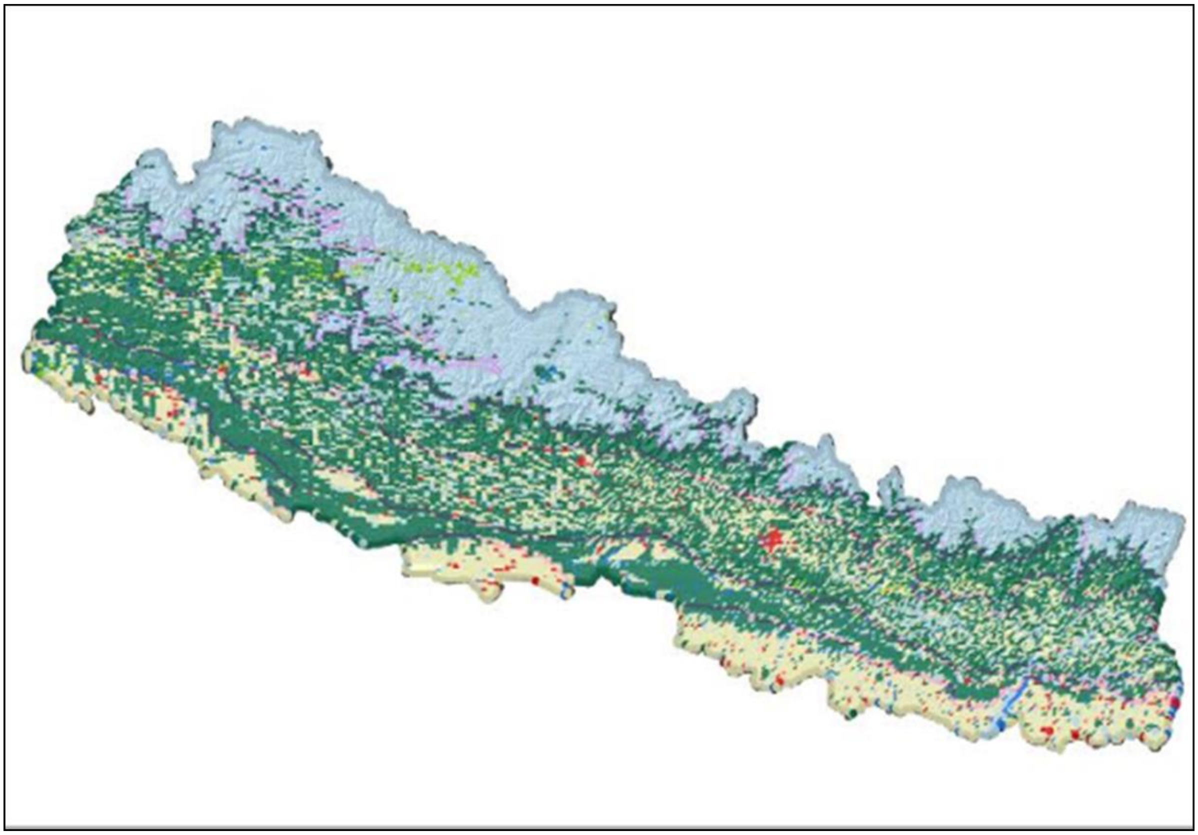
National Level Forests and Land Cover Analysis of Nepal using Google Earth Images



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Acronyms and Abbreviations

CHAL	Chitwan Annapurna Landscape
CL	Cropland
DoS	Department of Survey
DFRS	Department of Forest Research and Survey
FAO	Food and Agriculture Organization of the United Nations
FL	Forest land
FORESC	Forest Research and Survey Centre
FRA	Forest Resource Assessment
FRTC	Forest Research and Training Centre (Former DFRS)
GEOBIA	Geographic Object-Based Image Analysis
GFRA	Global Forest Resource Assessment
GHG	Greenhouse Gas
GL	Grassland
ICIMOD	International Centre for Integrated Mountain Development
IPCC	International Panel on Climate change
IUCN	International Union for Conservation of Nature
LCCS	Land cover classification system
LULUC	Land Use and Land Use Change
LULUCF	Land Use, Land-Use Change and Forestry
M ha.	Million hectares
MoFSC	Ministry of Forest and Soil Conservation
MoLRM	Ministry of Land Reform and Management
NFI	National Forest Inventory
NLCMS	National Land Cover Monitoring System
NTNC	National Trust for Nature Conservation
OT	Other land
SL	Settlement
TAL	Terai Arc Landscape
VHR	Very High Resolution
WECS	Water and Energy Commission Secretariat
WL	Wetland
WWF	World Wildlife Fund

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Executive Summary

Land cover on Earth has been continuously changing due to natural and anthropogenic activities. Analysis and mapping of land cover are important aspects of monitoring studies, resource management and planning activities. A detailed land-cover mapping is an important research topic in any landscape planning. Grazing, shifting cultivation, deforestation, urbanization and land degradation have been the major factors considering land cover change besides some socio-economic factors in Nepal. Monitoring Land Use and Land Use Change (LULUC) through remote sensing is a common approach to generating necessary data for quantifying impacts on the Earth's system. The freely available moderate to high-resolution satellite imageries (e.g, Landsat, Sentinel, etc.) and open source software have facilitated users to monitor land and fulfilled the needs of remote sensing experts.

*In this context, Forest Research and Training Centre (FRTC), formerly the Department of Forest Research and Survey (DFRS), and Hariyo Ban Program/WWF Nepal agreed to implement this study entitled "National Level Forests and Land Cover Analysis through Integration of Google Earth Images and Moderate Resolution Satellite Images in Nepal". The goal of this study was to develop a methodology for assessing the forests and land cover situation in such a way that it will be sustainable for years to come. Besides, this study which covered the whole territory of Nepal also targeted to facilitate national as well as international reporting regarding the forests and other land cover situation of the country. The land cover classes applied in this study were adopted from Good Practice Guidance for Land Use, Land-Use Change and Forestry developed by the International Panel on Climate change (IPCC) in 2003. IPCC has broadly classified land cover classes into six categories namely Forest, Cropland, Settlement, Wetland, Grassland and Other land. Map of Nepal was overlaid in a grid of 2 km * 2 km interval. A total of 36,843 sample points were generated as a dataset for visual interpretations. All the sample points were visually interpreted using Collect Earth platform of FAO's OpenForis system.*

The results from this study reveal the current status of forest and other different land cover classes. Forest occupies 6.5 million hectares which is equivalent to 44.47% of total area of Nepal. Beside Forest, Other land and Cropland respectively occupy 28.68% and 21.88%. The remaining area is covered by Settlement (1.15%), Wetland (1.22%) and Grassland (2.60%). The overall consistency of visual interpretations is 98.77%.

Implementation of this program on a broader theme of land use and land cover has enlightened some insights on the relation of forest with other land cover. The methodology developed under this study seems good to generate land cover situation of Forest, Cropland, Settlement and Wetland. However, further studies are necessary to generate more reliable results in terms of Grassland and Other land.The methodology adopted here might be developed as a tool for future monitoring programs on the status of different land cover classes. However, further exercise on Google Earth Engine platform is essential to validate the reliability of acquired results for each land cover classes.

Findings of this study in the six land cover classes based on IPCC Good Practice Guidance can be considered as the first level primitives during National Land Cover Monitoring System (NLCMS) preparation of Nepal. However, other levels of primitives are also essential to establish a complete dataset for NLCMS to make it compatible and consistent at the regional level. Thus, this study also recommends for a broader level of study to assess the appropriate system and further levels of land cover primitives in addition to assessing the drivers of land cover conversion.

1. Introduction

1.1 Background

Land cover is commonly known as coverage on the ground surface like forests, agriculture, settlements, urban infrastructures, water, grass, bare soils, rocks, snow or other. It can be considered as *a geographically explicit feature that can be used in different disciplines (geography, ecology, geology, forestry, land policy and planning etc.) as a geographical reference (e.g. for land-use, climatic or ecological studies)* (FAO, 2016). Analysis and mapping of land cover are important aspects in monitoring studies, resource management and planning activities (Aspinalls & Hill, 2008; Foody & Atkinson, 2002). Land cover patterns on the Earth are constantly being changed by different human activities, thereby influencing biophysical processes (Li & Shao, 2014). Thus, a detailed land-cover mapping is an important research topic in any landscape planning nowadays.

Land cover on Earth has been continuously changing due to natural and anthropogenic activities. Several studies have revealed various factors for land cover and land use change. For instance, conversion of natural ecosystems for agricultural practices has been a primary factor in land use and land cover (Ramankutty and Foley 1999). Besides, Nepal is recorded in the top ten fastest urbanizing countries (UNDESA, 2015), thus increasing infrastructures and superstructures could be considered as important elements of land cover change (Ishtiaque et. al., 2017). Considering the land cover change in Nepal, factors like grazing, shifting cultivation, deforestation, urbanization and land degradation have been revealed as the major actors in the past (Paudel et. al., 2016). On the other hand, some socio-economic factors are also responsible for the land cover change. A study by Ives and Messerli (1989) considered high population growth rate, economic activities based on natural resources and poverty having significant impacts on mass forest degradation and the environment which is called the theory of Himalayan Environmental Degradation.

Monitoring Land Use and Land Use Change (LULUC) through remote sensing is a common approach to generating necessary data for quantifying impacts on the Earth's system. Over past decades, significant changes in the remote sensing field have made land monitoring more cost-efficient and technically feasible. The freely available moderate to high-resolution satellite imageries (Landsat, Sentinel) and open source software have facilitated users to monitor land and fulfilled the needs of remote sensing experts.

In this context, Forest Research and Training Centre (FRTC), formerly the Department of Forest Research and Survey (DFRS), and Hariyo Ban Program/WWF Nepal agreed to implement this study on *National*

Level Forests and Land Cover Analysis through Integration of Google Earth Images and Moderate Resolution Satellite Images in Nepal.

1.2 Goal and objectives

The goal of this study was to assess the forests and land cover situation of the entire country and develop a methodology and workflow which will enable continuous forest and land cover monitoring. Furthermore, the following specific objectives were aimed at this program.

a) Assess forests and land cover situation of the country,

b) Compare the results with other assessments, and

c) Develop a methodology for assessing the forests and land cover situation at the national level

1.3 Target audience

The data and maps generated would be very helpful to design biodiversity conservation and climate change adaptation programs/activities. For example, the information can be useful for conservation priority areas such as Terai Arc Landscape (TAL) and Chitwan-Annapurna Landscape (CHAL) areas. Thus not only Hariyo Ban program (including WWF Nepal's other programs) but also concerned governmental agencies are the target audiences of this study. The outputs from this study shall be guidance to policymakers and planners related to forests, biodiversity and natural resources management. Various government agencies like National Planning Commission, Ministry of Forests and Environment, Ministry of Agriculture and Livestock Development, Department of Land Reform and Management, Ministry of Federal Affairs and General Administration along with Department of Forests and Soil Conservation, Survey Department, Department of National Parks and Wildlife Management, Department of Urban Development and Building Construction as well as Department of Plant Resources will be the primary target audiences. In addition, the outcomes from this project shall be concerning to a number of non-governmental agencies dealing with conservation and management like WWF Nepal, IUCN, NTNC and their various programs.

Furthermore, since the Food and Agricultural Organization of the United Nations has been continuously carrying out the Global Forest Resource Assessment, this type of forests and land cover maps would be a promising product for its reporting. This study adopted the broad six land cover classes as prescribed in the IPCC Good Practice Guidance. Thus the outcomes from this study shall be very useful to international reporting on REDD+ programs. Besides, individual researchers and students will also be the beneficiaries from the products of this project.

1.4 Study area

This study covered the whole territory of Nepal which is located between latitudes 26°22'–30°27’N and longitudes 80°04'–88°12’E (Figure 1). The country has a considerable variation in elevation, with the Himalayas at a maximum elevation of 8848 m, remarked at the top of the world (LRMP, 1986), obvious mountains scattered in its middle section (Mountains), and the Terai plain with the least elevation of 60 meters in the south. Politically the country is divided into seven federal states and 77 districts. The temperature and precipitation of this country vary with the vertical terrain. Such variation in topography and climate expedites hosting of 118 ecosystems, 75 vegetation types, and 35 types of forest (MoFSC, 2014). Besides, specific topographical, meteorological, and socio-economic conditions breed diverse and complex land cover in Nepal (Bhattarai et. al., 2009). The country has experienced several land cover changes in the past decades due to the conversion of forests to cropland and settlement with a rapid increment of urbanization. The land cover in Nepal mainly includes different types of forests (broadleaf, needle leaf, mixed), croplands, shrublands, grasslands, bare lands, as well as permanent ice/snow (Wang, 2004; Uddin et. al., 2015).

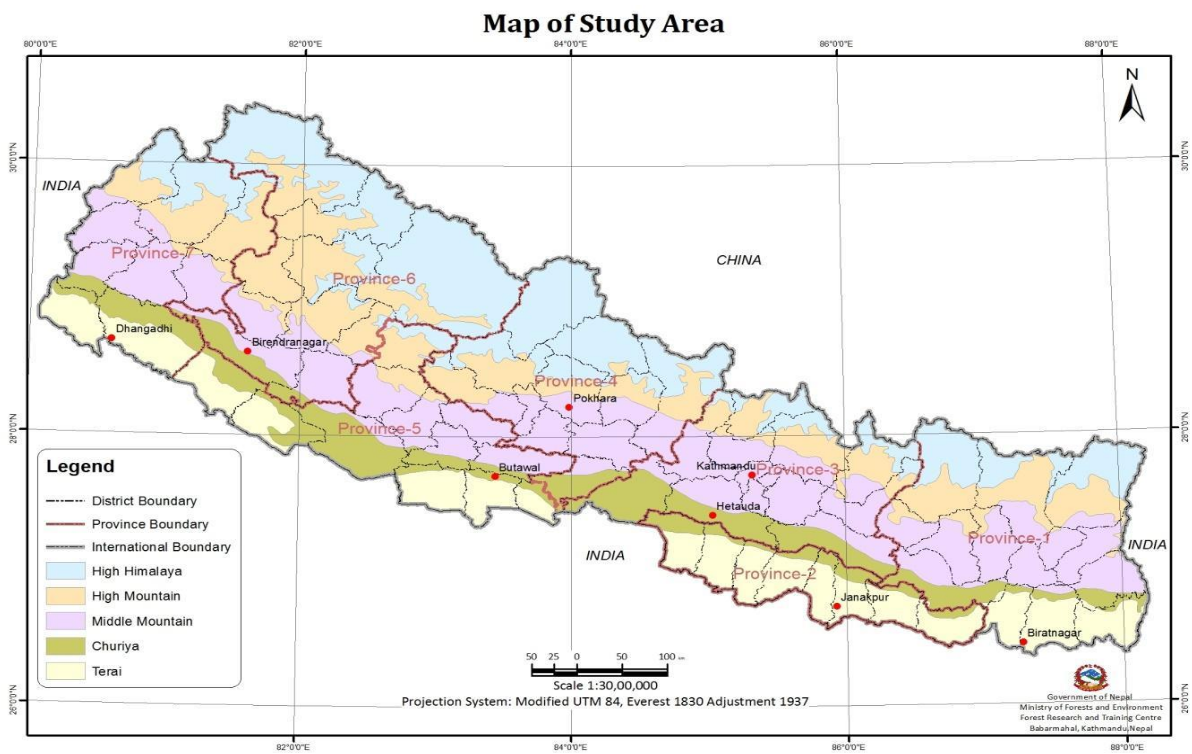


Figure 1: Map of the study area

1.5 Rationale of the study

Periodic monitoring of land cover (including forests) is essential to examine the total extent and changes over time. The information derived from forest and other land cover analysis provides a key input for policy formulation and management decisions. On this regard, a few national-level forest and land cover assessments have been conducted in Nepal. However, some of those assessments were focused on forest cover mapping only, e.g. National Forest Inventory (NFI) 1987–1998 (DFRS, 1999) and Forest Resource Assessment (FRA) 2010-2014 (DFRS, 2015). On the other hand, Forest Resources Survey (FRS) assessed land-cover of Nepal using aerial photography in 1963. Besides, a Land Resources Mapping Project (LRMP) used aerial photographs of 1978-1979 while mapping the different land use classes all over the country (LRMP, 1986). A study funded by USAID NASA (SERVIR Himalaya) used a machine-based interpretation for developing a national land cover database of 2010 (Uddin et. al., 2015). Araya & Hergart (2008) revealed that a sample-based approach has advantages for specific case-studies on land cover classification, image segmentation, and classification. The Figure 2) highlights the history of land cover analysis of Nepal in the past.

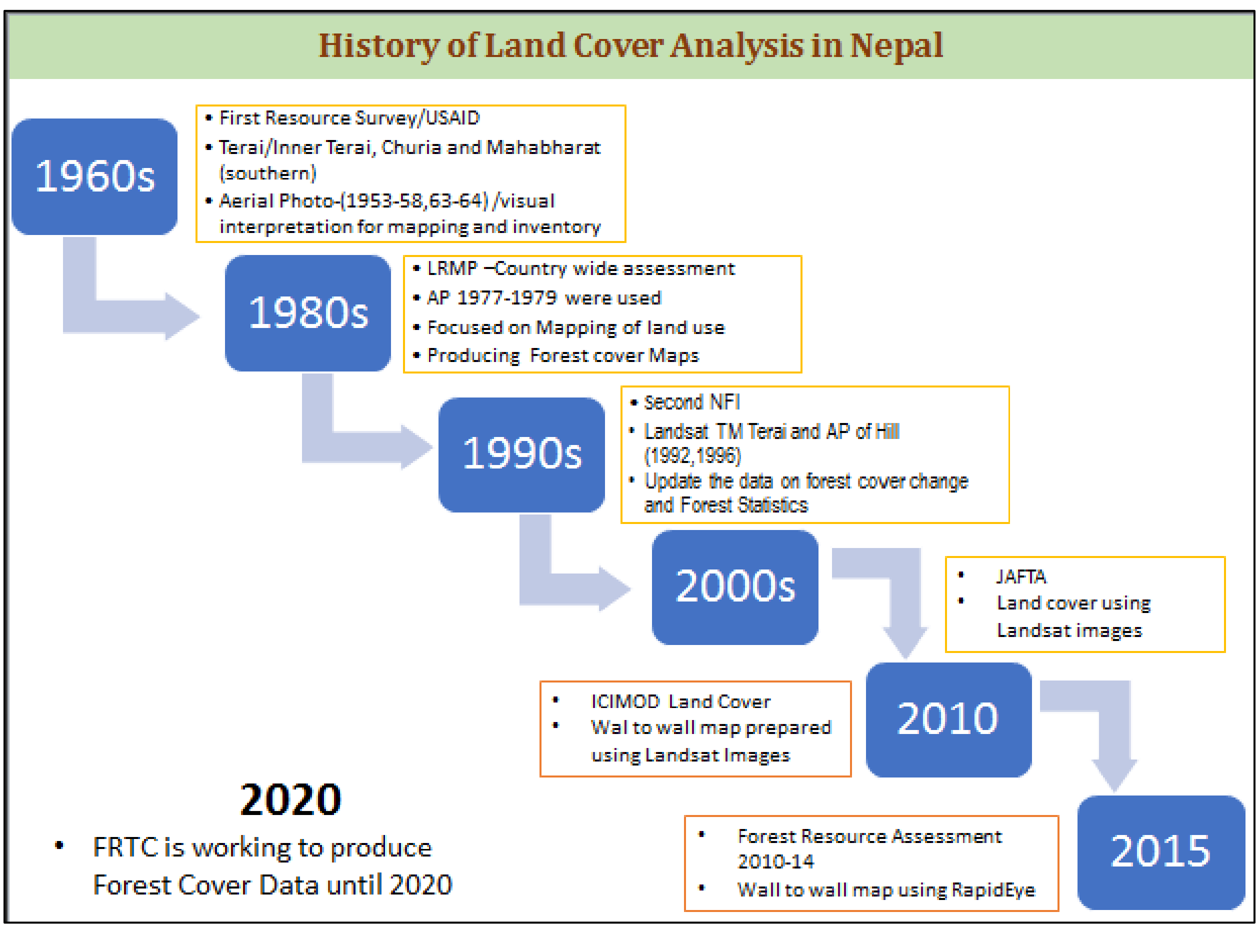


Figure 2: History of land cover analysis in Nepal

Some of the studies in Nepal had adopted a sample-based approach as well, for example, NFI (1987-1998) and FRA (2010-2014). However, the former study used sample-based approach to a limited area of Nepal and the latter study though used it all over the country as the first phase sampling but later published the results based on the wall to wall mapping. Direct comparison of available national scale forest cover datasets for Nepal is challenging for direct comparison and therefore need for future assessments based on consistent methods and datasets have been recommended (Khanal et al. 2016). Thus, a detailed forest and other land cover analysis of the entire country using the sample-based approach is not published yet.

Thus, this study was designed to assess the forests and land cover situation and develop a methodology and workflow which will enable continuous forest and land cover monitoring. An integrated approach of GIS and remote sensing has been very important for effective land cover mapping. FRTC has the mandate to conduct a nationwide forest resource assessment and conducted several such national assessments. The outputs from those national projects have been reference to national policies as well as reporting to international initiatives and convention requirements. FRTC completed latest national scale forest resource assessment from 2010 to 2014 and produced comprehensive information of Nepal's forest including forest cover maps. However, a detailed analysis of other land covers seems still missing. To fulfil the data gaps on Nepal's land cover status over several years of time, this study also aimed to produce current forest and other land cover situation along with conversion among each land cover classes over a period of time. Hence, the outcome from this study may also serve as an activity data for current initiatives of Nepal's national reporting to UNFCCC for assessing forest carbon fluxes as per the Good Practice Guidance of Intergovernmental Panel on Climate Change (IPCC).

2. Methodology

2.1 Review

Different approaches have been used in land cover classification and analysis. Uddin et. al. (2015) adopted a harmonized and standardized classification scheme with 12 classes using the land cover classification system (LCCS) while developing the 2010 national land cover database for Nepal. For image classification, they adopted Geographic Object-Based Image Analysis (GEOBIA) technique. GEOBIA is a methodological framework for the machine-based interpretation of complex classes defined by spectral, spatial, contextual, and hierarchical properties (Blaschke et. al., 2008; Duro et. al., 2012).

Several studies on land cover analysis have applied different classification methods (e.g. pixel, sub-pixel, per-field and object-oriented approaches) have been applied to classify satellite images. An object-based classification method was used to produce the Nepal Cover-2010 product (Le et. al., 2017). They adopted a two-level classification system with 8 and 31 classes at the first and second level. An automatic classification via a decision tree algorithm was done to generate a land cover product. Quite differently, a study on land cover of the Asmara region in Eritrea adopted both pixel-based and object-oriented classifiers to compare the results from two different approaches on which overall accuracy for an object-based approach was found higher (85%) than that of pixel-based approach (78%) (Araya & Hergart, 2008). Its success has been generally noticed higher with narrow band and high-resolution data (Willhauck, 2000). Thus an object-based image analysis has been used and is more popular in recent years. Its application is extended in various fields like forest mapping and land use land cover classification (Huth et. al., 2012; Kim et. al., 2011). However, the application of semi-automated classification methods like pixel and object-based on very high resolution (VHR) images while developing maps has proven to be challenging (Bey et. al., 2016). This is because of small geographic scope and the irregular time intervals of VHR imagery acquisition limit its use for national and subnational assessments on land monitoring.

Various tools and software have been developed so far for land cover assessment and monitoring. In present days, many free and open source software as well as imageries are also available (Table 1). This table implies that out of the several options for land assessment, Collect Earth is more comprehensive and offers more functionality.

Table 1: Overview of relevant existing free land assessment software

Attributes		Purpose				Type			Main Satellite Imagery Archives				
		LULC (Static) Assessment	LULC Change Assessment	Map Validation	Assessment of Other Land Characteristics	Browser-Based	Desktop Client	Google Maps	Google Street View	Google Earth (GE)	Bing Maps	Digital Globe	GE Engine
Software	Collect Earth*	X	X	X	X		X		X	X	X	X	X
	GeoWiki [14]	X		X		X		X					
	GLFC LT [15]	X	X	X		X		X					
	Laco-Wiki [16]	X		X		X		X					
	SkyTruth [19]				X	X		X					
	TimeSync [17]	X	X	X			X			X			
	Tomnod [20]				X	X						X	
	VIEW-IT [18]	X		X		X		X					

Attributes		Options for Accessing Supplementary Imagery Archives			Land Assessment and Map Validation Methods and Tools					Flexibility	
		GE Web Mapping Service	Other Spatial Data Import	ArcGIS Server Data Import	Visual Interpretation of Satellite Imagery	Visual Interpretation of Vegetation Indices	Visual Interpretation of Ground-Based Photos	Spatial Reference Data Accessible	Error or Uncertainty Estimation Tools	User-Generated Sampling Design	User-Generated Data Collection Form
Software	Collect Earth	X	X		X	X	X	X	X	X	X
	GeoWiki [14]	X			X		X	X			
	GLFC LT [15]		X		X	X	X	X	X	X	X
	Laco-Wiki [16]	X	X		X		X	X	X	X	X
	SkyTruth [19]				X						
	TimeSync [17]		X		X	X		X	X	X	X
	Tomnod [20]				X						
	VIEW-IT [18]		X	X	X	X	X	X	X	X	

Source: Bey et. al. (2016)

2.2 Data and software

A project was developed in OpenForis, Collect Earth server for this program. Since the systematic visual interpretation was planned during the design of this program, a map of Nepal was overlaid in a grid of 2 km * 2 km interval. A total of 36,843 sample points were generated as a dataset for visual interpretation. Cross-sections of the grid were considered as the sample points. FRTC has established permanent sample plots for national forest resource assessment which follow a cluster design at 4 km interval (DFRS, 2015). The systematic grid layout for this project was designed to overlap with all first plots established for national forest inventory. The sample points were interpreted using the high-resolution imagery in Google Earth with the help of OpenForis Collect Earth interface. Recent land cover class for each point were identified interpreting the sample points in a recent high-resolution image and the land cover change in that particular point had been identified using the archive of images in the Google Earth platform.

The recent land cover classes were interpreted from latest images updated in Google Earth, whereas images of the year 2008 were interpreted to assess the classes of the same sample. For those sample points whose images of aforementioned years in the Google Earth archive were not available, images from the nearby years were interpreted. Thus an attempt was made to identify the pattern of land cover conversion during this period. In this regard, most of the sample points of the latest updated imageries were available from 2017 (Figure 3). Year of reference imageries representing previous land cover categories for each sample points (facing conversion) were not recorded. However, consideration of the year 2008 or nearby years (e.g. 2007 and 2009) was mentioned under the protocol before visual interpretation activities (Annex-2). Thus, an arrangement of the imageries' dates (years) was made in such a way that it facilitates to have an overview of land cover conversion for a decade.

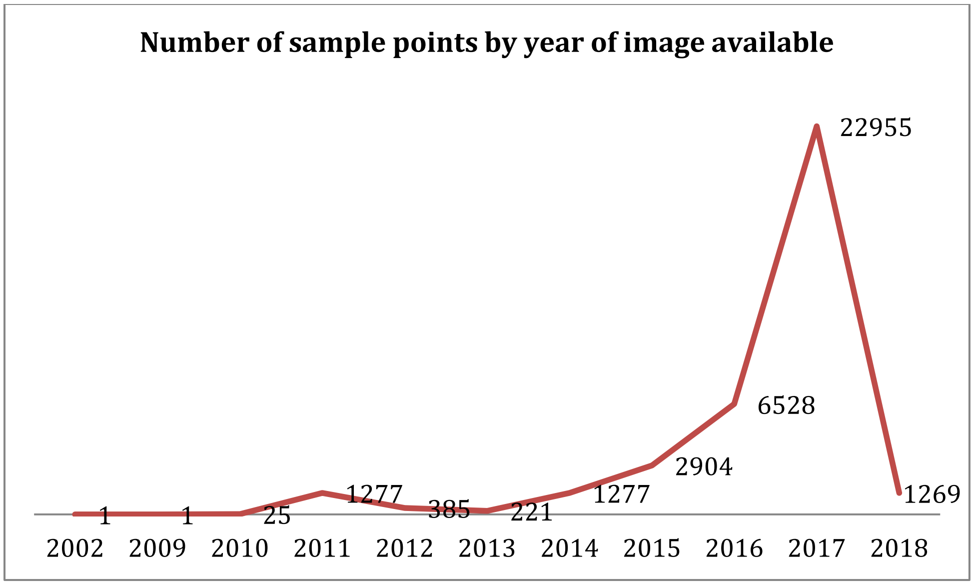


Figure 3: Total number of sample points by available imageries' year

The analyzed visual interpretation data were automatically stored in the Collect Earth database. However, periodic as well as final datasets were also stored as back up in Google drive and external storage devices. Visual interpretation data were then extracted and analyzed to calculate the proportion of different land cover classes across the country.

2.3 Introduction to Collect Earth

Collect Earth is an open source tool developed by the Food and Agriculture Organization of the United Nations (FAO). It facilitates the collection, management and analysis of land data enabling the users to draw upon Google technology to freely access and visually interpret satellite imagery for data collection. Users can analyze VHR satellite imagery in combination with Google Earth, Bing Maps and Google Earth Engine. Collect Earth can be used for a wide variety of purposes on land cover assessments, national forest inventories and quantifying deforestation and so on (Openforis, 2018). It can be recognized as a perfect tool for performing fast, accurate and cost-effective assessments due to its friendliness and smooth learning behaviour. Also, it is highly customizable for any specific needs and methodologies. *Collect Earth differs from previously existing land monitoring tools by offering access to (a) multiple archives of VHR satellite imagery that can support the assessment of land use and land cover dynamics; (b) graphical representations of inter-annual and intra-annual vegetation indices generated with Landsat and MODIS imagery in Google Earth Engine (GEE), new technology for cloud-based, automated processing of satellite imagery; and (c) built-in data analysis tools through an integration with Saiku*

Analytics (Bey et. al., 2016). Thus it has the potential to assess land use, land use change, natural disasters, sustainable management of scarce resources and ecosystem functioning.

2.4 Land cover classes

The land cover classes being used in national, regional and/or international level are rarely consistent. This has created a problem to land cover mapping that limits any comparison among regions and over time (Uddin et. al., 2015).

The Land Resources Mapping Project adopted 6 main land use classes (Table 2) to classify their proportion in each physiographic regions of Nepal. Similarly, the Land Use Policy, 2015 classified entire lands of the country into 11 zones (Table 2). Those were a few attempts by the Government of Nepal to develop land use land cover system of the country. Besides, ICIMOD developed 12 land cover classes to develop land cover databases for the Hindu Kush Himalaya region (Table 2).

Table 2: Land cover classes on different studies in Nepal

Project	Organisation	Land Cover Classes
First NFI 1960s	FORESC	[7 Classes]: Forest, Cropland, Grassland, Urban, Water, Badly Eroded Barren
LRMP 1970s/80s	DoS	[13 Classes]: Forest, Shrub, Grassland, Cultivated lands, Non cultivated lands, Abandoned, Settlement, Rock, Ice, Water bodies, Others
WECS 1988	WECS	[6 Classes]: Forest, Shrub land, Grassland, Cultivated land, NCl, Other land
MPFS 1989	MoFSC	[6 Classes]: Forest, Shrub land, Grassland, Cultivated land, NCl, Other land
Second NFI 1989-1992	DFRS	[3 Classes]: Forest, Shrub land, Non-Forest
Land Cover Mapping 2010	ICIMOD	[7 Classes]: Forest, Shrubs, Grass, Agriculture, Bare Areas, Snow, Built-up
Forest Resources Assessment 2010-2014	DFRS/FRA	[3 Classes]: Forest, Other Wooded Land, Other Land
Land Use Project/ Topographic Mapping	DoS	[7 Classes]: Agriculture, Built up Area, Forest, Riverine and Lake Area, Shrubs and Grassland, Snow and Glacier, Other
Land Use Policy, 2015	MoLRM	[11 Classes]: Agriculture, Residential, Commercial, Industrial, Mines, Cultural, Water body, Forest, Public Use Zone, Construction material extraction, Other

The land cover classes applied in this study were adopted from *Good Practice Guidance for Land Use, Land-Use Change and Forestry* developed by the International Panel on Climate change (IPCC) in 2003. IPCC has broadly classified land cover classes into six categories (Table 3). Those categories can be considered as top-level for designating land areas within a country and are consistent with the IPCC Guidelines and the requirements of the Kyoto Protocol (IPCC, 2003). Nevertheless, the land cover/land use classes can be further subdivided as per the national requirements.

Table 3: Top level land categories prescribed in the Good Practice Guidance of IPCC

SN	Land Categories	Description
1	Forest land	This category includes all land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory, sub-divided into managed and unmanaged, and also by ecosystem type as specified in the IPCC Guidelines. It also includes systems with vegetation that currently fall below, but are expected to exceed, the threshold of the forest land category.
2	Cropland	This category includes arable and tillage land and agro-forestry systems where vegetation falls below the thresholds used for the forest land category, consistent with the selection of national definitions.
3	Grassland	This category includes rangelands and pasture land that is not considered as cropland. It also includes systems with vegetation that fall below the thresholds used in the forest land category and are not expected to exceed, without human intervention, the threshold used in the forest land category. The category also includes all grassland from wild lands to recreational areas as well as agricultural and silvi-pastoral systems, subdivided into managed and unmanaged consistent with national definitions.
4	Wetlands	This category includes land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, grassland or settlements categories. The category can be subdivided into managed and unmanaged according to national definitions. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions.
5	Settlements	This category includes all developed land, including transportation infrastructure and human settlements of any size, unless they are already included under other categories. This should be consistent with the selection of national definitions.
6	Other land	This category includes bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available.

Source: IPCC (2003)

These land cover/use classes are the top-level land categories for greenhouse gas (GHG) inventory reporting. And since Nepal is a member country of REDD+ programs, adoption of these classes on land cover analysis would promote its current initiatives on national reporting to UNFCCC for assessing forest carbon fluxes.

However, the current land cover classes all over the country could not be incorporated within the pre-determined classification in six classes. Thus, a protocol (Annex-2) was developed to facilitate the visual interpretation of sample points. In addition, the protocol was important to maintain the consistency in land cover classification as well.

2.5 Field verification

Verification of sample points with field visits was a part of the program under this study. First of all, the sample points with land cover conversion were identified. Then, depending on the time and resources available, two field visits were planned to verify the conversion as well as identify the drivers of land cover conversion. The sub-sampled points were thoroughly visited and the required information such as confirmation of land cover change, probable drivers of conversion, etc. was collected.

The task of field verification was conducted in a single mission with two different field crews. One field was conducted in the eastern part of Nepal (Solukhumbu, Okhaldhunga, Ramechhap, Dolakha and Sindhupalchowk districts whereas the other one was conducted in the western districts, namely Lamjung, Kaski, Parbat, Baglung, Myagdi and Mustang. Field verifications were planned in such a way that sample points from Mid-hills to the Himalayas could be visited because samples from Terai and Siwalik regions were already verified during a program on Chure forest cover mapping.

A few informal consultations were conducted with relevant stakeholders at the district level. After collecting the data and required information, necessary amendments were made and the protocol for visual interpretation was also updated.

2.6 Consistency check

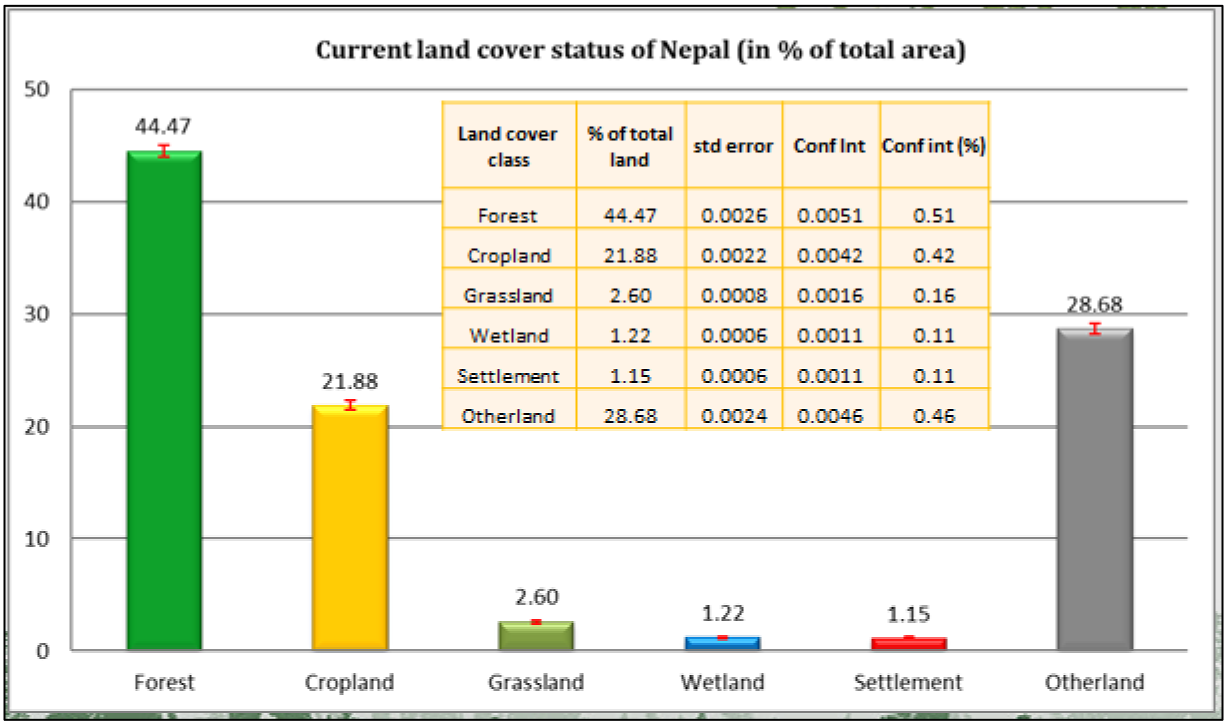
Although accuracy assessment is important for traditional remote sensing techniques, with the advent of more advanced digital satellite remote sensing the necessity of performing an accuracy assessment, has received new interest (Congalton, 1991). Accuracy assessment in any study is considered as an integral part. It should usually be performed with reference to some ancillary data such as aerial photographs, previously prepared maps or even high-resolution satellite imagery or field verification. However, since results of this study were not compared with other ancillary data and also could not generate sufficient data from field verification, an accuracy assessment was not performed. Instead this study adopted an error matrix approach for consistency check.

A set of 5% of the total sample points (1871 in number) was selected systematically at an interval of 20 with a random start. The reason behind the systematic selection of sample points was to incorporate data from all physiographic regions. The set of data was distributed to an internal expert for more careful visual interpretations. The outcomes from those independent visual interpretations of the same sample points were arranged as a confusion matrix and the overall consistency of the interpretation was calculated.

3. Results and Discussion

3.1 Current status of different land cover classes

The results from this study disclose the current status of forest and other different land cover classes. Forest occupies 6.54 million hectares which is equivalent to 44.47% of total area of Nepal (Figure 4). After forest, Other land occupies the next greater land area (4.22 million hectares) equivalent to 28.68% of total area. Then after, Cropland occupies 3.22 million hectares (i.e. 21.88% of total). Settlement and Wetland, on the other hand, cover 0.17 and 0.18 million hectares of land those are proportionate to respectively 1.15% and 1.22% of the total area of the country. Regarding Grassland, only 0.38 million hectares (equivalent to 2.60%) are recorded in this analysis.



Land cover class	% of total land	std error	Conf Int	Conf int (%)
Forest	44.47	0.0026	0.0051	0.51
Cropland	21.88	0.0022	0.0042	0.42
Grassland	2.60	0.0008	0.0016	0.16
Wetland	1.22	0.0006	0.0011	0.11
Settlement	1.15	0.0006	0.0011	0.11
Otherland	28.68	0.0024	0.0046	0.46

Figure 4: Current Land Cover status of Nepal

Generally, Grasslands are the most confusing land covers to identify in imageries (Zhao et. al., 2017). Thus a varied pattern has been noticed in the results of Grassland's cover in Nepal. Furthermore, Table 4 illustrates a decreasing trend of Grasslands' cover in Nepal. However, depending on the definition, input data and approach used, the estimates often vary.

Table 4: Grasslands cover in different studies

SN	Assessments	Grassland cover in %	References
1	Land Resources Mapping Project	12.00	(*LRMP, 1986*)
2	District, Regional and National Forest Cover Class Summaries of the Area, Fuel wood Yield and Wood Volume for the Kingdom of Nepal	11.90	(*WECS, 1988*)
3	Master Plan for Forestry Sector	11.83	(*MPFS, 1988*)
4	National Forage & Grassland Research Centre, Nepal	11.55	(*Pande, 2007*)
5	Development of 2010 national land cover database for Nepal	7.90	(*Uddin et al., 2015*)

3.2 Forest cover dynamics

This study has revealed the present forest cover of Nepal to be 6.54 m ha which is equivalent to 44.47% of total area of the country. According to the latest Forest Resource Assessment of Nepal (FRA 2010-2014), Forest and Other Wooded Land covered 5.96 and 0.65 million ha respectively which together occupied 44.74% of the total area of the country (DFRS, 2015). Table 5 highlights the comparison of forest cover from this study with the past assessments conducted in Nepal.

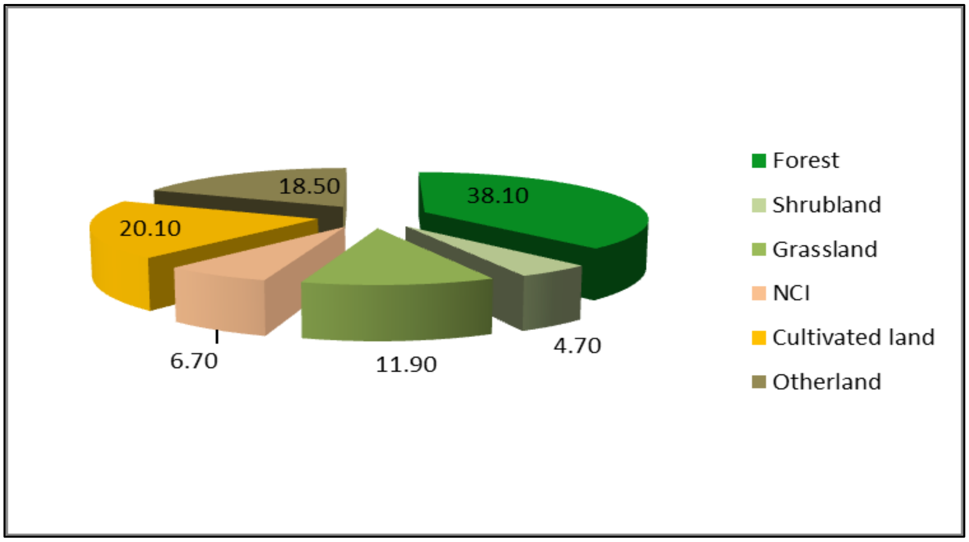
Table 5: Forest cover of Nepal from different assessments

Land cover	LRMP 1978/79	NRSC 1984	Master Plan 1985/86	WECS 1988	NFI 1994	DoS 1995	JAFTA 2000/01	FRA 2010-2014	This study 2018
Forest	38.0	35.9*	37.4	38.1	29.0	38.3	37.3	40.36	44.47
Shrub	4.7	-	4.8	4.7	10.6	-	9.3	4.38**	-
Forest + Shrub	42.7	35.9*	42.2	42.8	39.6	38.3	46.6	44.74	44.47

*Including some shrub areas; **Other Wooded Land *Source: DFRS (2015)*

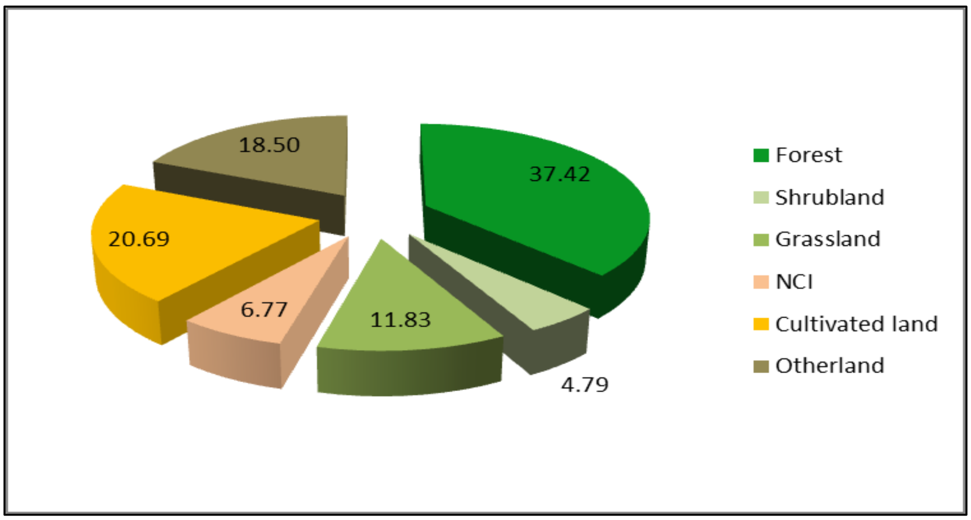
3.3 Review of land use/land cover status from different studies

Several studies have been conducted in the past with an aim to discover the status of land use/land cover. The following figures represent the proportion of the country by different land cover/land-use classes from those studies. However, due to inconsistencies on methods and adopted classes among those studies, a thorough comparison over different time periods is rather difficult.



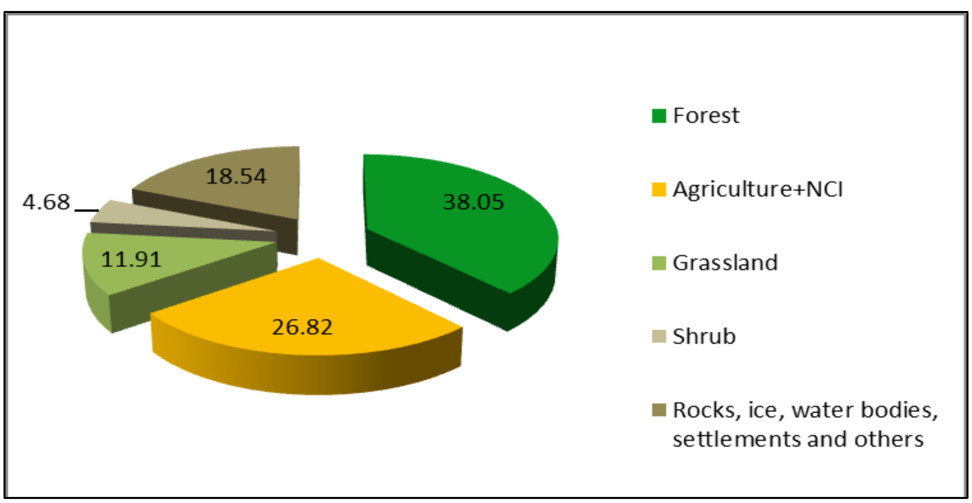
Source: WECS, 1988

Figure 5: Land-use distribution of Nepal in 1978/79



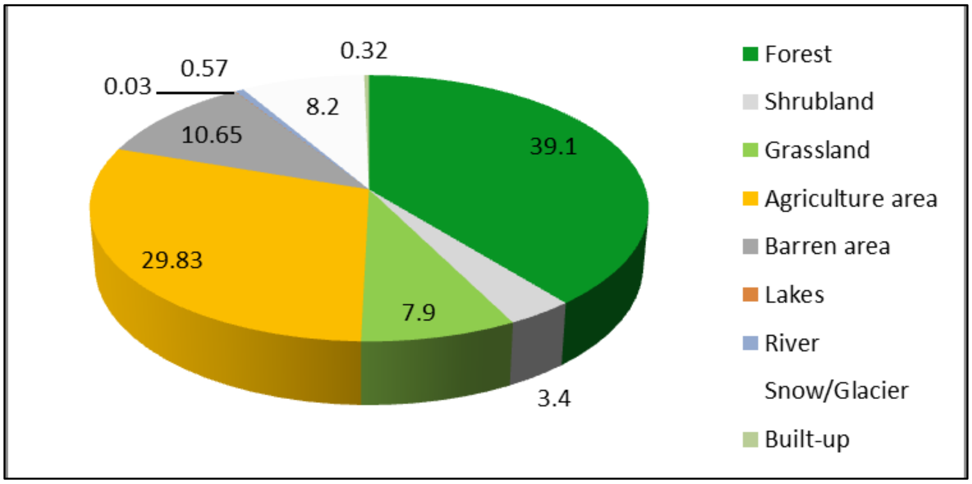
Source: MPFS, 1988

Figure 6: Land-use of Nepal in 1985/86



Source: LRMP, 1986

Figure 7: Land-use categories by Land Resources Mapping Project



Source: Uddin et al., 2015

Figure 8: Land-use categories assessed by ICIMOD under developing land cover database of 2010

3.4 Land cover conversion trend

Land-use and land-cover changes are considered as primary source environmental changes such as emission of greenhouse gases, global climate change, loss of biodiversity, and loss of soil resources (MEA, 2005). In the meantime, forests are vital in addressing these kinds of global concerns. Thus, land cover conversion can be regarded as an important issue in the present scenario.

According to this study, 99.29% of Forests from year 2008 remained intact until 2017/18 (Table 6). Whereas, 0.475 of Forests have been found converted to Other land. Similarly, 96.74% of Cropland from year 2008 remained intact until 2017/18. A greater proportion of Cropland (1.66%) has been noticed converted to Forest in this period. Thus, conversion of land cover has been noticed for all land cover classes except for Settlements in which 100% of its area from year 2008 remained intact.

Table 6: Land cover conversion in the past decade (2008-2017/18)

Land cover conversion (in %)		2017					
		Forest	**Cropland**	**Other land**	**Wetland**	**Grassland**	**Settlement**
2008	**Forest**	**99.29**	0.18	0.47	0.03	0.01	0.02
	Cropland	1.66	**96.74**	0.82	0.14	0.02	0.62
	Other land	0.82	0.06	**98.98**	0.04	0.01	0.09
	Wetland	0.45	0.90	2.04	**96.61**	0	0
	Grassland	3.54	0.32	0	0	**96.14**	0
	Settlement	0	0	0	0	0	**100**

3.5 Consistency check

The bulk dataset (Figure 9) of visually interpreted sample points are the records submitted by the visual interpretation experts (hired temporarily by FRTC). Out of all data, 5% (i.e. 1871 in number) were selected randomly and re-interpreted by an internal expert of FRTC. Consistency check was planned to compare the interpretation results with the sample (5%) points.

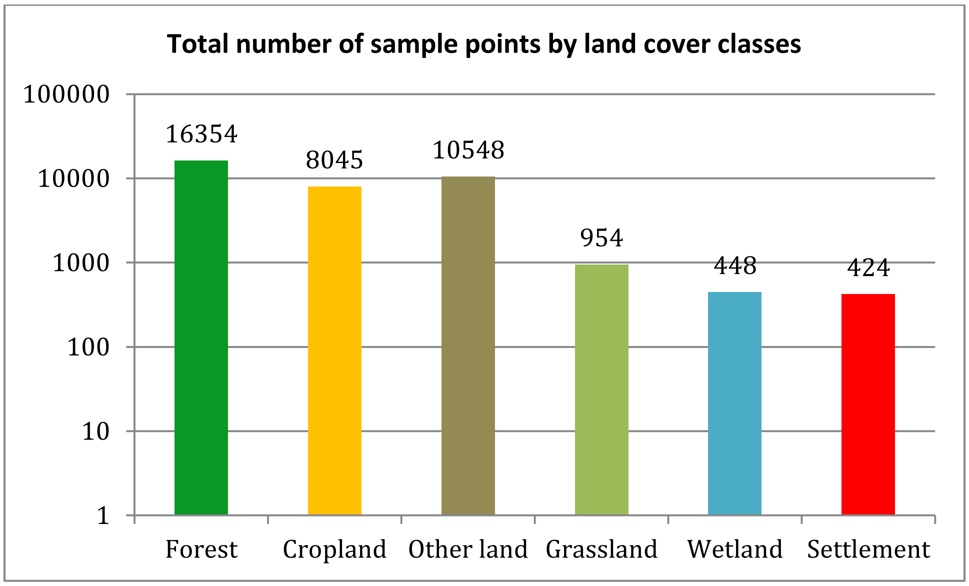


Figure 9: Total numbers of sample points by land cover classes

Interpretation of 5% of the total sample points (1871) selected from the sample point population found that the interpretation of the sample points was highly reliable. The overall consistency of the interpretation of all land use class was found to be more than 98%. Land cover class wise consistencies are presented in Table 7.

Table 7: Consistency checking of visual interpretations

	Expert Interpretations (Consistency Assessment)								
		Cropland	Forest	Grassland	Otherland	Settlement	Wetland	Row Total	Consistency
Original Interpretation	Cropland	438	4	0	1	1	1	445	98.43%
	Forest	2	821	0	1	0	0	824	99.64%
	Grassland	0	0	6	1	0	0	7	85.71%
	Otherland	2	1	5	540	0	1	549	98.36%
	Settlement	0	0	0	1	23	0	24	95.83%
	Wetland	0	1	0	1	0	20	22	90.91%
	Total	442	827	11	545	24	22	1871	

4. Conclusion

This analysis reveals the current status of forest and other different land cover classes. Based on the results derived from this assessment and comparison with the past studies, the calculated results of Forest, Cropland, Settlement and Wetland are reliable for reporting purpose. However, further studies are necessary to generate more reliable results in terms of Grassland and Other land. This is because of difficulty in identifying all the Grassland samples due to unavailability of seasonal imageries in Google Earth. Nevertheless, the methodological difference in the past assessments could also be one of the reasons behind it.

Land cover conversions in the past ten years have not been much significant with respect to the area of individual land cover classes. The higher conversions by area are recorded for Cropland to Forest, Other land to Forest and Forest to Other land by 54.83, 34.30 and 30.82 thousand ha respectively. Migration of people from hills to plains and cities on one hand and abandoning of agricultural land in mid hills and mountains, on the other hand, can be considered a few of the drivers of land cover conversion. However, a detailed study is essential to explore the several factors of land cover conversion.

Finally, the methodology adopted in the analysis of forests and land cover situation of the country can be recognized as a methodology for future monitoring programs. However, further exercises on Google Earth Engine platform are essential to validate the reliability of acquired results for each land cover classes. This will facilitate on the biannual reporting to UNFCCC regarding REDD+ program and every five years reporting to the Global Forest Resource Assessment of FAO in addition to other internal as well as international reporting.

5. Technical challenges and limitations

Opportunities, challenges and lessons learned

Implementation of this program on the broader theme of land use and land cover has enlightened some insights on the relation of forests with other land covers in addition to providing information on the current situation of different land cover of Nepal. Various types of forest cover maps were prepared at different time periods in the past. Those assignments were specified to the mapping of forests and their attributes due to which information on other land cover classes and their mappings were still missing. Thus, this study somehow attempted to supplement the data gaps identified in the previous forest cover maps. Furthermore, a methodology designed and adopted in this study follows the standards and protocols mentioned in IPCC's Good Practice Guidance and OpenForis/Collect Earth of FAO. Thus, a well-defined methodology is developed to assess and monitor land cover periodically that might be considered while performing similar assignments in the future.

The study was envisioned to obtain unbiased estimates of land cover at a national scale. The FAO/IPCC guided different six land cover classes were selected for analysis to facilitate the national requirements of reporting to the international organizations. The present results will be a basis of regular monitoring of forests and other land cover and shall also be a foundation while developing a national land cover monitory system for Nepal.

Visual interpretation of Grasslands, specifically of those sample points acquired during winter seasons, has been a limitation in this study. Assessment of NDVI values for each sample points was not an objective in this study. Most of the samples those could be Grasslands could have been interpreted as snow and ice (Other land) because a large number of the latest updated imageries are from winter and dry periods (Figure 10).

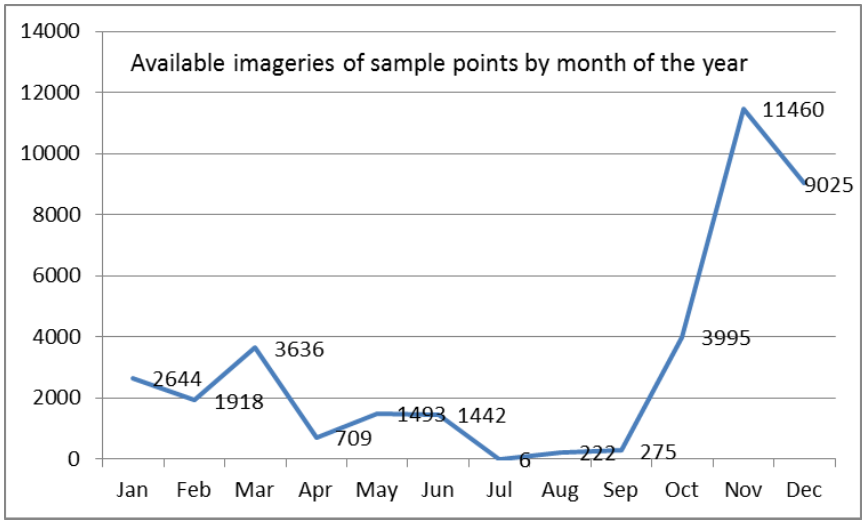


Figure 10: Imageries of sample points available by months of the year

Furthermore, building of a few more levels of primitives for land cover analysis is identified as a lesson learned during the implementation of this study. In addition, a number of sample points (around 550) have been marked as those converted to a different land cover class than those were 10 years before. Though a few of them were visited during the program, most of them are still to be verified and assessed to know the actual causes of conversion. Thus, information on drivers of land use change and land cover conversion is still lacking.

6. Way Forward

This study aimed to analyze national level forests and other land cover. The land cover classification classes were adopted from the *Good Practice Guidance* of IPCC which not only revealed the current status of different land cover classes at the national level but also enabled reporting as per national as well as international commitments. Besides, the six classes of land cover could be considered as the first level primitives for national land cover monitoring system (NLCMS). However, other levels of primitives are also essential to establish a complete dataset for NLCMS to make it compatible and consistent at the regional level. Thus the findings of this study suggest a broader level study to assess the appropriate system and further levels of land cover primitives in addition to assessing the drivers of land cover conversion.

On the other hand, this study has been succeeded to visually interpret around thirty-seven thousands of sample points. The status of land cover along with conversion from the past ten years has been recorded for each of the sample points. In this study period, only a few of the sample points, marked as conversion, were verified at the field level. So, verification of the greater number of the conversion points is essential to identify the several drivers of forests and other land cover conversion.

Besides, the use of conversion points out of all sample points would be helpful to design further studies on *Assessing the Drivers of Land Cover Change* in the near future.

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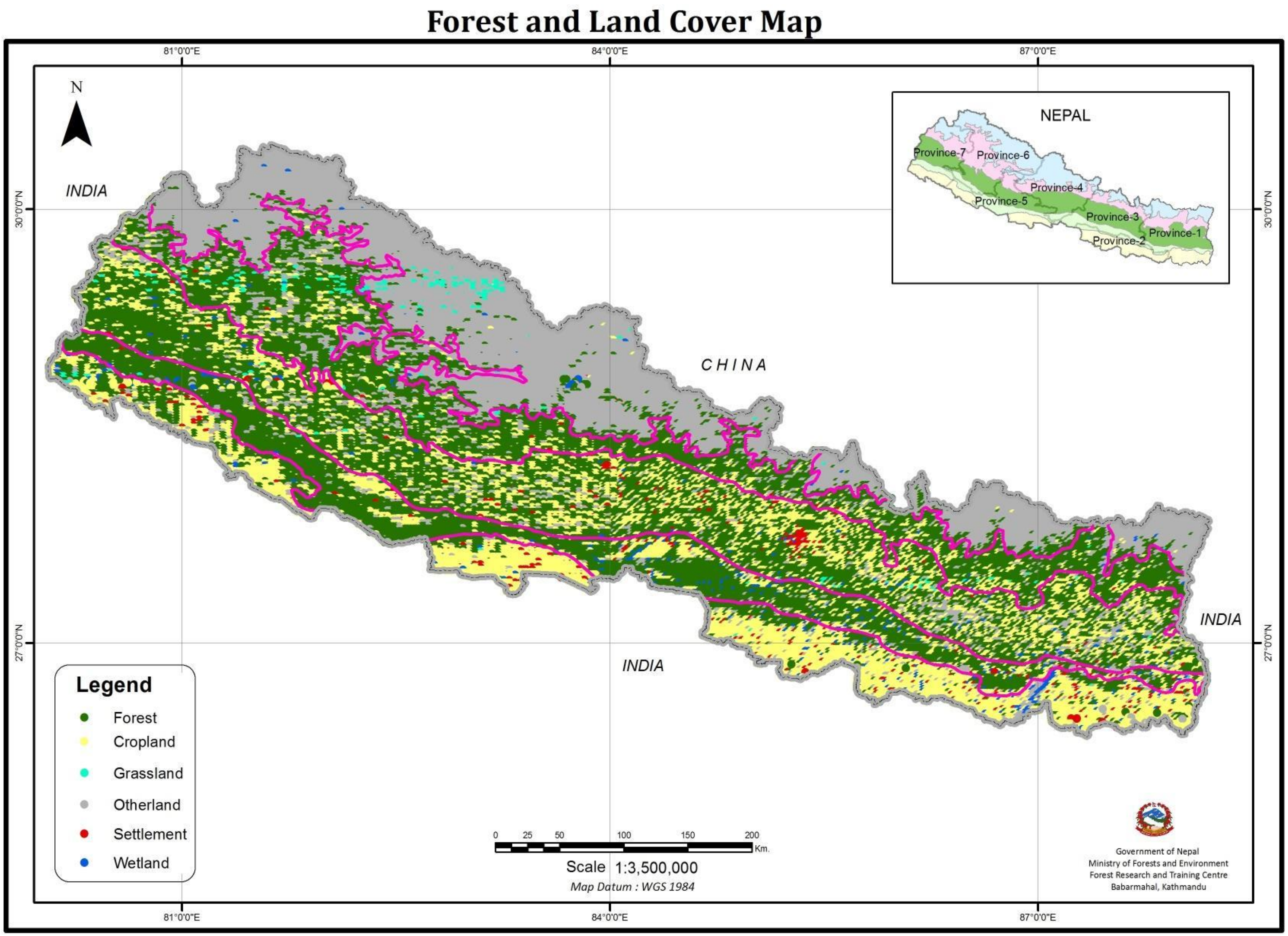
Annex 1: Forest and land cover map



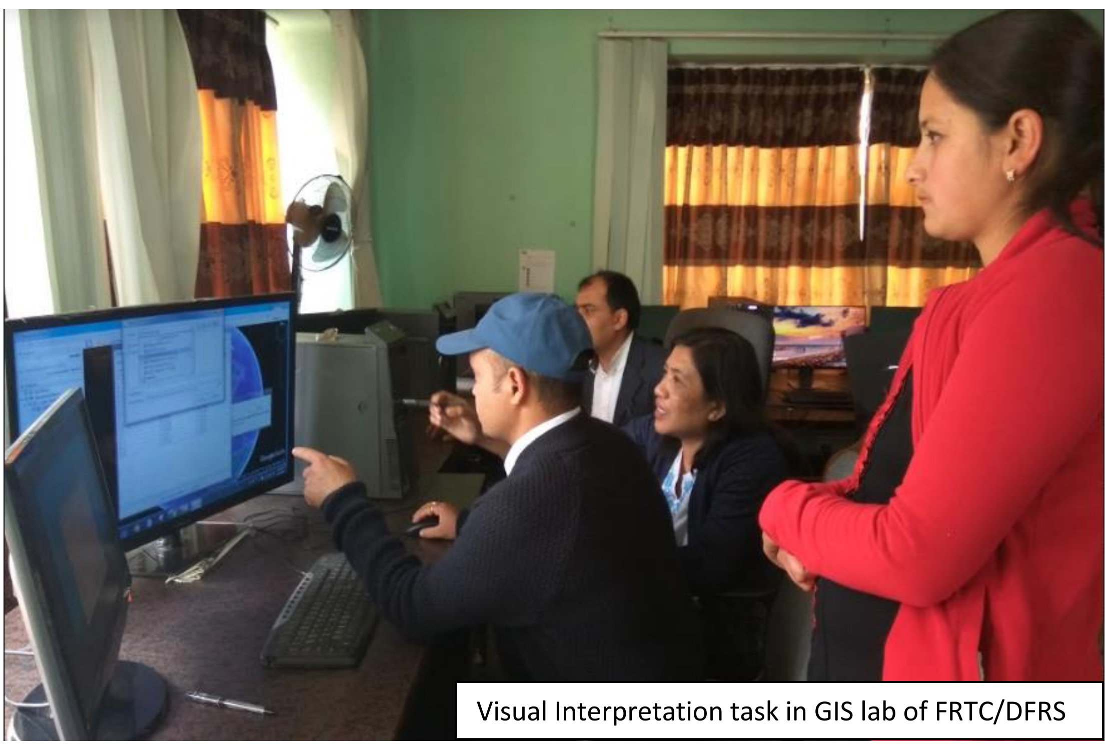
Annex 2: Protocol to facilitate visual interpretations

SN	Land situation	Land cover classes to assign	Remarks
1	Clear cut area within the forests (e.g. Sagarnath forest)	Forest/Other land/Grassland	
	1.1 Area > 0.5 ha (no signs of plantation but grasses visible)	Grassland	
	1.2 Area > 0.5 ha (no signs of the plantation, barren land)	Other land	
	1.3 Area < 0.5 ha (all conditions)	Forest land	
2	Abandoned land at the side of a river	Other land/Grassland	
	2.1 Abandoned land at the side of a river (no sign of grass)	Other land	
	2.1 Abandoned land at the side of a river (signs of grasses)	Grassland	
3	Abandoned land (previously agricultural land); now few tree cover (<10% CC)	Other land	
4	Abandoned land (previously agricultural land); now only shrubs	Other land	
5	Tree cover area having less than 10% crown cover	Grassland	
6	6.1 Shrub area (less than 10 % CC, less than 5m in height)	Other land	
	6.2 Shrub area (fulfilling forest criteria)	Forest land	
7	Pasture land having no vegetation cover (due to the seasonal effect)	Other land	
8	Tree cover area having less than 10% crown cover	Other Wooded Land	
9	Previously Crop Land, now open area (no Crop)	Other land	
10	Previously Water, now open area (no water)	Other land	
11	River bank area without water (only boulder, sand, etc.)	Another land	
12	Seasonal river	Wet land	
13	Previously Tree cover area now open area (no tree)	Other land	

14	Imageries' year to be referenced for visual interpretation		
	14.1 Year of interpreting current land cover status (Imageries of nearby years to be considered in case the images of this year is unavailable)	2017-2018	
	14.2 Year of interpreting the previous land cover status (Imageries of nearby years to be considered in case the images of this year is unavailable)	2008	

Annex-3: Photographs of events

Visual interpretation training for Technicians



Visual Interpretation task in GIS lab of FRTC/DFRS

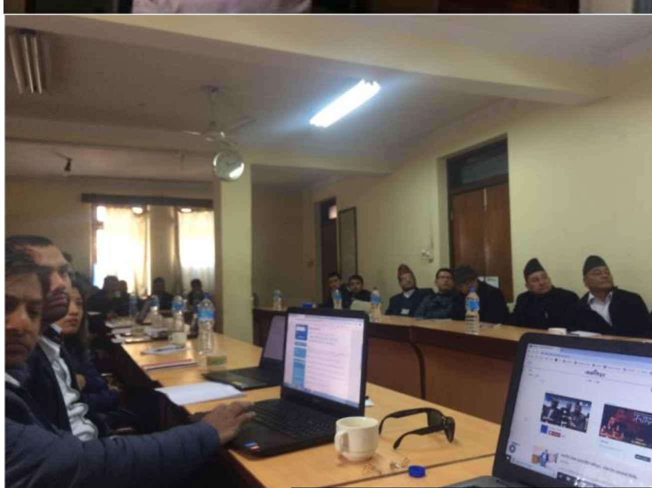
Field Verification site being visited by Deputy Director General

Field Verification: Abandoned cropland is developing into forest land use in a plot in Okhaldhunga

Field Verification: Abandoned cropland in Okhaldhunga district

Field verification: Abandoned house and cropland in High Mountain (Solukhumbu District)




An internal workshop for result sharing of the program

An interaction (final) workshop