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Carbon dynamics in protected area and community managed forest: A study from Banke, Nepal

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Abstract
The management practices affect the carbon stock but there are limited research regarding this. Thus, this research was objectively conducted to assess and compare the carbon stock according to management practice using remote sensing techniques. Community forest, buffer zone community forest and national park in Chure area of Banke district was selected as study site to collect primary data. Landsat 7 ETM+ and one Landsat 8 OLI/TIRS Satellite images dated 2000, 2010 and 2020 were downloaded from USGS website. Altogether 75 sample plots having 12.61, 5.64, 2.82 and 1.87 m radius were established for tree, pole, sapling and seedling respectively. The diameter at 1.3 m and height of the trees were measured. Landsat images were converted to false color composites using bands 5, 4, 3 (for Landsat OLI/TIRS image) and bands 4, 3, 2 (for Landsat TM image). The image was classified using maximum likelihood nearest neighborhood tools. The forest area was increased from 563.06 ha (39.40%) to 613.26 ha (42.92%) in the period of 2000 to 2010 and it reached 647.91 ha (45.34%) in 2020. The Kappa accuracy was 90% of classified map of 2000; it was 85% of 2010 and 87.55% of 2020. The above ground tree/pole carbon stock was found to be highest in Banke National Park with 93.002±15.569 t C ha^{-1} which was followed by buffer zone community forest with 81.744±8.239 t C ha^{-1} and lowest in community forest of with 66.119±10.761 t C ha^{-1} in 2020. The soil carbon stock was found to be highest in National Park with 43.287±5.658 t C ha^{-1} and followed by buffer zone community forest with 31.426±2.072 t C ha^{-1} and lowest in community forest of with 30.924±1.318 t C ha^{-1}. Assuming 10% less carbon in 2000 and 2010, the total forest carbon of 2010 and 2000 would be 70329.64t and 64572.62t and hence total CO_2 equivalent would be 257875.3t and 236766.3t respectively. This paper will be useful tool for scientific community and policy maker to set base line of carbon stock in National park, buffer zone and community forests.

Keywords: Land use land cover change, Chure, Carbon stock

Introduction

The change in land use land cover is the indicator of deforestation which affects the forest carbon but it is difficult to monitor. The remote sensing techniques using the change detection shows change in land use and land cover and their effect on carbon stock. Changes in land cover have a direct effect on carbon sequestration in vegetation cover with an influence on climate on a continental scale (Schulp *et al*., 2008, Sharma & Kakchapati, 2018) [27, 28]. There are several researches regarding this to evaluate the carbon stock change using different types of remote sensing techniques. Global deforestation is challenging one and the remote sensing techniques are used to assess and monitor the carbon stock. Even, the remote sensing techniques are used to assess the forest degradation as well. Land cover has a direct effect on Carbon stock (Mahmod *et al*.,2010, Ishtiaque *et al*., 2017, Mauya *et al*., 2019) [17, 22]. The deforestation and forest degradation affect the carbon stock in the forests (Ray *et al*., 2011, Ghimire, 2017) [25, 13]. Tropical deforestation is alarming and consequence is lowering the carbon stock. India, Bhutan, Pakistan and Sri Lanka are facing the serious problem of deforestation and forest degradation and so as Nepal. Chure range is distributed from low hill from Indus River in Pakistan in the west throughout the length of Nepal until it reaches Bramhaputra River in India in the east. The Chure-Terai Madhesh landscape region is ecologically diverse and so carbon stock is also diverse. This region is environmentally degraded and structurally weak and fragile due to deforestation, forestland fragmentation and encroachment, rural road construction, overgrazing, forest fire, cultivation on the steep slopes, and soil erosion (Editor., 2015) [9]. Terai region geographically consists of Chure, Bhabar, and Plain areas of Nepal (Acharya *et al*., 2019) [1] which is one of the country's most fragile landscape with friable soils, high vulnerability to various natural hazards such as extreme heat, water scarcity, wildfires, flooding, and landslides (DFRS, 2014) [7]. The researched are limited in Nepal particularly in Chure areas of Banke district. The existing practice of unmanaged cultivation, deforestation, improper use of agrochemicals, unmanaged and unscientific construction of roads, buildings, and excessive sand and stone quarrying are some of the anthropogenic activities leading to soil erosion and landslides, which ultimately influence negatively on forest carbon. The studies on land use land cover change generally been conducted in different areas but specifically research on the effect of land use land cover change on forest carbon was a major gap. After the establishment of Banke National park, the study regarding the Chure area is less. Realizing this gap, the current study is felt to be very important. Thus, this research was objectively conducted to assess the effects of land use and land cover changes on forest carbon in community forest, buffer zone community forest and national park in Chure area of Banke district, Nepal.

Materials and Methods

Study Area: The Chure area of Banke district is situated between 81°39'29" to 82°12'19"E latitude and 27°58'13" to 28°21'23"N longitude in the Terai region, a part of Province No. 5 in the mid-western part of our country Nepal. Chure covers the area 37.8% of Banke district which is also the part of Banke national park with three climatic zones namely Lower Tropical with elevation range below 300m covering an area of 79.1%, Upper Tropical climatic Zones with elevation range 300-1000m covering an area of 20.6% and Sub-Tropical with elevation range 1000-2000m covering an area of 0.3%. Chure hills are rugged, which are deeply dissected by gullies and streams. Escarpments and ant-dip steep slopes are common slope features as evidence of geological control and erosion. Chure hill slopes are generally dry and have poor soil development. Within the Chure range there exist several notable inner river valleys comprising small flood plains and river terraces of two or three tiers at some east-west sections. Average Temperature ranges between 39 °C to 6°C whereas average rainfall is around 1362mm.

Total area of the Banke district is 233700 ha in which 80871.1 ha area is covered by the Chure area. According to the report presented by division forest office Banke, forest land cover about 132959 ha, Agriculture land covers about 92068 ha, Shrubs land covers about 5375 ha, barren land covers about 2337 ha and other land covers about 931 ha. There is about 119939.74 ha forest area in Banke district. Out of this, 62200.68 ha (51.86%) is under Banke National Park and remaining 57739.06 ha (48.14%) is under National Forest. Similarly, there are 119 Community Forests (CFs) and 53 Buffer Zone Community Forest (BZCF). According to Land Resource Mapping Project, Chure Forest is divided into three types as Hardwood, Mixed forest, and Shrubs. Mainly Sal (*Shorea robusta*) (Tropical Mixed Hardwood/Sal) is the main Species in Banke District whereas Khayer (*Acacia Catechu*), Sissoo (*Dalbergia sissoo*) are the species found near the river. Major non timber forest species includes Kurilo (*Asparagus racemosus*), Bel (*Aegal marmelos*), Barro (*Terminalia bellerica*), Harro (*Termenalia chebula),* Amala (*Phylanthus emblica*), Simal (*Bombax ceiba*) etc. (DFRS, 2014) [6]. The Chure area of the Banke district holds major wild-life animal species such as Tiger (*Panthera tigris*), *four-horned antelope* (*Tetracerus quadricornis*) etc.

The study sites are Rapti Sonari Rural Municipality situated in the Chure region of Banke district which is around 500 km from Kathmandu valley. Eastern part of Kusum Area, Sati Bhawani Community Forest, Kusmeshower Buffer Zone Community Forest, and part of Banke National Park have been selected for the research study through consultation with President Chure Terai Madhesh Conservation Development Board and Division Forest Office (DFO) (figure 1).

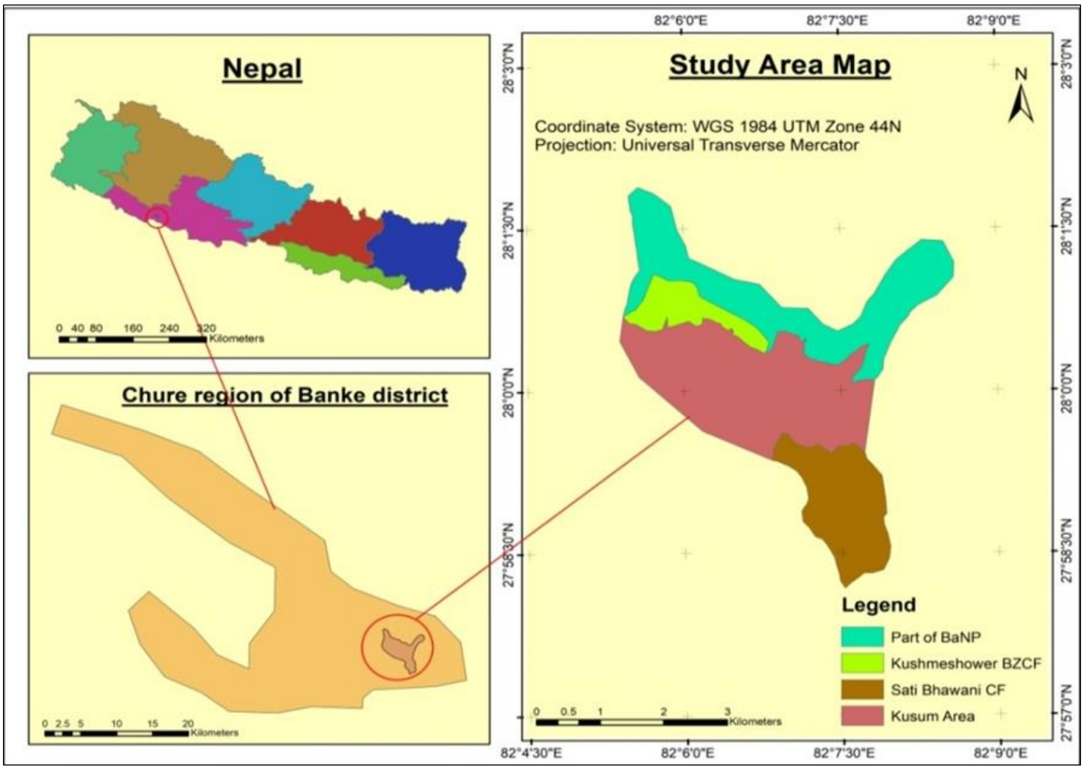


Fig 1: Map of Study Area

Sati Bhawani community forest: The community forest is located in the Chure region of Banke district. It was formally handed over to the users of Rapti Sonari rural Municipality-9 in 2063 BS by Divisional Forest Office, Banke. The community forest executive committee consists, 13 members, of which 2 members are female. There are 59 households in the community forest. It occupies 303.9 ha of land area and is divided into 2 Blocks which is again re-divided into 18 compartments. The altitude of the Sati Bhawani community forest ranges from 318 m to 464 m from the mean sea level. The slope varies from 15 to 45 degrees. The soil of this forest is the moist and loamy type and its color is black, yellow, and red. The tree species of this community forest is Sal (*Shorea robusta*), Saj (*Terminalia tomentosa*), Dhauti (*Anogeissus latifolia*), Jamun (*Syzygium cumini*), Sindure (*Mallotus philippensis*), Piyar (*Bauchenia latifolia*), Budhdhairo (*Lagestomia praviflora*), etc. The major non-timber forest species are Parijat (*Nyctanthes arbor-tristis*), Amala (*Phyllanthus emblica*), Barro (*Terminalia bellerica*), Harro (*Termenalia chebula*), Bel (*Aegal marmelos*), Kurilo (*Asparagus racemosus*), etc. Sati Bhawani community forest is also enriched with animal diversity as this community forest lies near the Banke National Park e.g. Tiger (*Panthera tigris*), *four-horned antelope* (*Tetracerus quadricornis*), etc.

Banke National Park: Banke National Park (BaNP) is the newest protected area of Nepal established on 12th July 2010 which covers many parts of the Chure region. BaNP extends over 550 square kilometers in Banke district and its buffer zone consists of 343 square kilometers which encompass parts of Banke, Dang, and Salyan districts. The Park is adjoining to the Kamdi corridor that joins Suhelwa Wildlife Sanctuary in India through national and community forests towards the south. It is connected with Bardia National Park (BNP) towards the west which further links with Katerniaghat Wildlife Sanctuary in India via the Khata corridor. The establishment of this park for the conservation of wild tigers, and endangered wildlife species, reflects the commitment of the Government of Nepal towards biodiversity conservation at the landscape level. The vegetation in Banke National Park is composed of at least 113 tree species, 107 herbal species, and 85 shrub and climber species. Common species include Sal (*Shorea robusta)*, Bhalayo (*Semecarpus anacardium*), Khair (*Acacia catechu)*, Sajh (*Terminalia alata)*, etc. The protected area holds Tiger (*Panthera tigris*), *four-horned antelope* (*Tetracerus quadricornis*).My study area falls in the eastern part of the BaNP.

Buffer Zone Area: This area is located in the periphery of Kusum belt in which Kusmeshower Buffer Zone Community Forest lies which was also the representation of the Chure area. It was formally handed over to the users of Raptisonari Rural Municipality-9 in 2072 BS by Banke National Park. The BZCF executive committee consists, 13 members, of which 2 members are female. There are 63 households in the Buffer Zone Community Forest. It occupies 29.51 ha of land area. The tree species of this Buffer Zone Area is Sal (*Shorea robusta*), Saj (*Terminalia tomentosa*), Dhauti (*Anogeissus latifolia*), Jamun (*Syzygium cumini*), Sindure (*Mallotus philippensis*), Piyari (*Bauchanania latifolia*), Budhdhairo (*Lagestomia praviflora*), etc. The major non-timber forest species are Amala (*Phyllanthus emblica*), Barro (*Terminalia bellerica*), Harro (*Termenalia chebula*), Bel (*Aegal marmelos*), Kurilo (*Asparagus racemosus*), etc. Sati Bhawani community forest is also enriched with animal diversity as this community forest lies near the Banke National Park e.g.Tiger (*Panthera tigris*), *four-horned antelope* (*Tetracerusqu adricornis*) etc.

Research design

Data Collection: Primary and secondary data were collected. In addition to these spatial data was also collected to analyze the effect of LULC on forest carbon. Primary data were collected from field observation, direct measurement, key Informant Interviews, laboratory analysis while the secondary data and information were collected from internet surfing, books, reports, journals, and community forest operational plans to meet the research objectives.

Two Landsat 7 ETM+ and one Landsat 8 OLI/TIRS Satellite images dated 2000, 2010 and 2020 were used to find a change between these periods. Both satellite images were downloaded from the United States Geological Survey (USGS) official website (https://earthexplorer.usgs.gov/) (Table 1) Priority was given to the data with less cloud cover and sensor noise, and at the same time attention was made for acquiring images with smaller seasonal variations.

Table 1: Details of Landsat Image

WRS (Path/Row)	Scene ID	Sensor	No. of Bands	Spatial Resolution	Acquired Date
Path = 143 Row = 41	LE71430412000085SGS00	Enhanced Thematic Mapper	7	30*30	2000/03/25
Path = 143 Row = 41	LE71430412010112SGS00	Enhanced Thematic Mapper	7	30*30	2010/04/22
Path = 143 Row = 41	LC81430412020068LGN00	Operational Land Imager and Thermal Infrared Sensor	11	30*30	2020/03/08

Total 75 GPS coordinates using a spatial reference system of WGS 84/UTM Zone 44 were collected in the field to train the maximum likelihood algorithm for properly supervised classification of 2000, 2010, and 2020 Landsat image. Some of the collected GPS coordinates were also used for the ground trothing during accuracy assessment. Also, GPS was used in study area demarcation and Inventory plots assessment. Google earth was used for the selection of the study site, including its “historical imagery” function, classification, and accuracy assessment of Landsat images. It was also used to download images of the study area and extract different features on the ground. Besides the above-mentioned sources, digital datasets were also used. They were used to delineate the study area, construct study area location map, and subset (clip) Landsat images, and Google earth images. All these data used were based on

World Geodetic System 1984 (WGS 84) with Universal Transverse Mercator projection (UTM) Zone 44. Direct Field Observation was carried out during the reconnaissance survey to get information about possible LULC classes and in which the study area can be classified. It was also done to speculate the location of areas having topographic shadows and cross-check the spatial information provided by the local people during the Key-informant interview.

Sampling Procedure: Stratified random sampling was applied based on management regime to collect biophysical and soil data. Altogether 75 Training Sample was taken for land use land cover class, 75 for the above-ground biomass and 75 Soil sample for the below-ground biomass. A circular plot was applied for the study because of its easiness of layout especially in sloping terrains and also to reduce the edge effect problem that normally occurs in rectangular plots. According to CFUG guideline (2003), the sample plot having 12.62 m radius was established for a tree, plot of 5.58 m radius was established for pole, plot of 2.78 m radius was established for Sapling, a plot of 1.76 m radius was established for an above ground seedling measurement and 0.56m radius plot for LGH.

Aboveground and below ground biomass: The diameter at breast height (DBH) at 1.3m height and height of individual tree greater than 10cm DBH were measured within 8.92 m radius using diameter tape, starting from the edge and working inwards, marking each tree as to prevent accidental double counting. Meanwhile, the height of the trees was measured using Criterion. Sub-plots having a 5.64 m radius inside the tree plots were established for saplings height, diameter and weight measurement. Smaller nested subplots having 1 m radius inside the plots were established for regeneration. Total no of sapling and seedling from these sub-plots were weighed and measured. Smaller nested subplots having 0.56 m radius inside the plots were established and LHG inside the sub-plot were collected, weighed and measured. The soil samples from different places at depth 0-10 cm, 10-20 cm, and 20-30 cm were collected in the soil core sampler of known volume and placed in the labeled sample bag. The collected samples were brought to the laboratory to determine the carbon content. Fresh Weight was taken to measure the bulk density. The soil samples were oven air-dried at air temperature in the laboratory to estimate the soil organic carbon content.

Social Data: To get information about the past LULC status and to understand what residents of the study area think of the ongoing LULC change, the driving forces behind those changes, and the impacts of the change, Key-Informant Interview (KII) was conducted. The key Informants were Assistant-Warden and Rangers from Banke National Park, President of Community Forest, President of Buffer Zone Community Forest, and Local Leader from Study Area who have been living in the area for an extensive period. KIIs were exclusively unstructured and all the questions were exclusively open-ended and Close-ended. This nature of conversation allows for spontaneity and for questions to develop during the interview, which are based on the interviewees' responses.

Data Processing and Analysis: The processing and analysis of Landsat images, GIS Data and Forest/Soil Inventory were done using ERDAS (Earth Resources Data Analysis System) Imagine 2015, SPSS (Statistical Package for the Social Science) tool, and ArcMap 10.2.1, also all the numerical data were analyzed using MS Excel for data entry and to interpret the numerical results into bar-graphs, charts, and tables also, SPSS was used for statistical analysis.
Layer stacking was done for combining multiple images into a single image. To have the same extent (number of rows and number of columns), which resample other bands which have different spatial resolution to the target resolution. The study area was sub-set from the three Landsat images using the Area of Interest (AOI) file having the delineated study area; by the application of subset tool in ERDAS IMAGINE 2015. The Landsat 7 TM+ image 2010 had Scanned line error. By using the focal analysis tool in ERDAS Imagine 2015 Scanned line error have been removed, in which overlapping of the image have been done. Image enhancement was done to improve the visual interpretability of features in the scene. Image enhancement tools in ERDAS IMAGINE 2015 such as General Contrast, and Brightness were used. To assist in the image classification process, Landsat images were converted to false-color composites using bands 5, 4, 3 for Landsat OLI/TIRS image and bands 4, 3, 2 for Landsat TM+ image.

Image Classification: First of all, Signature files were created from the training samples for all the classes and Supervised Classification was performed using the maximum likelihood classifier in ERDAS IMAGINE 2015. The maximum likelihood classifier is one of the most popular methods of classification in remote sensing, in which a pixel with the maximum likelihood is classified into the corresponding class (Sisodia *et al*., 2014) [30]. The study area was classified into the 4 LULC classes (Forest, Agriculture, Water Body, and Bare land).

Change analysis: The classified images were imported in ArcMap 10.2.1 and the area of each class was computed using the "Zonal geometry as Table" tool in Spatial Analyst Extension. Also, the LULC conversion table (Table showing the quantity of one LULC converted into other over three periods) was computed using the "Tabulate Area" tool in Spatial Analyst Extension.

Rate of change in land use and land cover
The following formula was used to compute the rate of change of land cover and land use in the study area.

Rate of change (%) = $[(a_2/a_1)1\ /n - 1] \times 100$ (FAO, 1995) [11]

Where,
a_1 = base year data
a_2 = End year data
n = no. of years

Accuracy Assessment: An accuracy assessment was carried out using the kappa coefficient. The percentage of agreement gained after eliminating the percentage of agreement that could occur by chance is the kappa coefficient; it lies on a scale between 0 and 1 where 1 represents a complete agreement.
Kappa statistic was computed as;

$K = N\sum^{r}_{i=1} X_{ii} - \sum^{r}_{i=1} (X_i * X_{x+1}) / N^2 - \sum^{r}_{i=1} (X_i * X_{x+1})$ (Cohen, 1995) [5]

Where;
r = number of rows and columns in error matrix,
N = total number of observations (pixels)
X_{ii} = observation in row i and column i,
X_{x+i} = marginal total of row i, and X_{x+i} = marginal total of column i

Aboveground Tree/Pole/Sapling Biomass Calculation: AGTB = 0.0509 x $\rho D^2 H$ (Chave *et al*., 2005) [4].

Whereas,
AGTB = above ground tree biomass (kg)
ρ = dry wood density (gm/cm^3)
D = tree diameter at breast height (cm)
H = tree height (m)

After taking the sum of all the individual weights in kg of a sampling plot and dividing it by the area of a sampling plot (m^2), the tree biomass stock was attained in kg/m^2. This value was converted to t/ha by using the unitary method.
Above ground sapling/Seedling biomass calculation: To determine the aboveground sapling/seedling biomass fresh weight was taken from the sample plots.
Litter, Herbs and Grass Biomass (LHGB) calculation:
LHG = (W field /A) × (W sample, dry/W sample, wet) × 1/10000
Where, LHG= Biomass of leaf litter, herbs, and grass (t/ha)
W field = weight of the fresh field sample of leaf litter, herbs, and grasses, which was sampled destructively within the given area in (g)
A = size of the area in which leaf litter, herbs, and the grass was collected (ha);
W sample, dry = weight of the oven-dry sub-sample of leaf litter, herbs and grasses that was taken to determine moisture content (g); (Approximately 40% of the fresh weight)
And W sample, wet = weight of the fresh sub-sample of leaf litter, herbs, and grasses that was taken to determine moisture content (g)
Below ground tree/pole carbon stock: Below ground biomass was estimated as 25% of aboveground tree/pole biomass (Mac Dicken, 1997) [20].

Soil organic carbon: The soil samples were analyzed by Walkley Black Method (Walkley & Black, 1958) [33] by digestion using Sulphuric acid and oxidized by the Potassium dichromate in the laboratory. The soil samples were oven-dried at room temperature in the laboratory for 3 days to remove moisture from the sample.
The bulk density of the soil sample was calculated for each soil depth for which soil carbon was estimated. Then, oven-dried soil samples were divided by its volume to estimate bulk density.
For the calculation of soil organic carbon (SOC), the following formula was used (Chabbra et. al, 2002).
Bulk Density (gm/cm^3) = (oven-dry weight of soil) / (volume of soil in the core).
SOC= Organic Carbon Content % * Soil Bulk Density (gm/cm^3)*thickens of the horizon and was expressed in tons per ha.
Whereas, SOC = soil organic carbon stock per unit area (t/ha), % C = carbon concentration
ρ = soil bulk density (gm/cm^3) & d = total depth at which the sample was taken (cm)
Default value i.e. root shoot ratio 0.125 was used (IPCC, 2006) to calculate the root biomass. The root shoot ratio of 0.125 was multiplied in the above-ground biomass for the biomass of root.
Similarly, the universal conversion factor generally, 0.47 was used to convert dry biomass of tree, pole, sapling, regeneration, herbs, litter, grasses, and dead wood into carbon content (Andreae & Merlet, 2001) [2].
Total Carbon Stock
C (TB) = C (AGTB) + C (AGSB) + C (BB) + C (LHG) + SOC
Whereas, C (TB) = Total Carbon Stock Biomass (t C/ha),
C (ABTG) = Carbon in above ground tree biomass (t C/ha)
C (AGSB) = Carbon in above ground sapling/Seedling biomass (t C/ha)
C (BB) = Carbon in below ground biomass (t C/ha)
C (LHG) = Carbon in litter, herb and grass (t C/ha)
SOC = Soil Organic Carbon (t C/ha)
Effect of land use land cover change on Forest Carbon: Carbon stock of 2000 and 2010 cannot be calculated because of unavailability of past record of filed measurement. Thus different scenario was assumed to estimate the effect of land use land cover on forest carbon stock.

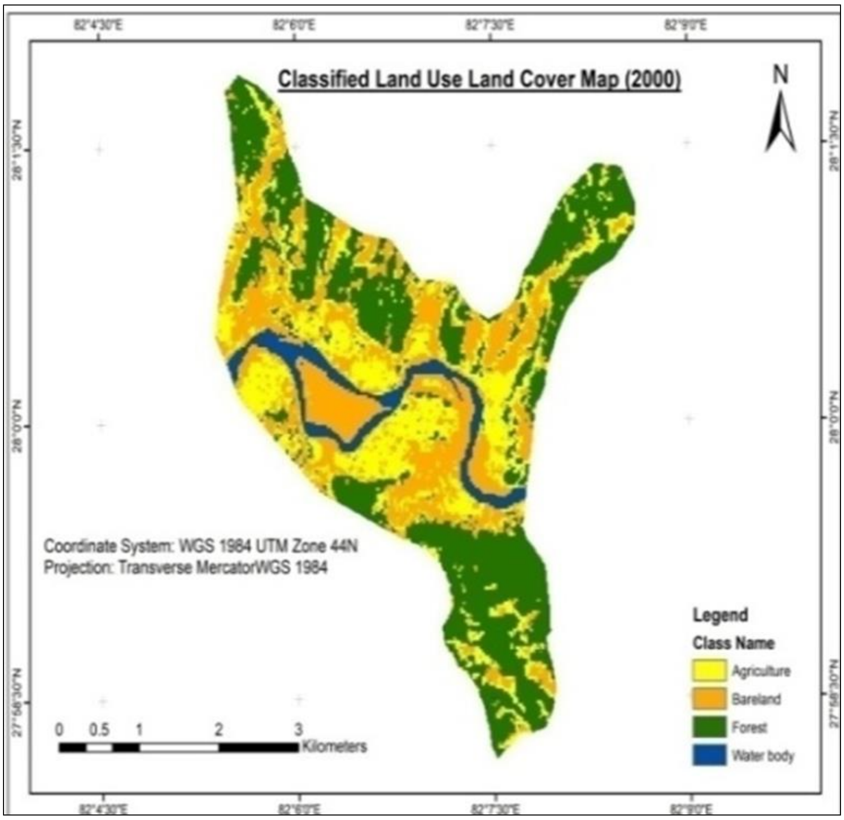
Estimation of forest carbon based on business as usual scenario
The present carbon stock is estimated based on the field data of 2020. For the estimation of carbon stock of 2000 and 2010 the following formula was used.
Carbon stock of 2000
Carbon stock of 2000 = Carbon stock t/ha of 2020* Forest area of 2000 Co_2 equivalent of 2000 = Carbon stock of 2000 *44/12 (IPCC, 2006)
Carbon Stock of 2010
Carbon stock of 2010 = Carbon stock t/ha of 2020* Forest area of 2010
CO_2 equivalent of 2010 = Carbon stock of 2010 *44/12
(Mac Diken, 1997)
Effect of land use land cover change on Forest Carbon Stock. Total carbon stock of 2020- Total carbon stock of 2000 Total carbon stock of 2020- Total carbon stock of 2010

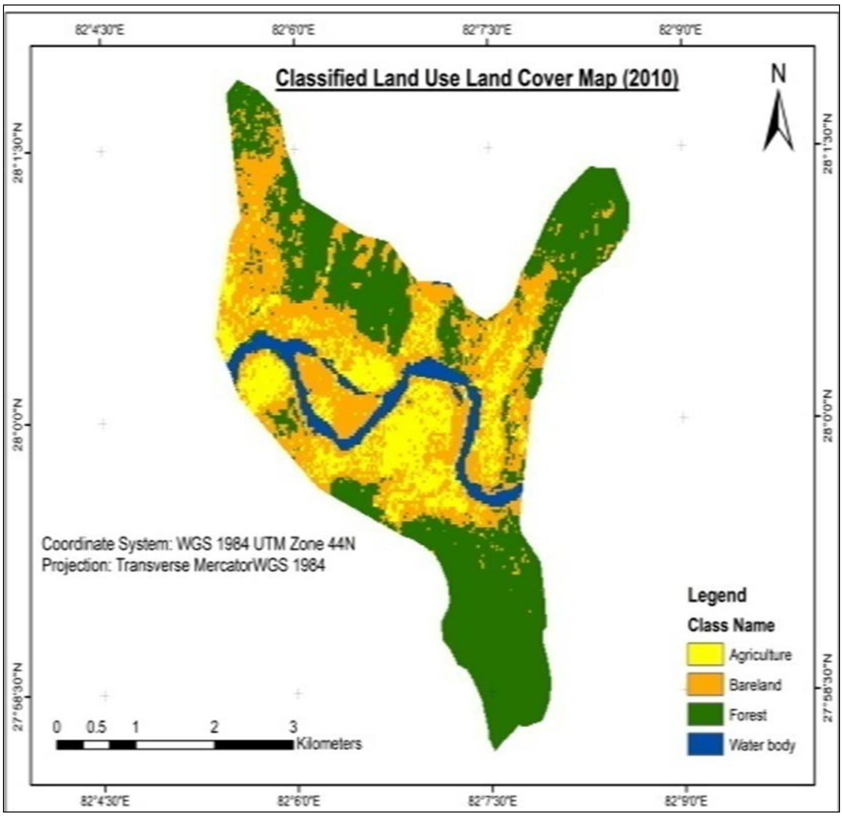
Result and Discussion

Image Classification of Chure Area in Banke district of year 2000, 2010 and 2020: The image classification of 2000 revealed that 39.40 percent of total land was covered by forest which was the major land cover type in the study area, whereas Agriculture occupying 23.78 percent was the major land use. Bare land and water occupied 31.30 percent and 5.50 percent respectively. Similarly, the image classification of 2010 showed that forest remains the major land cover type covering 42.92 percent of total land. Similarly, Agriculture is still the major land use occupying 16.34 percent. Bare land and water cover 34.52 percent and 6.20 percent respectively; in the year 2020 also Forest remains the major land cover occupying 45.34 percentages whereas Agriculture remains the major land use occupying 24.45 percentages. Bare land and water occupied 24.91 percent and 5.28 percent respectively (Table 2, figure 2).

Table 2: Land use and land cover status of 2000, 2010 and 2020

SN	LULC Classes	LULC Status in the year 2000		LULC Status in the year 2010		LULC Status in the year 2020	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
1	Forest	563.061	39.400	613.262	42.921	647.914	45.341
2	Agriculture	339.812	23.781	233.543	16.343	349.401	24.452
3	Bare land	447.261	31.302	493.314	34.522	355.982	24.911
4	Water body	78.541	5.501	88.581	6.204	75.501	5.281
Grand Total		1429	100	1429	100	1429	100





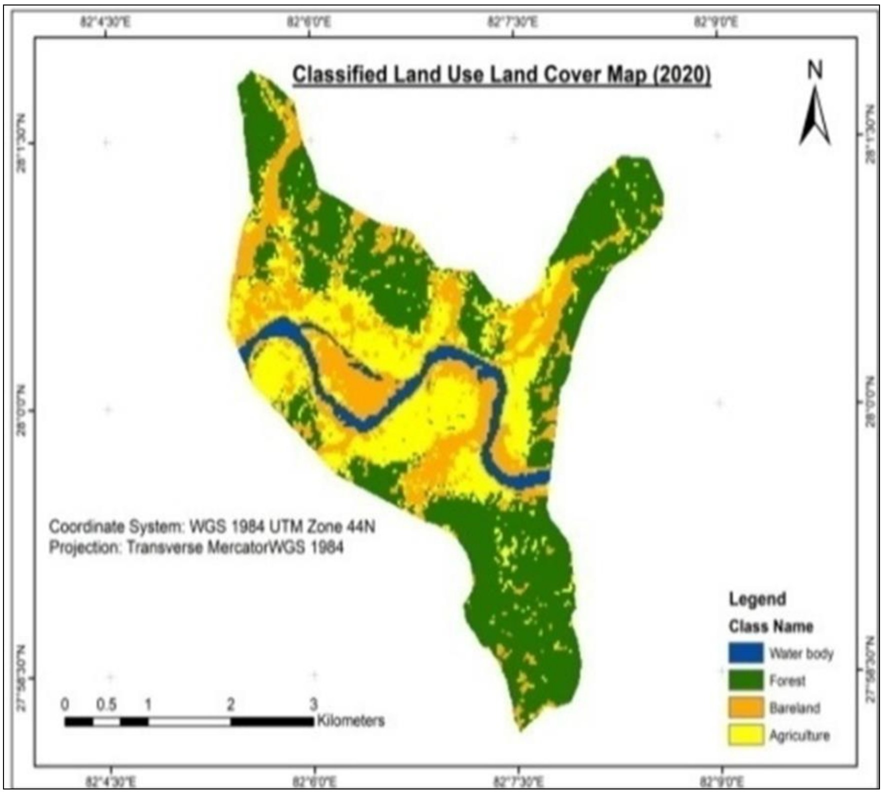


Fig 2: Thematic map of 2000, 2010 and 2020

Kappa coefficients were 0.8667, 0.800 and 0.833 of classified map of 2000, 2010 and 2020. (Table 3). The Accuracy was 90% of the classified map of 2000, 85% of 2010 and 87.55% of 2020.

Table 3: Accuracy assessment of thematic map

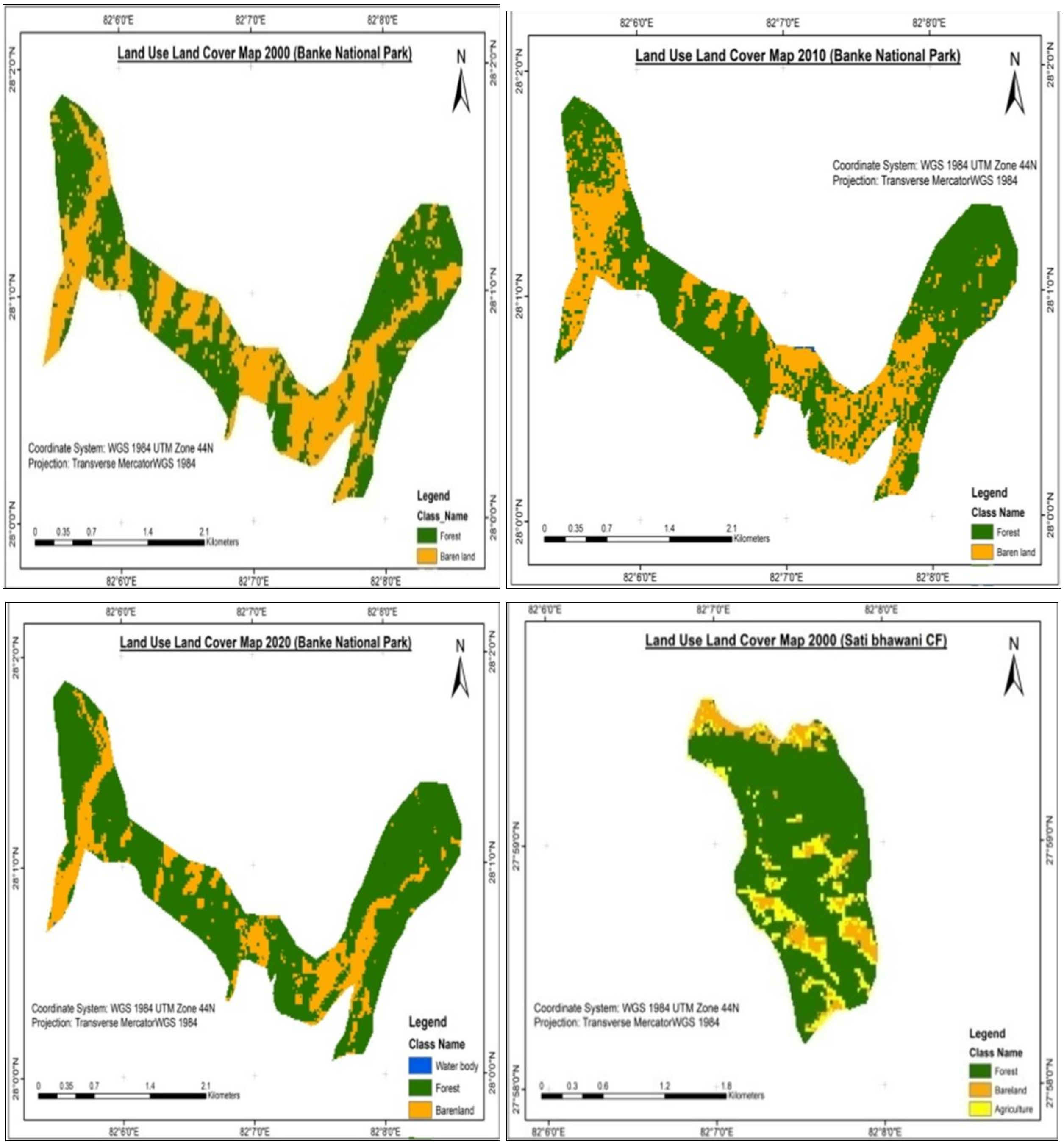
Accuracy Assessment 2000					
Class Name	Totals Reference	Totals Classified	Correct Number	Producer's Accuracy	User's Accuracy
Bare land	10	12	9	90.00%	75.00%
Forest	10	10	10	100.00%	100.00%
Water body	10	8	8	80.00%	100.00%
Agriculture	10	10	9	90.00%	90.00%
Totals	40	40	36	**Overall Accuracy=90.00%**	
Kappa Coefficient=0.8667					
Accuracy Assessment 2010					
Class Name	Totals Reference	Totals Classified	Correct Number	Producer's Accuracy	User's Accuracy
Agriculture	10	13	9	90.00%	69.23%
Forest	10	10	10	100.00%	100.00%
Water body	10	9	9	90.00%	100.00%
Bare land	10	8	6	60.00%	75.00%
Totals	40	40	34	**Overall Accuracy=85.00%**	
Kappa Coefficient=0.800					
Accuracy Assessment 2020					
Class Name	Totals Reference	Totals Classified	Correct Number	Producer's Accuracy	User's Accuracy
Forest	10	11	10	100.00%	90.911%
Bare land	10	11	8	80.00%	72.732%
Agriculture	10	10	9	90.00%	90.00%
Water body	10	8	8	80.00%	100.00%
Totals	40	40	35	**Overall Accuracy=87.500%**	
Kappa Coefficient=0.833					

Status of LULCC in Different Management Regime at Different Period (2000, 2010 and 2010)

In Banke National Park over the change in the period, forest area was increased. In which in 2000 the forest area was 274.088 ha but in 2010 it was increased up to 288.721 ha. Similarly in 2020 also it was increased up to 339.007 ha. In Sati Bhawani Community Forest in 2000 the forest area was 197.825 ha but in 2010 it was increased up to 244.873 ha but in 2020 it was decreased up to 236.416 ha whereas, Agriculture land was decreased in 2010 and again increased was seen in 2020. Similarly certain change was observed in the water and barren land. In Buffer Zone area, forest was decreased in from 2000 to 2010 i.e.108.999 ha to 104.007 ha whereas it was increased from 2010 to 2020 i.e. 104.007 ha to 119.156 ha (Figure 3 & table 4).

Table 4: Land use and land cover status of different management regimes (2000, 2010 & 2020)

LULC	Banke National Park:			Sati-Bhawani Community Forest			Buffer Zone Area		
	2000	2010	2020	2000	2010	2020	2000	2010	2020
Forest (ha)	274.09	288.72	339.01	197.83	244.88	236.42	108.99	104.01	119.16
Bare Land (ha)	170.29	155.82	105.45	35.113	21.364	24.662	298.35	310.33	241.11
Water Body (ha)	0.057	0.017	0.067	0	0	0	80.485	89.502	75.222
Agriculture (ha)	0	0	0	36.699	3.822	9.280	226.657	210.533	278.295
Total (ha)	445	445	445	270	270	270	714	714	714



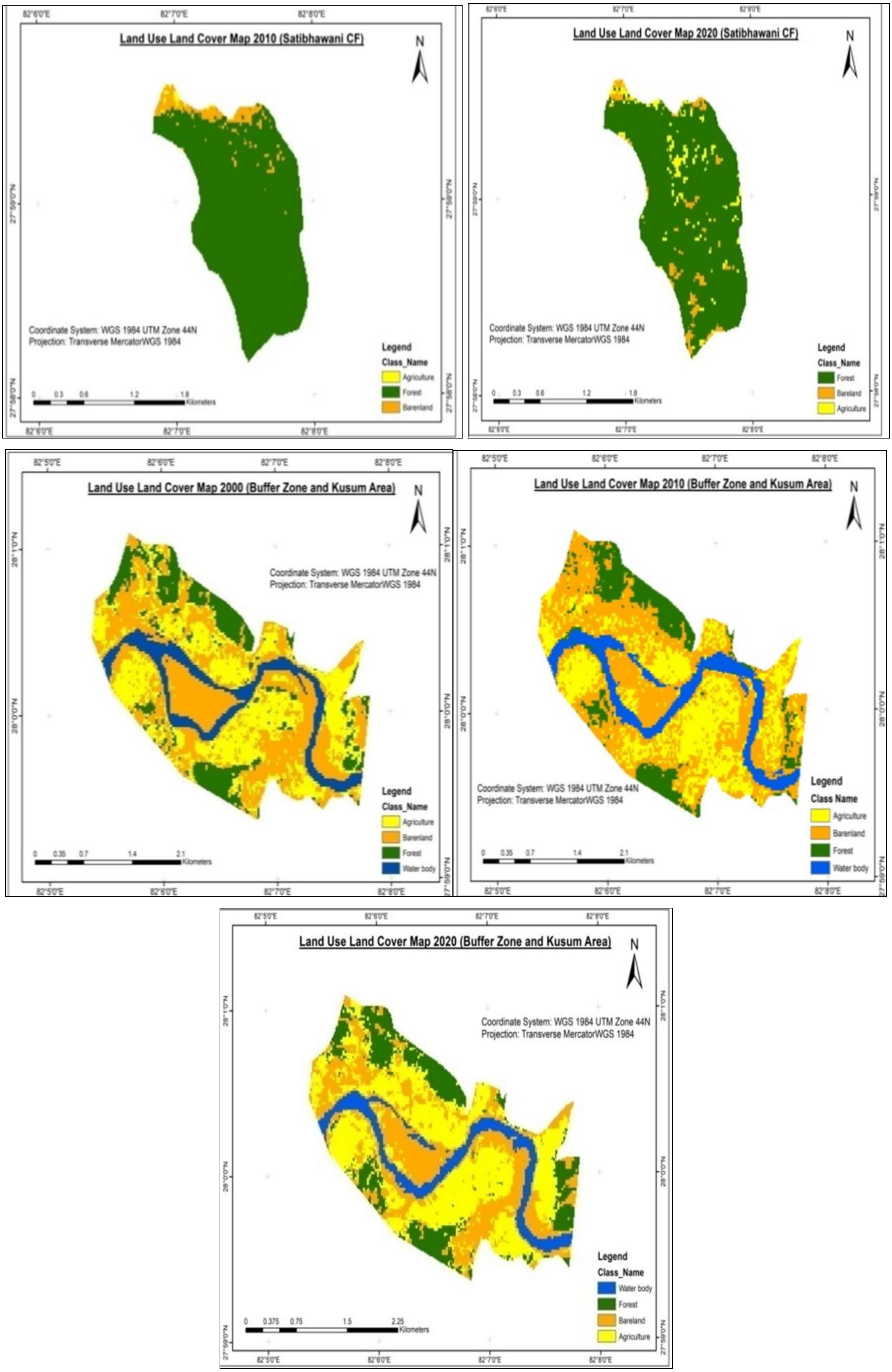


Fig 3: Land use land cover map of different forests (2000, 2010 & 2020)

Change detection of land use land cover change between 2000 and 2010: The figure and table depict that the highest amount of land cover change had taken place from Agriculture land to bare land (9.49%), Agriculture to forest (5.64%), and from forest to bare land (5.78%) in the period between 2000 and 2010. Similarly, a small amount of conversion had taken place from bare land to water body and all other's conversion is below 1% hence neglected. The highest amount of land cover change had taken place from Agriculture land to bare land (10.72%) and forest to bare land (7.42%) in the period between 2010 and 2020. Similarly, a small amount of conversion had taken place from Agriculture to forest, bare land to forest and bare land to water body whereas all other's conversion is below 1% hence neglected. Also, the figure and table shows that the highest amount of land cover change had taken place from bare land to Agriculture (8.05%), Agriculture land to the forest (5.84%), and Agriculture to bare land (5.12%) in the period between 2000 and 2020. Similarly, a small amount of conversion had taken place from bare land to forest and Forest to Agriculture whereas all other conversions are below 2% hence neglected (Figure 4, Table 5).

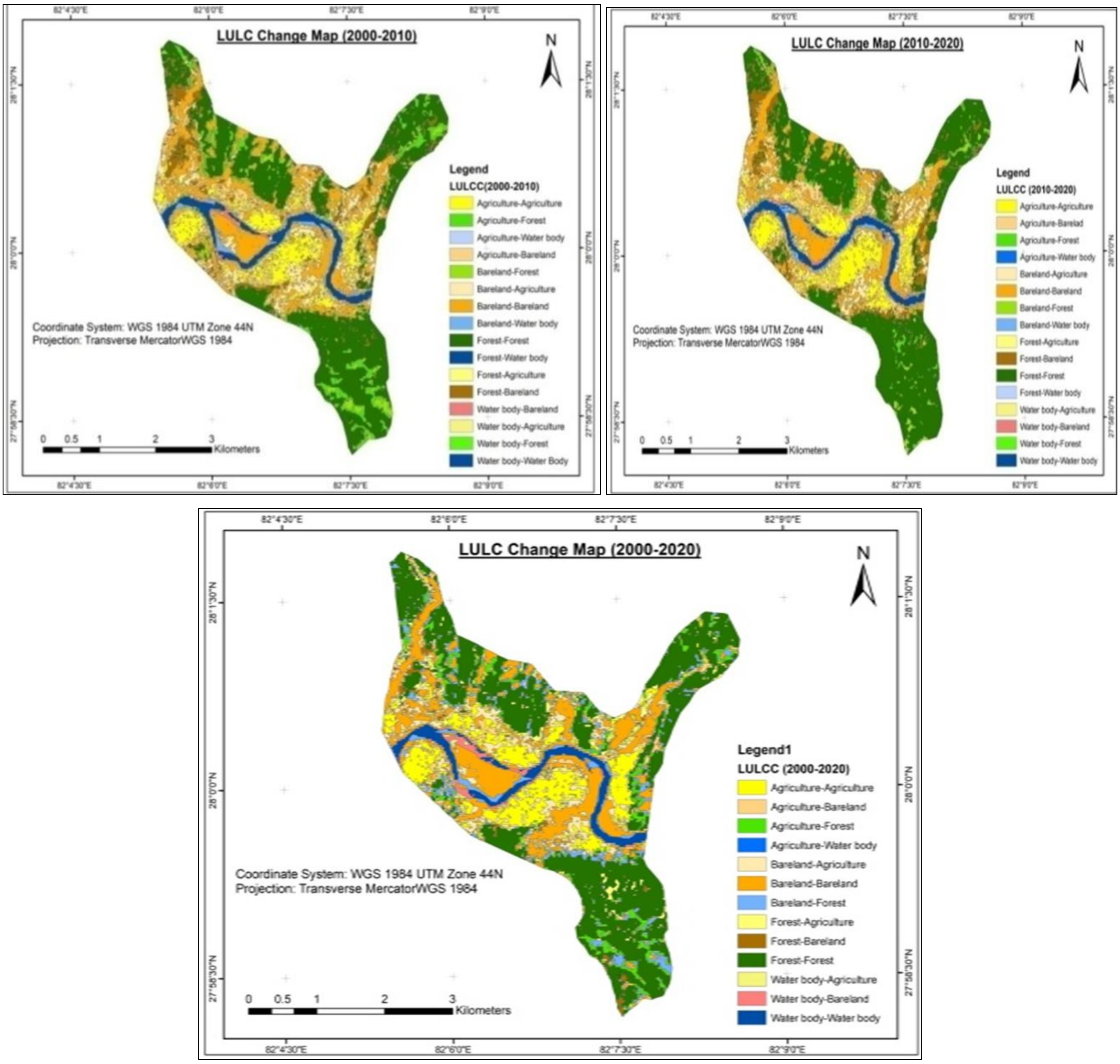


Fig 4: Total change from 2000 to 2020

Table 5: land use and land cover change from 2000 to 2020

	LULC Change	Agriculture	Bare land	Forest	Water body	Grand Total(2000)
Change between 2000 & 2010	Agriculture(ha)	122.791	135.631	80.711	1.171	339.812
	Bare land(ha)	105.452	264.462	55.512	21.842	447.263
	Forest(ha)	4.231	82.696	475.844	0.293	563.054
	Water body(ha)	1.563	10.531	1.195	65.266	78.545
	Grand Total(2010)(ha)	233.541	493.312	613.261	88.554	1429
Change between 2010 & 2020	**LULC Change**	**Agriculture**	**Bare land**	**Forest**	**Water body**	**Grand Total (2020)**
	Agriculture(ha)	150.629	153.164	41.005	2.642	347.441
	Bare land(ha)	76.721	224.885	33.022	21.884	356.513

	Forest(ha)	4.019	106.082	538.88	0.362	649.344
	Water body(ha)	1.541	9.181	1.126	63.560	75.411
	Grand Total(2010) (ha)	232.911	493.312	614.035	88.450	1429
Change between 2000 & 2020	**LULC Change**	**Agriculture**	**Bare land**	**Forest**	**Water body**	**Grand Total(2000)**
	Agriculture(ha)	185.503	73.127	83.448	0.189	342.268
	Bare land(ha)	114.991	249.116	66.328	16.352	446.786
	Forest(ha)	46.011	18.983	496.919	0	561.914
	Water body(ha)	2.280	17.326	0	58.908	78.515
	Grand Total(2020) (ha)	348.785	358.554	646.695	75.450	1429

Rate of LULC Change of Chure Area in Banke district
Forest area was increased by 0.86% from 2000 to 2010 and 0.55% from 2010 to 2020.The rate of change for Agriculture was decreased from 2000 to 2010 that was -3.68% but and it was increased by 4.11% from 2010 to 2020 (Table 5).

Table 5: Rate of LULC Change of Chure Area in Banke district

LULC Classes	Rate of Increment(%) and Decrement(-%) per Year	
	From 2000 to 2010	**From 2010 to 2020**
Forest	0.861	0.550
Agriculture	-3.682	4.110
Bare Land	0.981	-3.210
Water body	1.214	-1.580

Carbon Stock in National Park, Buffer Zone and Community Forest
The above-ground tree/pole carbon stock was found to be highest in the National Park of Chure region with 91.78±15.574 t C ha-^{1} because of the presence of dense forest in Banke national park. This was followed by buffer zone Area with 80.994±8.234 t C ha-^{1} and lowest in Sati Bhawani community forest with 64.041±10.741 t C ha-^{1}. The above-ground sapling carbon stock was found to be highest in community forest with 1.240±0.145 t C ha^{-1} because more saplings are present in this forest in comparison to National Park and Buffer Zone Area. This was followed by National Park in the plain with 0.748±0.085 t C ha^{-1} and lowest in Buffer Zone Area with 0.462±0.045 t C ha^{-1}. The seedling carbon stock was found to be highest in community forest with 0.838±0.098 t C ha^{-1} and followed by National Park with 0.473±0.096t C ha^{-1} and lowest in Buffer Zone Area with 0.286±0.031 t C ha^{-1}.The leaf litter, herb, and grass biomass was found to be more in National Park with 1.277±0.213 t C ha^{-1} followed by Buffer Zone Area1.081±0.317 t C ha^{-1} and lowest at Community Forest 0.723±0.159 t C ha^{-1}.
The total above-ground carbon stock was found to be highest in National park of Chure region with 93.002±15.569t C ha^{-1} because of dense forest with a large number of pole accompanied by the tree with larger diameter (upto130 cm from 30cm) and height (22m) of Sal (*Shorea robusta*), Saajh (*Terminalia tomentosa*), and associated species It was followed by Buffer Zone Area with 81.744±8.239t C ha^{-1} and lowest in Community forest with 66.119±10.761t C ha^{-1}. The reason for the lowest carbon may be due to the various effects of drivers of deforestation and forest degradation. After the establishment of Banke National Park in 2010 A.D in the Chure area, there was banned for deforestation which effects to enhance carbon stocks more in National Park. Forest Management Practices have been adopted in community forest so that it enhances more carbon stock of seedling & sapling.

Below Ground Soil Carbon Stock of Chure Area in Banke district: The soil carbon stock was found to be highest in the National Park of Chure region with 43.287±5.658t C ha^{-1} and followed by buffer zone Area with31.426±2.072t C ha^{-1} and lowest in community forest with 30.924±1.318t C ha^{-1}. CF in the Chure region faced erosion and pressure on land due to illegal human settlements resulting in a decrease of soil organic carbon. Likewise, the study shows that the more soil organic carbon in National Park followed by a Buffer Zone Area and lowest in community forest.

Total carbon stock of Chure Area in Banke district: The estimated carbon stock was varied indifferent study areas. The estimated total carbon stock per ha was found to be highest in National Park with 149.34±12.386t C ha^{-1} and followed by Buffer Area with 124.55±14.231t C ha^{-1} and lowest in community forest with 106.28±15.285t C ha^{-1}. The total above ground and below ground carbon pools represents the total carbon stocks per ha of NP, BZ Area& CF which depends on the biomass of above ground, below ground, and soil organic carbon. The NP, BZ Area& CF was well managed which helps to sequestrate high CO_2. Good management practice can be helpful to reduce carbon dioxide emissions and to increase carbon sequestration (Table 6)

Table 6: Carbon status in the forest according to management regime

	Above Ground Carbon (ton/ha)	Below Ground Carbon (ton/ha)	Total Carbon (ton/ha)
Sati Bhawani CF	66.841±8.621	39.44±5.324	106.28±15.285
BZ Area	82.823±5.101	41.73±3.241	124.55±14.231
Banke NP	94.282±9.689	55.07±7.820	149.34±12.386

In the Nepalese forest, an average carbon stock account to 203 t ha^{-1} (including shrub land) which is higher than the world's average i.e. 161.1 t ha^{-1} (FAO, 2006) [11]. In this study, the average carbon stock of three community forests was estimated at 126.73 t C ha^{-1} including above-ground tree C, below ground C, above ground sapling C, leaf litter, herb, grass C & soil C.

In three regions of the study area, the data distribution of carbon stocks of sample plots was tested for normal distribution. ANOVA was applied when significant differences were observed whereas Kurskal wallis was applied to not normal data when significant differences were observed. In Tree/Pole and Sapling follow the Kurskal wallis test because the data obtained are not normal and the test shows that there was no significant difference in Tree/Pole carbon stock and significant difference in seedling carbon stock in Banke National Park, BZ Area and Sati Bhawani CF at 5% level of significance as $p<0.05$. Similarly, Sapling, LHG, and Soil Carbon follow the One Way ANOVA test because the data obtained are normal and the test shows that there was a significant difference in Sapling and not a significant difference in soil carbon & LHG carbon stock in Banke National Park, BZ Area and Sati Bhawani CF at 5% level of significance as $p<0.05$ (Table 7).

Table 7: Comparison of carbon stock in different management regime

	Data type	Type of test	P-value	Decision
Tree/Pole	Not normal	Kurskal wallis	0.111	Not significant
Sapling	Normal	One Way ANOVA	0.001	Significant
Seedling	Not normal	Kurskal wallis	0.001	Significant
LHG	Normal	One Way ANOVA	0.290	Not Significant
Soil Carbon	Normal	One Way ANOVA	0.051	Not Significant

Effect of land use land cover change on forest carbon: By assuming the usual scenario the effect of land use land cover on forest carbon was found. Total carbon stock of 2000 and 2010 cannot be calculated because of unavailability of the past record. Assuming business based on the field data of 2020, the total forest carbon of 2010 and 2000 would be 77712.31 t and 71350.96 t and hence the total co_2 equivalent was found to be 284945.1 t and 261620.2 t. Assuming 5% less carbon in 2000 and 2010 based on the field data of 2020, the total forest carbon of 2010 and 2000 would be 73826.69 t and 67783.42 t and hence the total co_2 equivalent was found to be 270697.9 t and 248539.2 t. Assuming 10% less carbon in 2000 and 2010 based on the field data of 2020, the total forest carbon of 2010 and 2000 would be 70329.64t and 64572.62t and hence total CO_2 equivalent would be 257875.3t and 236766.3t respectively (Table 8).

Table 8: Carbon stock and CO_2 equivalent in 2000, 2010 and 2020

Year	Forest Area(ha)	Business as usual Total Carbon (t)	Business as usual Total CO_2 equivalent (t)	Total C t	Total CO_2 equivalent (t)	Total C t	Total CO_2 equivalent t (t)
		Business as usual scenario		Assuming 5% less carbon		Assuming 10% less carbon	
2020	647.910	82103.161	301044.912	16057.960	58879.181	16057.961	58879.188
2010	613.260	77712.312	284945.132	73826.690	270697.921	70329.642	257875.301
2000	563.060	71350.961	261620.211	67783.421	248539.232	64572.623	236766.305

Discussion

The carbon stock varies according to the temporal and spatial changes. The change in land use and land cover has obvious effect on the carbon stock in the forest. The local people also justified stating that there was massive change in forest area which was increased in Chure area. According to the result obtained from the research, forest area was increased by 5.94% over 20 years. From 2000 to 2010 it was increased by 2.82% and from 2010 to 2020 it increased by 3.12%. The reason behind the increase of forest area was the establishment of Banke National Park which covers more Chure area of Banke District, and community forest management practices as well. Various studies show that land cover over the different regions of our country Nepal was increased in different regions (Gautam *et al*., 2002; Awasthi *et al*., 2002) [12]. Also from the report present by the DFRS (2015) [6] in the whole country, the forest area was increased from 39.6% to 44.74%.

Similarly, one of the major changes in land use is Agriculture land which was decreased by 6.56% from 2000 to 2010 and it was again increased by 7.23% from 2010 to 2000 the reason behind the change in Agriculture land is urbanization. Most of the villagers either migrated towards the city or choose any other profession for livelihood in recent years. This reason was also supported by the author Paudel *et al*., (2017) [24]. People's perception is one of the media to find the causes of land use land cover change in the study area in this research. According to people's perception, the establishment of Banke national park, handover of Forest to CFUG for their management, use of the alternative source of energy for cooking, and awareness among local people are the reason behind increasing forest. Negative land use land cover changes are soil erosion, migration, unplanned infrastructure development such as roads and buildings.

The carbon in the forest depends upon forest types, climate, moisture, temperature, and types of soil (Chaudhari *et al*., 2013) [3]. Total carbon stock was found to be highest in Banke national park in Chure region with 149.34 ton/ha which was because of presence of dense forest. The National park was applying the conservation practices which lead to restrict the removal of logging and encroachment. Another important part is application of buffer zone community forest management and community forest management which emphasize to reduce the logging and encroachment. Various author Khadka *et al*., (2019) [19] concluded that forest under the protected areas of Nepal had higher amount of total carbon stock per hectare compared to the forest outside the protected area. Similarly, Sapling and seedling carbon stock was found to be highest in Community forest i.e. 2.08 ton/ha which was due to the scientific management practices applied in Community forest which results to increase in the regeneration forest. The soil carbon stock was found to be highest in the National Park of Chure region with 43.287±5.658t C ha^{-1}. Land use and soil depth both affected the SOC (Ghimire *et al*., 2019) [35]. The clear trend was seen in soil carbon according to the soil depth. It was highest in 0-10 cm while lowest in 20-30 cm depth which was supported by the author Sah *et al*., (2019) [26]. The soil carbon was highest in the upper layer and it decreases according to the soil depth due to rapid decomposition of forest litter in a upper layer (Mandal *et al*., 2019) [19].

When time changes forest area also changes mainly there was degradation and the deforestation of the forest area. Change in forest area can be measured easily but it is difficult to measure the effect of land use land cover change in the forest area which needs high quality data. So, we use usual scenario to find effect of land use land cover change on forest carbon of the year 2000 and 2010.

Business as usual scenario total carbon stock of 2020 was 82103.16 ton. Various author Sharma and Rai, (2007) [29] explained that land use land cover change have direct effect on the forest carbon so, from assumption, we found total carbon of 2000 was 71350.96 ton in which when forest area decreases carbon stock also decreases. LULCC have direct effect on the Carbon stock but Land-cover did not significantly affect SOC concentrations in non-domestic green space, but values beneath trees were higher than under both pasture and arable land, whereas concentrations under shrub and herbaceous land-covers were only higher than arable fields (Edmondson *et al*., 2015) [8]. The sources and sinks of carbon from LULCC are significant in the global carbon budget. Deforestation and other land-cover changes are responsible for 53–58% of the difference between current and potential biomass stocks (Erb *et al*., 2018). Thus, land use change effects and forest carbon cycling during different period are dominated by changes in tree carbon stocks (Woodbury *et al*., 2006). So in overall comparison when the land cover on the given area was decreased carbon stock also decreased.

Conclusion and Recommendations

The land use land cover change map showed that forest area was less in 2000 which was increased in 2010 and the increase was continued to 2020 as well. The above ground tree/pole carbon stock was found to be highest in National Park of Chure region because of dense forest but the forest carbon was the lowest in community forest. Similar result was found that the soil carbon was found to be highest in National Park of Chure region. The carbon stock was increasing from 2000 to 2020 since the forest area was increased in this period. Assuming 10% less carbon in 2000 and 2010, the total forest carbon of 2010 and 2000 would be less and hence total CO_2 equivalent would also be less and same principle is applied for assuming other scenario. Effect of land use and land cover change was monitored using remote sensing analysis which can be useful tool for forest manager and policy maker. The carbon stock in Chure forest managed under the national park can be used as reference for other part of Nepal as well. The increasing trend of carbon and their link with the land use land cover change will be useful to develop the policy related to carbon enhancement. Carbon assessment study should be extended to all over Chure area of Nepal and this should be linked with the land use land cover change.

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