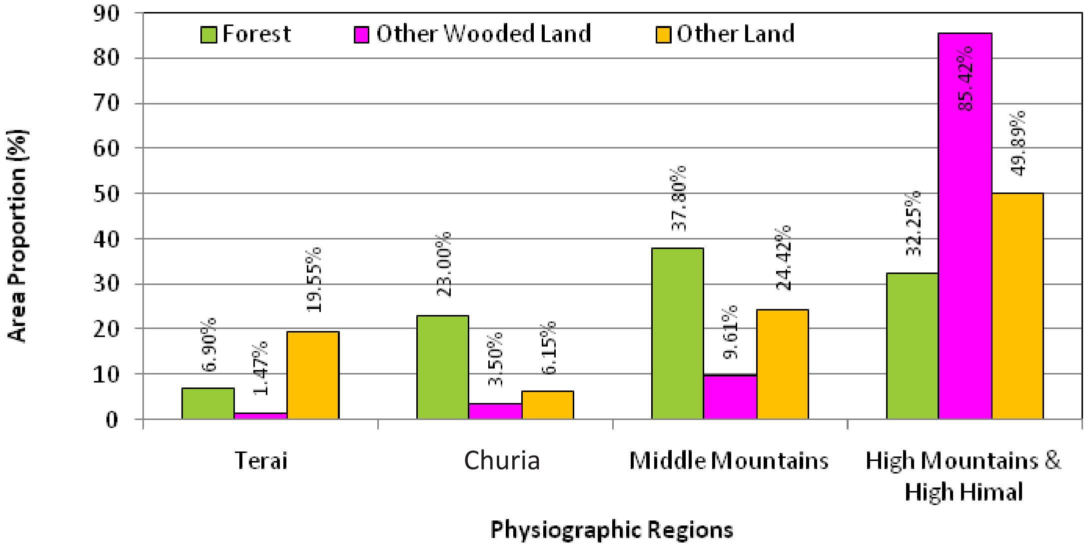

Figure 13: *Proportion of land cover in each physiographic region*

5.1.2 Land Cover by Development Region and District

Mid-Western Development Region (MWDR) contains 26.68% of the total Forest of Nepal. Far-Western Development Region (FWDR) has the lowest proportion of Forest i.e., 16.94% of the total Forest of Nepal. Other Wooded Land (OWL) ranges from 7.17% in Central Development Region (CDR) to 39.46% in MWRD (Table 8). District-wise land cover area is given in Annex 1.

Table 8*: Land cover by Development Region (ha)*

Development Region	Forest	Other Wooded Land (OWL)			Other Land	Total
		Tree crown Cover 5–10%	*Shrubs*	Total OWL		
EDR	1,072,379	*82,807*	*18,392*	101,198	1,679,374	2,852,952
CDR	1,268,667	*40,264*	*6,248*	46,512	1,432,112	2,747,292
WDR	1,020,065	*87,117*	*21,522*	108,639	1,816,150	2,944,852
MWDR	1,590,722	*194,439*	*61,204*	255,643	2,404,594	4,250,959
FWDR	1,010,207	*126,439*	*9,461*	135,900	831,261	1,977,367
National total	**5,962,038**	*531,066*	*116,826*	647,892	**8,163,492**	**14,773,423**

5.1.3 Forest Cover by Physiographic and Development Region

Out of the total Forest in Terai physiographic region, FWDR has the highest proportion (30.93%) whereas Western Development Region (WDR) has the lowest (11.47%). Similarly, out of the total Forest in Churia, CDR has the highest proportion (31.30%), whereas Eastern Development Region (EDR) has the lowest (12.62%). Forest in Middle Mountains physiographic region is more or less evenly distributed in all the Development Regions. Out of the total Forest in High Mountains and High Himal physiographic region, MWDR has the highest proportion (34.43%) of Forest whereas CDR has the lowest (13.74%) (Table 9 and Figure 14).

Table 9: *Forest cover by physiographic and Development Region (ha)*

Development Region	Terai	Churia	Middle Mountains	High Mountains and High Himal	Total
EDR	56,220	173,298	481,314	361,547	1,072,379
CDR	95,219	430,029	479,295	264,124	1,268,667
WDR	47,209	175,133	440,204	357,519	1,020,065
MWDR	85,618	414,795	428,187	662,122	1,590,722
FWDR	127,314	180,489	424,807	277,597	1,010,207
National total	**411,580**	**1,373,743**	**2,253,807**	**1,922,909**	**5,962,038**

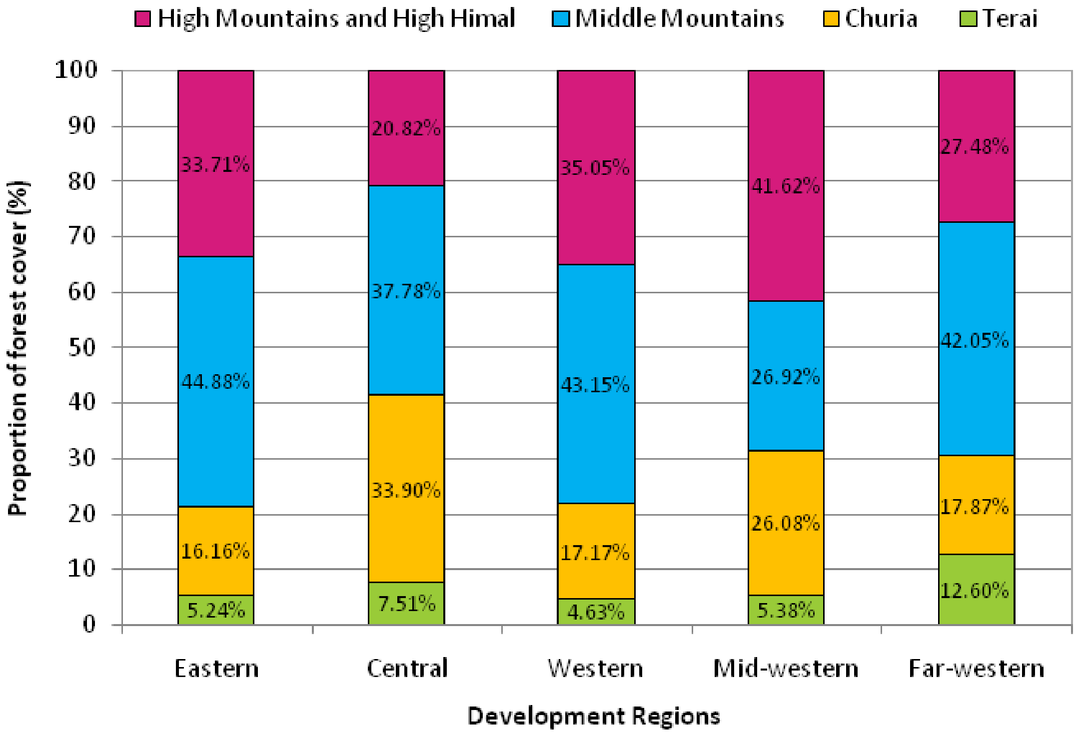

Figure 14: *Proportion of forest cover by development and physiographic region*

5.1.4 Forest Cover Inside and Outside Protected Area by Physiographic Region

Out of the total Forest of the country, 4.93 million ha (82.68%) lies outside Protected Areas and 1.03 million ha (17.32%) inside Protected Areas. Within the Protected Areas, Core Areas have 0.79 million ha Forest and Buffer Zones have 0.24 million ha. Of the total Forest inside the Core Areas, High Mountains and High Himal regions together have the highest share (57.95%) and Middle Mountains region has the lowest (2.10%) (Table 10).

Table 10: *Forest cover inside and outside Protected Areas by physiographic region*

Physiographic region	Outside PAs	Protected Area (ha)		Total
		Core Area	Buffer Zone	
Terai	314,660	69,847	27,074	411,580
Churia	1,043,194	246,750	83,799	1,373,743
Middle Mountains	2,226,273	16,669	10,865	2,253,807
High Mountains and High Himal	1,345,309	459,240	118,360	1,922,909
National total	**4,929,436**	**792,506**	**240,098**	**5,962,038**

5.1.5 Forest Cover by Forest Types

According to forest cover mapping, the Terai Mixed Hardwood (TMH) forest type has the highest coverage (24.61%) followed by the Upper Mixed Hardwood (UMH) (18.23%). Similarly, the share of *Shorea robusta* and *Pinus roxburghii* forest types are 15.27% and 8.45%, respectively. Nearly 60% of the total forest area is composed of mixed types (Figure 15 and 16).

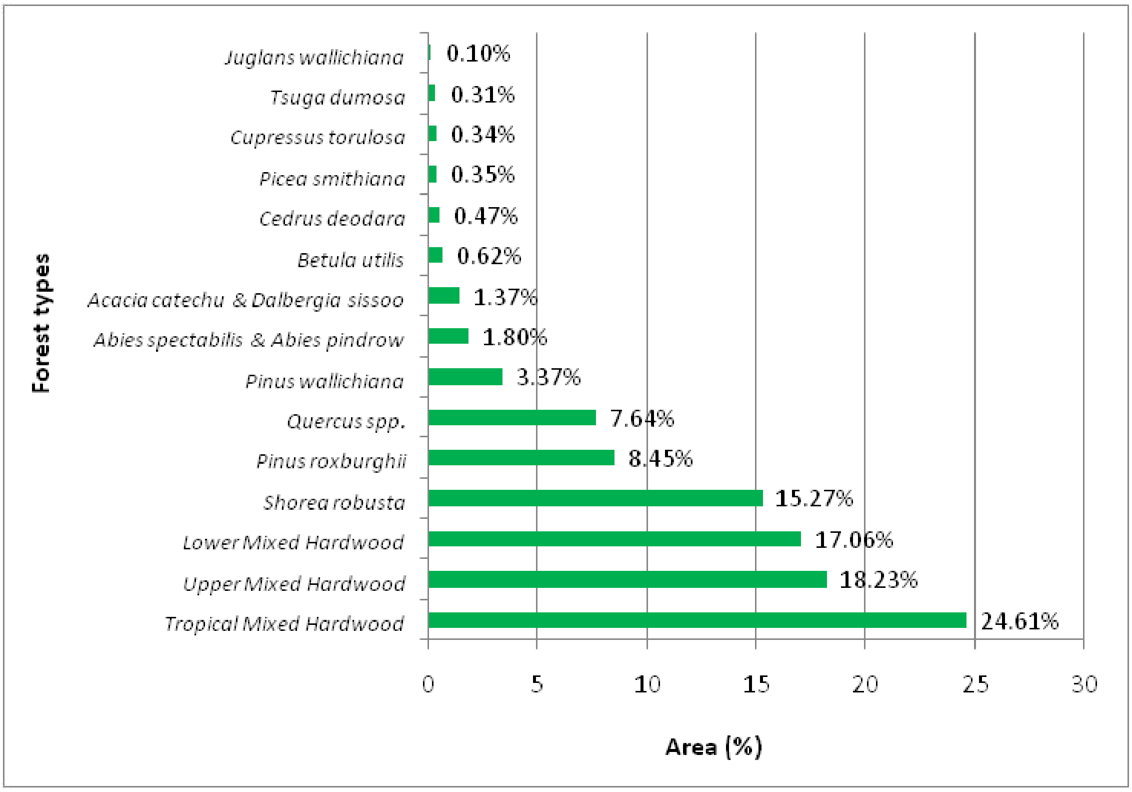

***Figure 15**: Proportion of forest types at national level*

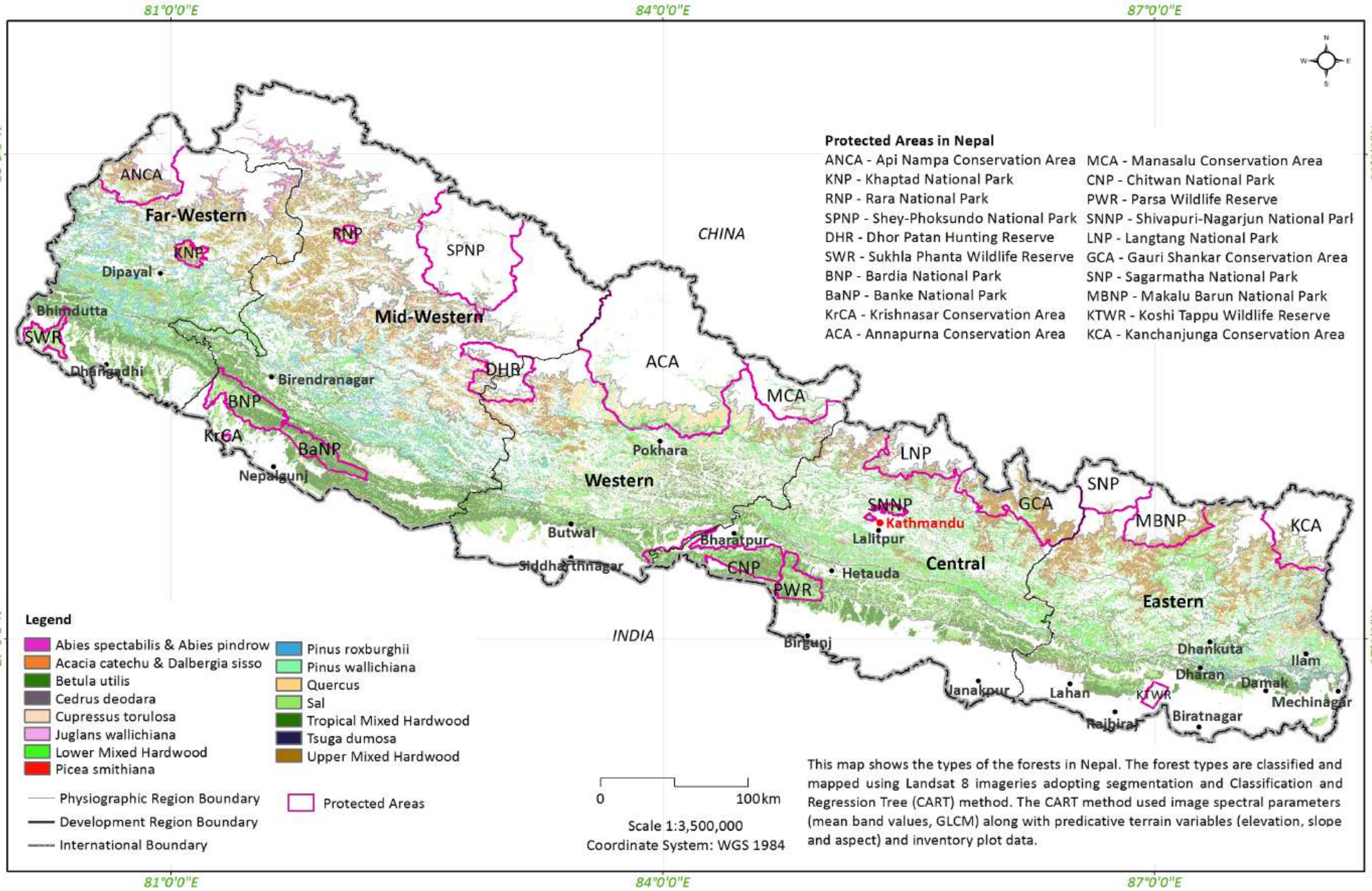

Figure 16: *Forest type map of Nepal*

5.1.6 Accuracy Assessments

Land/Forest Cover Mapping

The land cover classes (Forest, OWL and OL) observed in the field were compared with the classified land cover classes. The comparison revealed an overall accuracy of 85.16%, a Cohen's Kappa (κ) of 0.72, and a Kappa standard error of 0.02 for the national level wall-to-wall land cover map (Table 11).

Table 11: *Error matrix of land cover map using independent ground verification samples*

Classified class	Land cover class (ground truth)				Users' accuracy (%)	Commission error (%)
	Forest	OWL	OL	Total		
Forest	1,096	53	16	1,165	94.08%	5.92%
OWL	56	362	34	452	80.09%	19.91%
Other Land	49	73	155	277	55.96%	44.04%
Total	1,201	488	205	1,894		
Producer's accuracy (%)	91.26%	74.18%	75.61%			
Omission error (%)	8.74%	25.82%	24.39%			
Overall accuracy	**85.16%**					

Forest Type Mapping

The accuracy assessment yielded an overall accuracy of 69.85% (95% confidence limit, range 66.08%–73.61%; Standard Deviation (SD) = 0.02; Coefficient of Variance (CV) = 2.7%). The Kappa statistics (*k*) was obtained as 0.63 (95% confidence limit, range = 0.58–0.67; SD = 0.02 and CV = 3.6%). These figures indicate good overall accuracy.

5.1.7 Comparison with Previous Assessments

The FRA (2010–2014) results cannot be statistically compared with the previous surveys due to methodological differences. However, among the six national-level assessments in the last four decades, FRA (2010–2014) found the largest coverage of forest and/or shrub in Nepal (Table 12).

Table 12*: Forest cover found by different assessments (%)*

Land cover	LRMP 1978/79	NRSC 1984	Master Plan 1985–1986	NFI 1994	DoS 1995	FRA 2010–2014
Forest	38.0	35.9*	37.4	29.0	38.3	40.36
Shrub	4.7	-	4.8	10.6	-	4.38**
Total	**42.7**	**35.9**	**42.2**	**39.6**	**38.3**	**44.74**

* Includes some shrub area; **OWL

Although estimation of these six assessments does not show a clear trend of change in forest cover, the figure of forest area estimated by FRA (2010–2014) is more than that of NFI (1994). This may be attributed to the following three factors:

First, in NFI (1994), the area estimates were compiled from different assessments with a larger minimum mapping unit (MMU) than that of FRA (2010–2014), which applied uniform method based on high-resolution image classification with MMU of 0.5 ha. Therefore, it is likely that the smaller forest patches which were excluded in the previous inventory could have been included in the recent one. Second, as observed by various studies at local level (Niraula *et al*. 2013; Gautam *et al.* 2002; Poudel *et al.* 2015), forest area in the country, particularly in the mountains, may have increased due to community forestry intervention. Third, forest area may have increased due to abandonment of agricultural land, particularly in the mountainous region. Studies show that increasing migration in the recent years has resulted in 'unprecedented' land abandonment in the mountains (Poudel *et al*. 2014); it has contributed to increased forest and/or shrub cover (Jaquet *et al.* 2015; Sharma *et al.* 2014). However, further studies are suggested to determine the extent of contribution of these factors to forest/shrub cover change at the national level. Table 13 presents areas of forest by Development Region estimated by the three assessments.

***Table 13**: Forest cover by Development Region (in '000 ha)*

Development Region	LRMP 1978/79	NFI 1994	FRA 2010–2014
Eastern	948.7	736.1	1,072.4
Central	1,104.9	918.6	1,268.7
Western	924.0	734.3	1,020.1
Mid-Western	1,649.7	1,192.4	1,590.7
Far-Western	989.5	687.4	1,010.2
National total	**5,616.8**	**4,268.8**	**5,962.1**

Note: NFI 1994 used 147,181 km^2 as the total area of the country for its calculations while LRMP and FRA used the mapped areas calculated in their assessments i.e. 147,484 $km^2$and 147,734 km^2, respectively.

5.2 Forest Inventory

5.2.1 Number of Stems in Forest (DBH <10 cm)

At the national level, the number of stems less than 10 cm DBH was 11,566 per hectare. The average number of seedlings (<1.3 m height) was 10,095. The corresponding figures for saplings (≥1.3 m height and <5 cm DBH) and bigger saplings (5–10 cm DBH) were 1,045 and 426, respectively (Table 14).

***Table 14:** Number of seedlings and saplings per ha in Forest by physiographic region*

Physiographic region	Seedlings/ha (<1.3 m height)	Saplings/ha (≥1.3 m height and <5 cm DBH)	Saplings/ha (5–10 cm DBH)	Total/ha
Terai	29,649	1,662	309	31,620
Churia	19,805	958	389	21,152
Middle Mountains	7,171	1,167	442	8,780
High Mountains and High Himal	2,399	831	459	3,689
National weighted average	**10,095**	**1,045**	**426**	**11,565**

5.2.2 Number of Stems in Forest (DBH ≥10 cm)

In Nepal, the total number of stems with diameter ≥10 cm was 3,112.28 million, of which 2,563.27 million stems were in Forest, 17.49 million in OWL and 531.52 million in Other Land. The forest in High Mountains and High Himal regions had the highest number of stems (1,012.43 million). Terai forest had the lowest number of stems (112.85 million). Similar pattern was found in the case of OWL. However, in Middle Mountains the largest number of stems was found in Other Land (Table 15).

Table 15: *Number of stems (≥10 cm DBH) by land cover class*

Physiographic region	Forest		Other Wooded Land		Other Land	
	Stems / ha	Total stems (million)	Stems / ha	Total stems (million)	Stems / ha	Total stems (million)
Terai	274.19	112.85	50.31	0.48	25.14	40.11
Churia	342.46	470.45	35.49	0.80	65.72	32.98
Middle Mountains	429.29	967.53	52.34	3.26	187.42	373.59
High Mountains and High Himal	526.51	1,012.43	26.74	12.95	70.87	84.84
National weighted average/ Total	**429.93**	**2,563.27**	**30.22**	**17.49**	**100.51**	**531.52**

The stocking of all DBH classes was the highest in High Mountains and High Himal regions. The total number of stems per hectare was the highest in High Mountains and High Himal, and the lowest in Terai physiographic region (Table 16).

Table 16: *Number of stems/ha in Forest by DBH class and physiographic region*

Physiographic region	Pole		Small-saw timber	Large-saw timber	Total
	10–20 cm	20–30 cm	30–50 cm	≥50 cm	
Terai	167.40	49.31	35.61	21.87	274.19
Churia	215.78	61.76	48.79	16.12	342.46
Middle Mountains	298.20	80.98	39.32	10.79	429.29
High Mountains and High Himal	349.32	96.05	53.18	27.96	526.51
National weighted average	**286.67**	**79.23**	**45.72**	**18.32**	**429.93**

An analysis of DBH classes of stems for the country revealed that the proportion of small trees was higher than that of large ones (Figure 17).

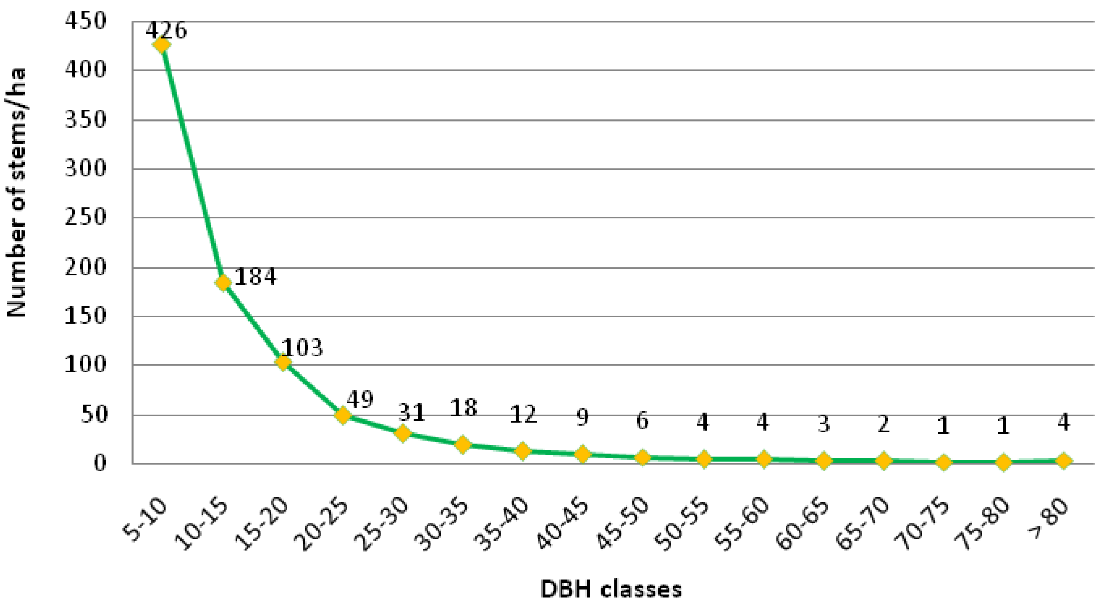

Figure 17: *Number of stems by DBH class*

Of the total species measured in the forests of Nepal, 14 species make up more than 1% of the total trees. In terms of the number of stems (≥ 10 cm DBH) per hectare, *Shorea robusta* was the most frequently occurring species (65.00 stem/ha or 15.1%), followed by *Rhododendron* spp. (57.82 stems/ha or 13.5%) (Figure 18).

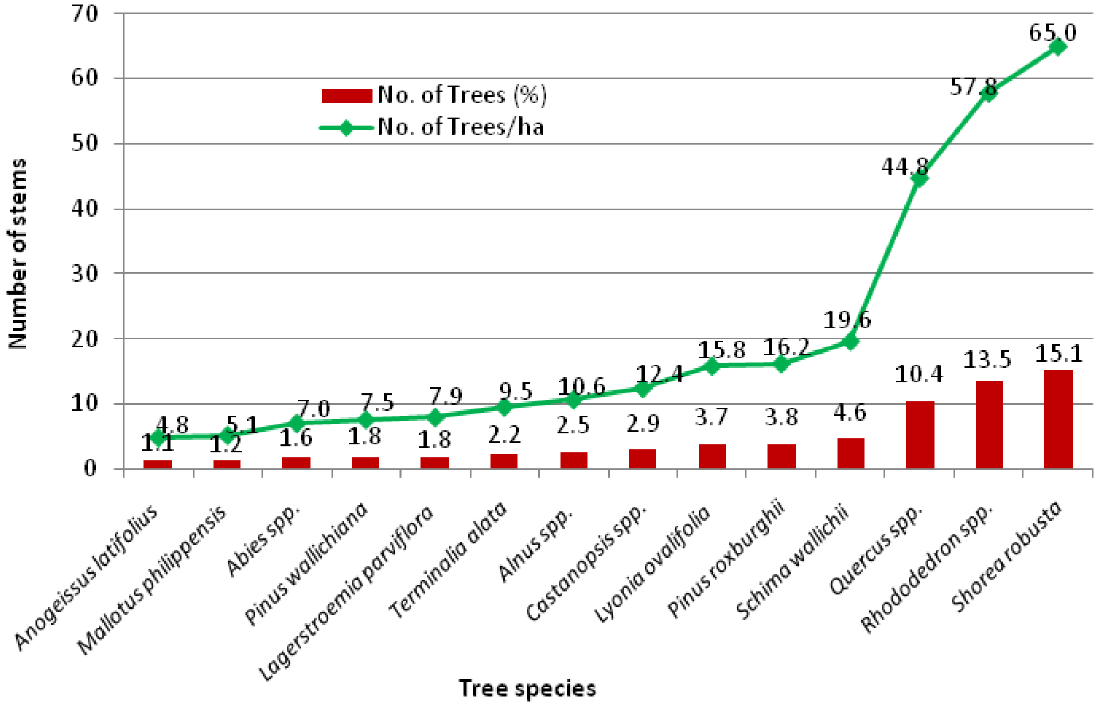

Figure 18: *Number of stems per hectare in Forest by common species*

Number of stems by quality class is shown in Figure 19. High-quality sound trees were most frequently enumerated in Middle Mountains region (121.77 stems/ha) and least frequently enumerated in High Mountains and High Himal (101.71 stems/ha). Similarly, cull trees were most frequently enumerated in High Mountains and High Himal (289.40 stems/ha) and least frequently enumerated in Terai region (87.01 stems/ha).

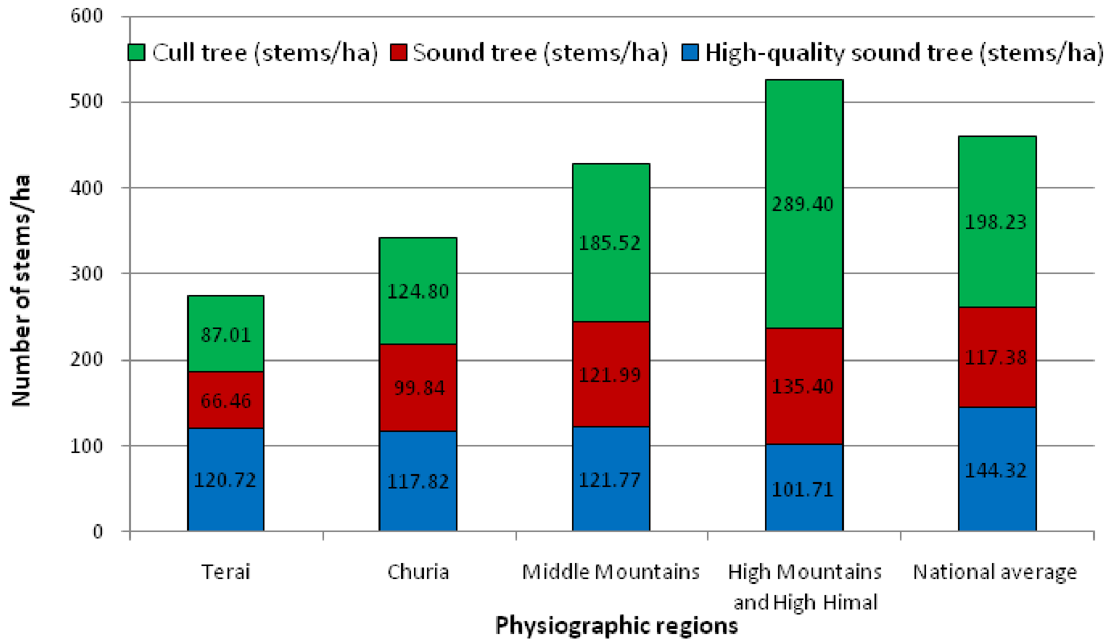

Figure 19: *Number of stems per hectare in Forest by quality class and physiographic region*

Of the total number of stems by quality classes in Nepal's forest, the number of cull trees was the highest (1,181.87 million). The number of stems of high-quality sound trees as well as sound trees was the highest in Middle Mountains region. High Mountains and High Himal region contain the highest number of stems of cull trees (Table 17).

Table 17: *Stem distribution by quality class in Forest (million)*

Physiographic region	High-quality sound tree	Sound tree	Cull tree	Total
Terai	49.68	27.35	35.81	112.85
Churia	161.85	137.15	171.44	470.45
Middle Mountains	274.45	274.94	418.13	967.53
High Mountains and High Himal	195.58	260.36	556.49	1,012.43
National total	**681.57**	**699.81**	**1,181.87**	**2,563.26**

5.2.3 Basal Area (≥10 cm DBH)

Basal area of stems (≥10 cm DBH) was 20.57 m^2/ha in Forest, 1.40 m^2/ha in OWL, and 2.49 m^2/ha in Other Land. The basal area in Forest and OWL was found to be the highest in High Mountains and High Himal (28.49 m^2/ha) and Terai region (3.72 m^2/ha), respectively (Table 18).

Table 18: *Basal area by land cover class (m^2/ha)*

Physiographic region	Forest	Other Wooded Land	Other Land
Terai	17.08	3.72	0.91
Churia	17.17	1.79	1.55
Middle Mountains	16.53	1.99	4.12
High Mountains and High Himal	28.48	1.26	2.26
National weighted average	**20.57**	**1.40**	**2.49**

In the Forest, the highest basal area (28.48 m^2/ha) was in High Mountains and High Himal region, and the lowest (16.53 m^2/ha) in Middle Mountains. Total basal area figures in Terai, Churia and Middle Mountains regions were found to be more or less similar. The basal area of all DBH classes was the highest in High Mountains and High Himal (Table 19).

Table 19: *Basal area (m^2/ha) by DBH class*

Physiographic region	Pole		Small-saw timber	Large-saw timber	Total
	10–20 cm	20–30 cm	30–50 cm	≥50 cm	
Terai	2.62	2.28	4.21	7.97	17.08
Churia	3.37	2.92	5.62	5.26	17.17
Middle Mountains	4.78	3.74	4.36	3.66	16.53
High Mountains and High Himal	5.61	4.46	6.05	12.38	28.50
National weighted average	**4.57**	**3.68**	**5.19**	**7.14**	**20.57**

5.2.4 Stem Volume (≥10 cm DBH)

The total stem volume with DBH ≥10 cm was 1,063.56 million m^3 out of which 982.33 million m^3 (164.76 m^3/ha) was in Forest, 4.58 million m^3 (7.91 m^3/ha) in OWL and 76.65 million m^3 (14.49 m^3/ha) in Other Land. The Forest of High Mountains and High Himal region had the highest stem volume (225.24 m^3/ha) and that of Middle Mountains had the lowest (124.26 m^3/ha). Similarly, OWL of Terai region had the highest stem volume (30.59 m^3/ha) and that of High Mountains and High Himal region had the lowest (6.73 m^3/ha) (Table 20).

Table 20: *Total stem volume per ha (≥10 cm DBH) by land cover class*

Physiographic region	Forest		Other Wooded Land		Other Land	
	Stem volume (m^3/ha)	Stem volume (million m^3)	Stem volume (m^3/ha)	Stem volume (million m^3)	Stem volume (m^3/ha)	Stem volume (million m^3)
Terai	161.66	66.54	30.59	0.29	5.41	8.63
Churia	147.49	202.61	15.05	0.34	9.32	4.68
Middle Mountains	124.26	280.06	11.04	0.69	23.72	47.29
High Mountains and High Himal	225.24	433.12	6.73	3.26	13.41	16.05
National weighted average/Total	164.76	982.33	7.91	4.58	14.49	76.65

The stem volume per hectare of large trees (>50 cm DBH) in High Mountains and High Himal physiographic region (124.94 m^3/ha) was particularly noteworthy. In contrast, the volume of large sized trees (>50 cm DBH) was only 37.12 m^3/ha in Middle Mountains (Table 21 and Figure 20).

Table 21: *Stem volume (m^3/ha) in Forest by DBH class*

Physiographic region	Pole		Small-saw timber	Large-saw timber	Total stem volume
	10–20 cm	20–30 cm	30–50 cm	≥50 cm	
Terai	16.87	17.41	40.08	87.29	161.66
Churia	19.56	21.19	49.96	56.78	147.49
Middle Mountains	25.29	25.47	36.38	37.12	124.26
High Mountains and High Himal	26.63	27.40	46.28	124.94	225.24
National weighted average	23.82	24.55	42.96	73.44	164.76

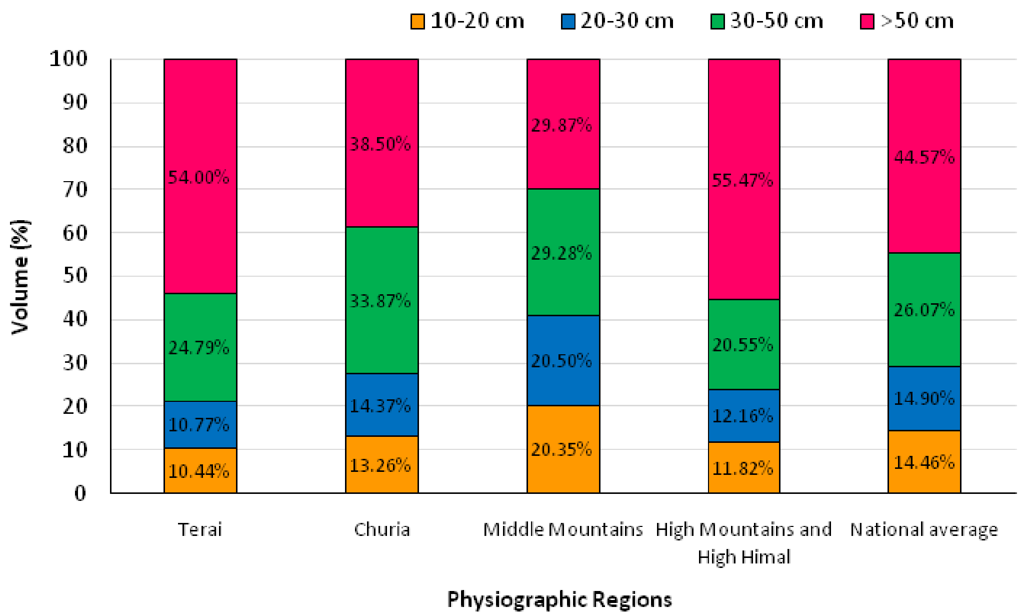

Figure 20: *Proportional volumes by DBH class and physiographic region*

Of the total stem volume calculated in the Forest, 16 species have more than 1% of the total stem volume. At the national level, *Shorea robusta* had the highest stem volume (31.76 m^3/ha or 19.28%), followed by *Quercus* spp. with 24.39 m^3/ha or 14.80% (Table 22).

Table 22: *Stem volume in Forest by species*

SN	Species	Stem volume (m^3/ha)	Stem volume (%)
1	*Shorea robusta*	31.76	19.28
2	*Quercus* spp.	24.39	14.80
3	*Pinus roxburghii*	11.62	7.05
4	*Rhododendron* spp.	8.68	5.27
5	*Terminalia alata*	7.70	4.67
6	*Abies* spp.	7.57	4.59
7	*Pinus wallichiana*	6.18	3.75
8	*Alnus* spp.	5.86	3.56
9	*Tsuga dumosa*	5.73	3.48
10	*Schima wallichii*	4.38	2.66
11	*Castanopsis* spp.	2.85	1.73
12	*Betula utilis*	2.65	1.61
13	*Picea smithiana*	2.36	1.43
14	*Lyonia ovalifolia*	2.36	1.43
15	*Lagerstroemia parviflora*	1.75	1.06
16	*Acer* spp.	1.65	1.00

Stem volume per hectare by quality class and physiographic region is presented in Table 23. Stem volume per hectare of high-quality sound trees as well as sound trees was the highest in High Mountains and High Himal and the lowest in Middle Mountains region. Interestingly, the highest per hectare volume of cull tree quality class was also found in High Mountains and High Himal.

Table 23: *Stem volume (m^3/ha) in Forest by quality class and physiographic region*

Physiographic region	Quality Class			Total
	High-quality sound tree	Sound tree	Cull tree	
Terai	121.54	22.24	17.88	161.66
Churia	100.79	28.87	17.83	147.49
Middle Mountains	69.75	27.77	26.74	124.26
High Mountains and High Himal	136.28	42.52	46.44	225.24
National weighted average	101.94	32.40	30.43	164.76

Among the three tree quality classes, the high-quality sound trees constituted the highest stem volume in all regions (Table 24).

Table 24: *Stem volume in Forest by quality class and physiographic region (million m³)*

Physiographic region	Quality Class (million m³)			Total
	High-quality sound tree	Sound tree	Cull tree	
Terai	50.02	9.15	7.36	66.54
Churia	138.46	39.66	24.49	202.62
Middle Mountains	157.20	62.60	60.26	280.06
High Mountains and High Himal	262.05	81.77	89.30	433.12
National total	607.74	193.18	181.41	982.33

5.2.5 Above-ground Air-dried Tree Biomass

The total air-dried biomass of trees with DBH ≥10 cm was 1,243.62 million tonnes of which 1,159.65 million tonnes (194.51 t/ha) was in Forest, 6.30 million tonnes (10.88 t/ha) in OWL and 77.67 million tonnes (14.69 t/ha) in Other Land (Table 25).

Table 25: *Tree component-wise total biomass by land cover class*

Land cover class	Tree component	Air-dried biomass (≥10 cm DBH) (t/ha)	Air-dried biomass (≥10 cm DBH) (million tonnes)
Forest	Stem	118.14	704.35
	Branch	62.95	375.31
	Foliage	13.42	79.99
	Total	**194.51**	**1,159.65**
OWL	Stem	5.53	3.20
	Branch	4.59	2.66
	Foliage	0.76	0.44
	Total	**10.88**	**6.30**
Other Land	Stem	9.49	50.19
	Branch	4.53	23.94
	Foliage	0.67	3.54
	Total	**14.69**	**77.67**

The above-ground air-dried biomass in Forest was 194.51 tonnes per hectare. The forests of High Mountains and High Himal contained the highest above-ground biomass per hectare (271.46 tonnes, air-dried), whilst Middle Mountains Forests had the lowest (143.26 tonnes, air-dried). The average above-ground oven-dried biomass in Nepal's forest was 176.82 t/ha (Table 26).

Table 26: *Above-ground air- and oven-dried biomass of tree component (t/ha)*

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

Total above-ground air-dried biomass of trees per hectare increased with an increase in DBH class (Table 27).

Table 27: *Above-ground air-dried biomass (t/ha) of tree component by DBH class*

DBH class	Stem biomass	Branch biomass	Foliage biomass	Total above-ground air-dried biomass
10–20	17.19	7.56	2.26	27.02
20–30	17.42	8.41	2.18	28.00
30–50	31.39	15.64	3.25	50.29
≥50	52.13	31.34	5.73	89.20

Of the total air-dried biomass calculated in Forest, 16 species contribute more than one percent. At the national level, *Quercus* species had the highest total air-dried biomass (46.09 t/ha or 23.70%), followed by *Shorea robusta* with 37.83 t/ha or 19.45% (Table 28).

Table 28: *Total above-ground air-dried biomass in Forest by species*

SN	Species	Total air-dried biomass (t/ha)	Total air-dried biomass (%)
1	*Quercus* spp.	46.09	23.70
2	*Shorea robusta*	37.83	19.45
3	*Rhododendron* spp.	11.22	5.77
4	*Terminalia alata*	10.58	5.44
5	*Pinus roxburghii*	9.90	5.09
6	*Abies* spp.	5.45	2.80
7	*Alnus* spp.	5.31	2.73
8	*Pinus wallichiana*	4.22	2.17
9	*Betula utilis*	4.11	2.11
10	*Schima wallichii*	4.07	2.09
11	*Castanopsis* spp.	3.88	2.00
12	*Lyonia ovalifolia*	3.84	1.97
13	*Tsuga dumosa*	3.79	1.95
14	*Acer* spp.	2.33	1.20
15	*Picea smithiana*	2.30	1.18
16	*Lagerstroemia parviflora*	2.17	1.12

5.2.6 Reliability of Inventory Results

Each sample cluster in Forest was allocated systematically in all physiographic regions or strata. Reliability of the inventory results in terms of stem volume per hectare was first determined for each stratum on the basis of which reliability of results for national level was determined. While designing this assessment, 95% confidence limit was set for the inventory result with the range of plus or minus 10% of the stem volume or biomass (FRA Nepal, 2010). The standard error for Forest was found to be 6.17 and percentage of error of mean stem volume was 7.34% at national level (Table 29). This is within the reliability limits set out in the project document.

Table 29: *Standard errors and confidence limits in Forest for physiographic region*

Physiographic region	No. of cluster	No. of plot	Mean stem volume (m³/ha)	Standard error of mean	Percentage of error of mean at 95% CL	95% Confidence limits of mean	
Terai	56	175	161.66	10.08	12.22	141.90	181.42
Churia	109	477	147.49	6.27	8.33	135.21	159.77
Middle Mountains	146	433	124.26	8.12	12.82	108.34	140.18
High Mountains and High Himal	139	468	225.24	15.84	13.78	194.20	256.29
National weighted average/Total	450	1,553	164.76	6.17	7.34	152.67	176.86

5.2.7 Changes in Growing Stock in Two Assessment Periods

The number of stems with DBH ≥10 cm was 430 per hectare. The corresponding figure of NFI 1987–1998 was 408/ha. The increase, however, was observed only in the smaller trees (DBH class 10–20 cm) (Table 30).

Table 30*: Number of stems per hectare by DBH class in two inventories*

Inventory	DBH class			Total
	10–20 cm	20–50 cm	≥50 cm	
NFI 1987–1998	244	143	21	408
FRA 2010–2014	287	125	18	430

Mean stem volume per hectare was found to be less in FRA 2010–2014 (165 m³/ha) than in NFI 1987–1998 (178 m³/ha). The proportion of stem volume of *Shorea robusta, Terminalia alata* and *Abies* spp. showed a decreasing trend, while an increasing trend was observed for *Quercus* spp., *Rhododendron* spp., *Pinus wallichiana* and *Schima wallichii* (Table 31).

Table 31: Proportion (%) of stem volume available in two inventories by common species

Species	Stem volume (NFI 1987–1998)	Stem volume (FRA 2010–2014)
Shorea robusta	28.2	19.3
Quercus spp.	7.6	14.8
Pinus roxburghii	6.3	7.1
Rhododendron spp.	3.3	5.3
Terminalia alata	7.6	4.7
Abies spp.	4.9	4.6
Pinus wallichiana	1.1	3.8
Schima wallichii	2.0	2.7

5.3 Carbon Stock

In Nepal, the total carbon stock in Forest, OWL and Other Land (OL) was 1,157.37 million tonnes out of which Forest, OWL and OL constituted 1,054.97 million tonnes (176.95 t/ha), 60.92 million tonnes (105.24 t/ha) and 41.48 million tonnes (7.84 t/ha), respectively. In the case of OL, the carbon content of only the tree component was estimated. Out of the total forest carbon stock, tree component (live, dead standing, dead wood and below-ground biomass), forest soils, and litter and debris made up 61.53%, 37.80%, and 0.67%, respectively (Table 32).

Table 32: *Carbon stock (t/ha) in Nepal*

Land cover class	Tree component	Litter and debris	Soil	Total
Forest	108.88	1.18	66.88	176.95
OWL	5.81	0.45	98.98	105.24
OL	7.84	-	-	7.84

The carbon stocks in forests of different physiographic regions are summarised in Table 33. The average organic carbon in soil, litter and debris, and tree component (≥10 cm DBH) are 66.88 t/ha, 1.18 t/ha and 108.88 t/ha, respectively. The highest soil organic carbon stock (114.03 t/ha) was estimated in High Mountains and High Himal regions. SOC was the lowest in Churia region with an average of 31.44 t/ha. The results from Middle Mountains region showed an average SOC stock of 54.33 t/ha. SOC stock in the forests of the Terai was found to be slightly higher than in Churia.

Table 33: *Soil organic carbon, litter and debris and tree component carbon stock in Forest by physiographic region (t/ha)*

Physiographic region	SOC	Litter and debris	Tree component (≥10 cm DBH)
Terai	33.66	0.28	104.47
Churia	31.44	0.32	97.69
Middle Mountains	54.33	1.65	79.42
High Mountains and High Himal	114.03	1.44	152.36
National average	66.88	1.18	108.88

The SOC stock in forest was found to increase with increasing altitude especially in Middle Mountains region (Figure 21).

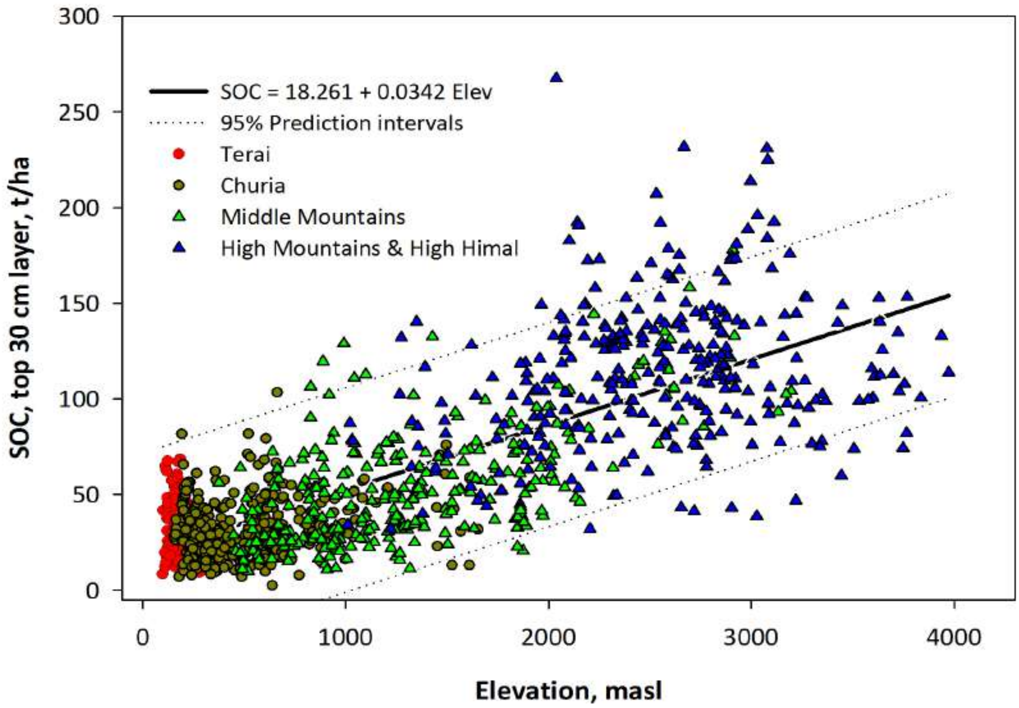

Figure 21*: Variability of SOC with the elevation in different physiographic regions*

5.4 Biodiversity

5.4.1 Tree Species Diversity

Altogether 443 tree species belonging to 239 genera and 99 families were recorded in the sample plots. The highest number of taxa was found in Middle Mountains region and the lowest in Terai region (Figure 22). Fabaceae (19 genera and 37 species) was the largest family followed by Lauraceae (9 genera and 29 species). Other large families were Rosaceae (7 genera and 23 species) and Moraceae (4 genera and 21 species). In terms of genera, *Ficus* was the largest genus comprising of 15 species followed by *Acer* and *Litsea* each comprising of eight species.

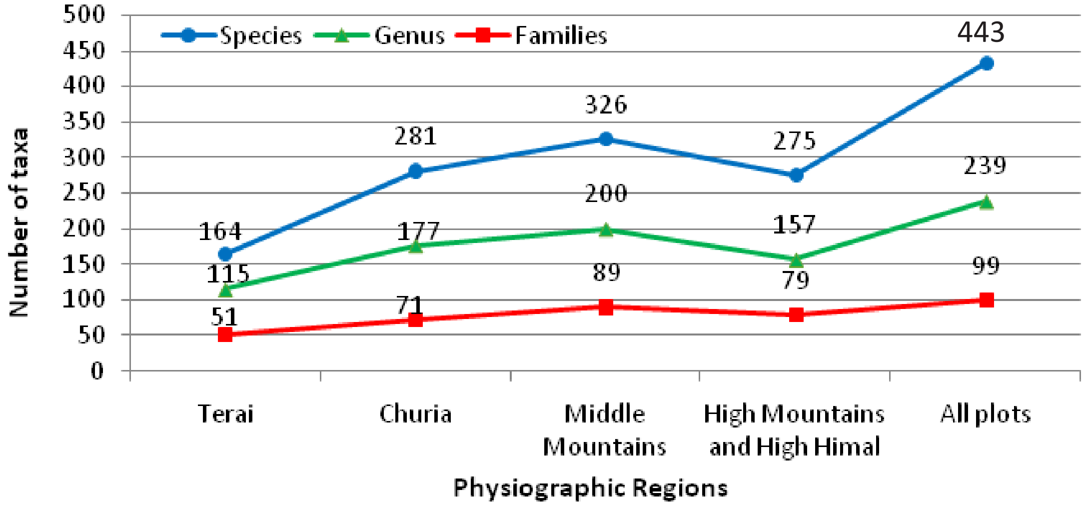

Figure 22: *Number of families, genera and species of tree by physiographic region*

5.4.2 Tree Species Occurrence

Shorea robusta was the most frequently occurring tree species in the FRA sample plots. It was found in the Terai as well as Middle Mountains and was measured in 42% of the total sample plots. In order of descending presence, the other major tree species were *Terminalia alata* (28%), *Schima wallichii* (19%), *Lagerstroemia parviflora* (18%), *Rhododendron arboreum* (16%), *Syzygium cumini* (14%), *Anogeissus latifolia* (13%), and *Pinus roxburghii* (12%). Twenty-one tree species occurred in more than 5% of the measured sample plots (Figure 23).

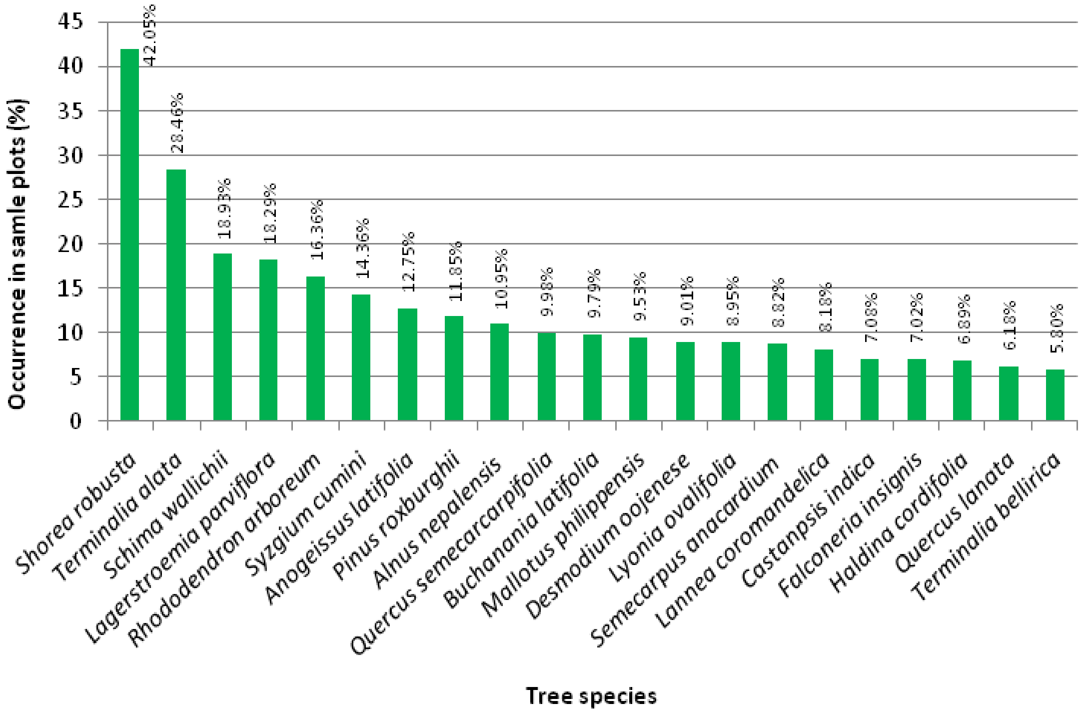

Figure 23: *Occurrence of common tree species in Forest sample plots*

5.5 Forest Disturbances

Nearly two-thirds of the total forest area in the country was affected by grazing. Tree cutting, bush cutting, *lathra* cutting, lopping and forest fire were also common. Other anthropogenic disturbances, such as bark removal from the base of a tree, snaring, foot trails, forest roads, etc. were observed in about one-quarter of the surveyed forest areas (Figure 24).

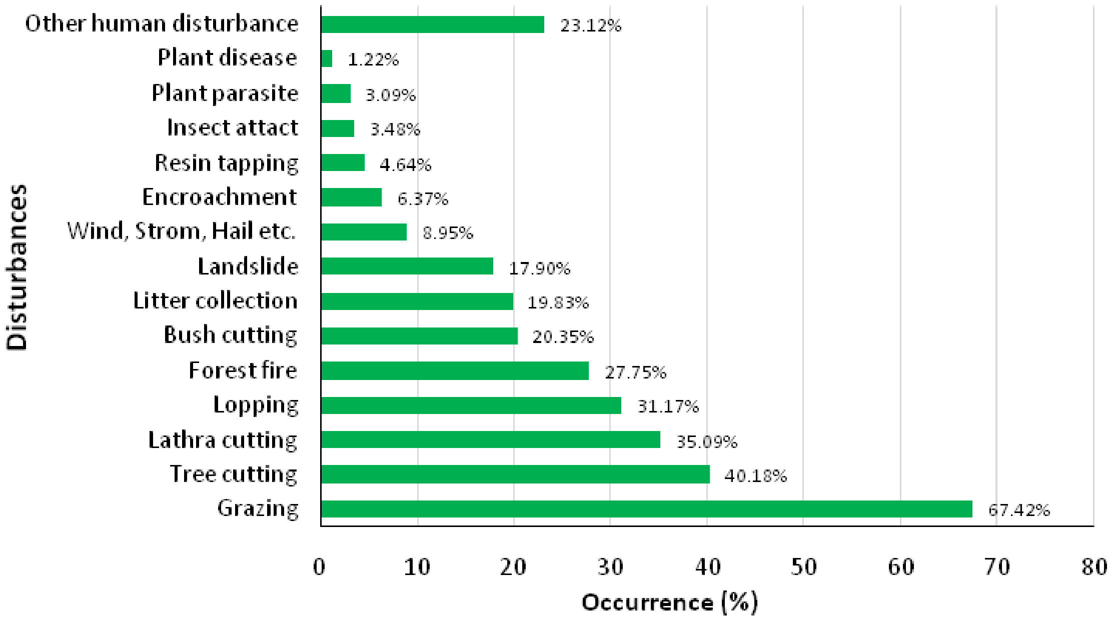

Figure 24: *Occurrence of forest disturbances*

Among all the physiographic regions, Churia was observed to have the highest occurrence of forest disturbance, particularly grazing, forest fire, landslide and cutting of vegetation. Tree cutting and lopping were the highest in forests of Terai region. Litter collection was higher in forests of the Middle Mountains region (Figure 25).

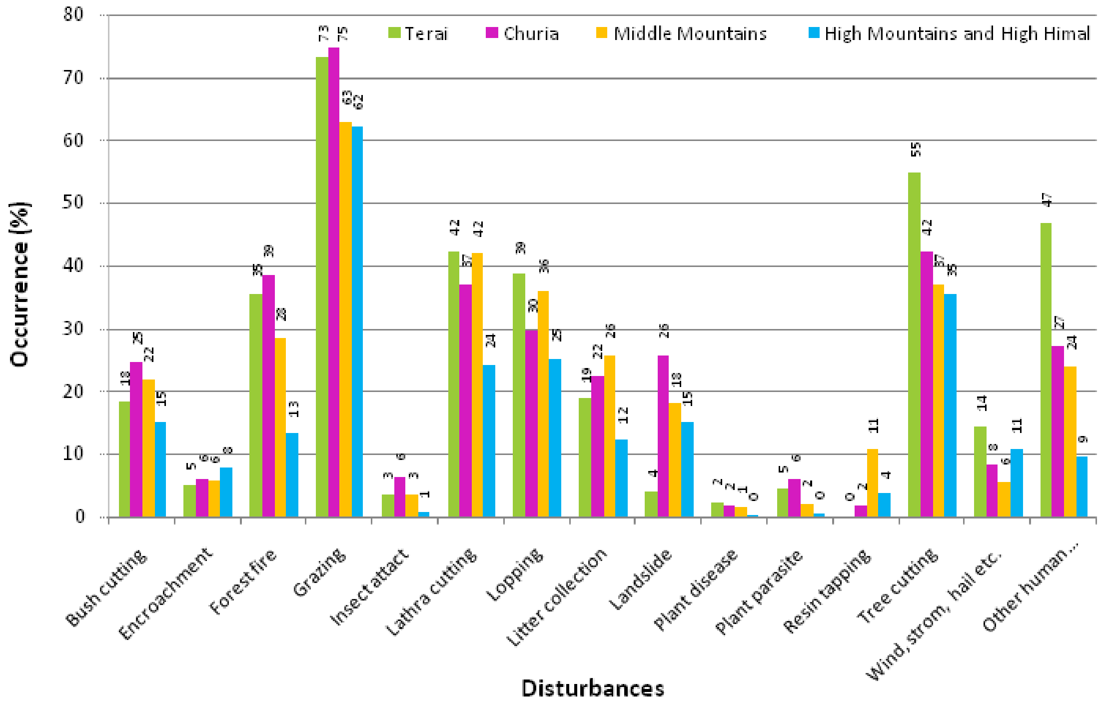

Figure 25: *Proportional occurrence of forest disturbances by physiographic region*

6

WAY FORWARD

Forest Resource Assessment of 2010–2014 has generated comprehensive and up-to-date national level forest information which is summarised in this report. This report provides information on wall-to-wall mapping of land cover (Forest, Other Wooded Land and Other Land), growing stock (number of stems, basal area, volume, and biomass), carbon stock (of tree component, forest soil, litter and debris), occurrence of tree species and forest disturbance.

Information generated from the assessment will help the government and concerned stakeholders in decision-making towards sustainable forest resource management. The results are equally important for international reporting by Nepal under various multilateral environmental conventions and for Global Forest Resource Assessment (GFRA).

During the assessment, permanent sample plots were established in all physiographic regions, and re-measurement of these plots will provide a basis for assessing temporal changes in forest characteristics. The results will also serve as a baseline for REDD+ measurement, reporting and verification (MRV) process.

In the course of Forest Resource Assessment of 2010–2014, a fully functional RS/GIS laboratory with trained personnel and hardware, software and data support, has been established. Furthermore, not only the capacity of government staff to plan and carry out field inventory has been enhanced but DFRS is also now equipped with advanced tools and technology for forest resource assessment. This institutional capacity should be continuously enhanced to undertake periodic forest resource assessment in the future.

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Annex 1: District-wise land cover area (ha)

Development Region	District	Forest (A)	Tree Cover 5–10 % (B)	Shrubs (C)	OWL (B+C)	Other Land (D)	Total (A+B+C+D)
Eastern	Bhojpur	72,881	161	676	837	78,957	152,675
	Dhankuta	36,779	226	11	237	53,080	90,095
	Ilam	93,849	596	75	670	74,582	169,101
	Jhapa	17,349	223	135	358	142,662	160,369
	Khotang	73,865	109	960	1,069	84,252	159,187
	Morang	44,375	132	-	132	137,715	182,221
	Okhaldhunga	51,619	587	540	1,127	54,992	107,738
	Panchthar	71,872	804	-	804	52,501	125,177
	Sankhuwasava	156,102	32,210	3,717	35,926	155,654	347,682
	Saptari	20,362	161	613	774	106,954	128,090
	Siraha	17,937	224	30	254	95,698	113,890
	Solukhumbu	87,144	13,356	10,422	23,778	225,020	335,942
	Sunsari	21,719	96	811	907	96,507	119,132
	Taplejung	125,010	32,356	246	32,602	206,786	364,398
	Terhathum	32,391	695	84	778	34,071	67,240
	Udayapur	149,125	871	73	945	79,944	230,013
	Total	**1,072,379**	**82,807**	**18,392**	**101,198**	**1,679,374**	**2,852,952**
Central	Bara	45,981	596	51	647	80,639	127,266
	Bhaktapur	2,459	15	-	15	9,836	12,311
	Chitwan	141,668	5,762	59	5,821	76,481	223,970
	Dhading	86,067	5,832	844	6,676	97,932	190,674
	Dhanusha	26,975	174	-	174	91,702	118,851
	Dolakha	97,091	10,616	135	10,751	107,028	214,871
	Kathmandu	15,129	67	83	150	26,082	41,361
	Kavrepalanchowk	72,533	2,073	702	2,775	64,135	139,443
	Lalitpur	23,924	319	216	536	15,224	39,683
	Mahottari	22,189	47	-	47	77,812	100,048
	Makwanpur	163,943	1,907	683	2,590	77,833	244,366
	Nuwakot	49,423	650	1,966	2,616	67,277	119,317
	Parsa	75,843	374	12	387	64,453	140,682
	Ramechap	65,248	3,713	412	4,125	87,180	156,553
	Rasuwa	49,821	4,735	199	4,935	95,368	150,123
	Rautahat	25,874	322	92	414	77,528	103,816
	Sarlahi	25,597	175	-	175	100,554	126,326
	Sindhuli	165,099	1,048	549	1,598	81,907	248,603
	Sindhupalchowk	113,803	1,838	242	2,080	133,142	249,026
	Total	**1,268,667**	**40,264**	**6,248**	**46,512**	**1,432,112**	**2,747,292**

Development Region	District	Forest (A)	Tree Cover 5–10 % (B)	Shrubs (C)	OWL (B+C)	Other Land (D)	Total (A+B+C+D)
Western	Arghakhanchi	73,142	792	26	818	49,950	123,909
	Baglung	89,773	251	2,643	2,894	90,909	183,576
	Gorkha	109,300	21,933	877	22,810	232,468	364,578
	Gulmi	45,215	310	814	1,124	64,439	110,777
	Kapilbastu	59,025	1,778	166	1,944	104,167	165,136
	Kaski	85,442	7,201	800	8,000	113,250	206,693
	Lamjung	86,930	4,568	557	5,125	74,181	166,236
	Manang	17,394	9,721	771	10,493	204,152	232,038
	Mustang	11,767	14,536	2,189	16,725	327,878	356,370
	Myagdi	80,233	22,286	5,888	28,174	120,073	228,480
	Nawalparasi	103,593	1,100	713	1,813	109,849	215,255
	Palpa	77,974	639	4,160	4,799	63,418	146,191
	Parbat	26,454	869	327	1,196	26,506	54,156
	Rupandehi	25,105	372	31	403	105,013	130,522
	Syangja	46,516	417	1,051	1,468	55,764	103,749
	Tanahu	82,200	344	508	852	74,134	157,186
	Total	**1,020,063**	**87,117**	**21,522**	**108,639**	**1,816,150**	**2,944,852**
Mid-Western	Banke	116,360	663	886	1,549	70,137	188,046
	Bardiya	111,550	1,696	441	2,137	86,378	200,065
	Dailekh	73,033	1,382	3,741	5,123	70,402	148,559
	Dang	192,682	7,143	900	8,043	105,261	305,986
	Dolpa	71,560	45,689	4,363	50,052	672,865	794,477
	Humla	81,717	45,631	313	45,944	473,562	601,223
	Jajarkot	119,074	6,550	8,852	15,401	87,861	222,336
	Jumla	92,841	16,414	12,076	28,490	134,187	255,518
	Kalikot	96,075	7,136	12,579	19,715	48,342	164,133
	Mugu	76,742	42,177	757	42,934	203,754	323,431
	Pyuthan	64,235	347	84	431	67,427	132,092
	Rolpa	94,447	731	4,420	5,151	88,951	188,549
	Rukum	108,631	15,843	6,973	22,817	158,127	289,575
	Salyan	121,258	541	3,257	3,798	63,058	188,114
	Surkhet	170,517	2,496	1,563	4,059	74,281	248,857
	Total	**1,590,722**	**194,439**	**61,204**	**255,643**	**2,404,594**	**4,250,959**
Far-Western	Achham	98,664	9,514	733	10,248	61,359	170,271
	Baitadi	86,581	5,088	1,507	6,595	56,458	149,634
	Bajhang	115,312	39,260	788	40,048	191,074	346,433
	Bajura	94,430	39,529	1,275	40,804	94,804	230,037
	Dadeldhura	111,312	647	1,350	1,997	37,303	150,613
	Darchula	78,956	27,918	873	28,791	126,714	234,461
	Doti	149,083	1,645	2,270	3,916	52,465	205,463
	Kailali	198,239	2,093	241	2,334	128,143	328,716
	Kanchanpur	77,630	745	422	1,167	82,942	161,740
	Total	**1,010,206**	**126,439**	**9,461**	**135,900**	**831,261**	**1,977,367**
Grand Total		**5,962,038**	**531,066**	**116,826**	**647,892**	**8,163,492**	**14,773,423**