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Research Article

Impact of Land cover Dynamics on Ecosystem services value of Siwalik range of Madhesh Province Nepal

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ABSTRACT
The Siwalik region is the area that lies between the hills in the north and Terai in the south. It provides a wide range of services and is of particular interest from a land use land cover (LULC) change perspective as it is naturally fragile and prone to degradation. The study was conducted in Madhesh Province Siwalik to assess the LULC change over three time periods and to quantify the change in ecosystem services value (ESV) due to LULC change. Remote sensing, Google Earth Engine and Arc GIS were used to prepare the land cover map. In 2000, 2010 and 2020 total area covered by the forest was 68.46%, 65.58% and 71.17%, agriculture was 16.50%, 18.21% and 16.21% and waterbodies were 4.40%, 3.89% and 3.79% respectively. From 2000-2010 forest and waterbodies decreased by 3.87%, and 0.54% respectively whereas agriculture and other land increased by 1.7% and 2.71% respectively. Similarly, from 2010 to 2020, agriculture, water bodies, and other land decreased by 1.99%, 0.10%, and 4.48% whereas forests increased by 6.58% respectively. The overall accuracy of the map is 90%, 89% and 88% for the years 2000, 2010 and 2020. The ESV was estimated using the value transfer method, which was 28 million USD/year, 26.84 million USD/year, and 28.97 million USD/year in 2000, 2010 and 2020, which showed that the total ESV has decreased by 1.16 and increased by 2.12 million USD from 2000-2020. An elasticity indicator shows 1% of land conversion in Siwalik resulted in 0.47 % and 0.21 % changes in ESVs during the two periods, respectively. Overall findings of this study, suggest that ESV has increased in the Siwalik region of Madhesh province in the last two decades, primarily due to an increase in forest cover. This increase should be taken as an opportunity to leverage policy support and programmatic implementation to increase forest cover and reduce land conversion.
Keywords: Chure region, Elasticity, Google Earth Engine, Land use land cover change, Remote sensing.

INTRODUCTION
The Land is a crucial feature and the foundation for the survival of human beings and ecosystem services on Earth (Yoshida et al., 2010). Changes in land use and land cover (LUCC) have a profound impact on the ecosystem's core components and are indicators of changes to the world's ecology (Xu et al., 2016). Ecosystem services maintain the ecological process and function and support the living organism on the Earth. Over the past few decades, 60% of ecosystem services around the world have deteriorated (Costanza et al., 2014). Change in land cover is a dynamic and continuous process (Mondal, 2016); both natural and artificial processes can cause it. Anthropogenic activities have become a major force that dramatically reshapes the ecosystem (Randin et al., 2020). So, Continuous LULC observation of those changes is essential in monitoring overall environmental and ecosystem services (Lal & Anouncia, 2015).

The application of Remote Sensing, GIS, and Google Earth Engine (GEE) acts as an efficient tool in mapping the LULC change and Ecosystem services (ES) Value research. The method used by various researchers for the Valuation of Ecosystem Services (Sharma et al., 2019; Shrestha et al., 2019; Rai et al., 2018). So, the study used remote sensing and GEE for the LULC change and benefit transfer method for the evaluation of ES value.

Although biodiversity and ecosystem conservation have greatly improved in Nepal, there has been little progress in the concept's application. Various work has been done by the Nepal government to make the use of ecosystem services idea, for example, the inclusion of ES in the national plan and preparation of national policy on payment of ecosystem services. However, there is still a lack of policy and planning for the conservation and management of natural resources, which has a huge negative impact on ES and forces trade-offs.

Nepal has fragile geography among them, Chure is one of the ecologically weak and disaster-prone areas (Aulestia, 2019) which makes it the fastest land cover changing place. Chure acts as the water tower for the southern region of Nepal. To convey to the people about the land use land cover change impact it is necessary to assess the value of the service the land cover provides. Hence continuous assessment of LULC and ESV is essential for the conservation and Management of the Chure region. The study provides baseline data for better land use planning and further research.

MATERIALS AND METHODS

Study area

The study was conducted in Nepal's Madhesh Province Chure (Siwalik) Physiographic region (Figure 1) as it is a region naturally ecologically fragile and prone to degradation. The region geologically belongs to the Palaeocene and the early Quaternary consists of conglomerate, sandstone, and shale (MFSC, 1988). The region comprises about 2065 Km^2 of landmass extending across 8 districts of Madhesh Province, which covers 21 % of the total landmass. The climate of Siwalik ranges from tropical to sub-tropical. The region supports the agro- productivity of the Terai region of Nepal.

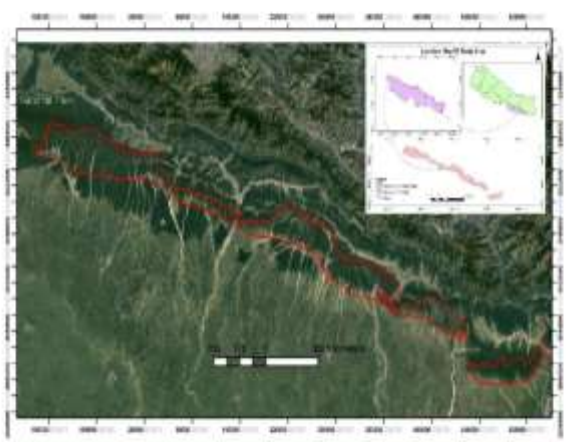

Figure 1. Location Map of Siwalik range

Land use land cover Classification

Freely available time series Landsat imagery for 2000, 2010 and 2020 was used. For the year 2000 and 2010 Landsat 7 Enhanced Thematic Mapper (ETM+) and 2020 Landsat 8 Operational Land Imager images (OLI) from United State Geological Survey (USGS) was extracted. The maximum cloud cover was taken less than 30%. A geometric and radiometric correction was conducted after that three Land use land cover classes were classified based on the requirement. The total land cover types are shown in Table 1

Table 1. Land cover classes

Land cover	Description
Agriculture (Cropland)	Lands covered with temporary crops followed by harvest period & crop Field.
Forest	Areas covered with trees forming closed or nearly closed canopies.
Waterbodies	Rivers, Lakes, ponds, and other areas with the presence of water.
Other lands	Includes all the excluded lands like bare land, bare soil, and built-up areas grassland.

A supervised approach, Random Forest classier was used for LULC classification. High-resolution images from Google Earth and Global Positing system points were collected from the Forest research and training centre for the year 2020. Training samples and a total of 20-30 % of the training sample were collected for the validation of the LULC map as shown in Table 2.

Table 2. Training and validation points for LULC classification

Year	Land Cover Classes	Training Points	Validation Points
	Forest	252	63
2000	Agriculture	319	85
	Water body	171	55
	Forest	261	57
2010	Agriculture	331	93
	Water body	177	44
	Forest	268	54
2020	Agriculture	398	90
	Water body	192	49

Estimation of Ecosystem Services Value and its Change due to LULC changes

The benefit transfer Method was used to extrapolate the ecosystem services value to the Siwalik physiographic region. The method, in the absence of site-specific valuation data, uses the current values and other information from the original study to estimate ESVs of additional similar locations. The method is used because it is cost-effective (Oh, 2014). The research use Ecosystem Services Value (Rai et al., 2017) for LULC types. The paper contains the site-specific value of the Chure region. All value coefficients were changed to 2000 USD per hectare per year using the inflation factor to account for the time effect of value to simplify the estimating procedure of ESV changes. The formula used to calculate the Ecosystem services value is given in Equation 1:

$ESV = \sum (A_k \times VC_k)$ …. (Costanza et al., 1997) ……………………………. Equation 1

Where → ESV is the estimated ecosystem services value,

→ Ak = area (ha),

→VCk = the value coefficient (USD/ha/year) for the land use category "k"

Elasticity of ESV changes in the response to LULC changes

Elasticity, which is defined by (Song & Deng, 2017) was applied to examine the relationship between LULC and ESVs. The major reason for the use of elasticity is to calculate the percentage change in ESV to the percentage change in LULC. The given formula was used to calculate the elasticity are shown in Equation 2:

$$EEL = \frac{\frac{Eend-Estart}{Estart}*\frac{1}{T}*100\%}{LCP} \text{........... Equation 1}$$

$$LCP = \frac{\sum_{n=1}^{n} \Delta LUTi}{\sum_{n=1}^{n} LUTi} * \frac{1}{T} * 100\%$$

Where,

EEL= Elasticity of changes in ESV in response to LULCC

E_{end}=ESV at the end of the research period

E_{start}=ESV at the start of the research period

LCP=Land conversion percentage

LCP can reveal both the conversion speed and degree of LUCC, ΔLUTi is the converted area of LUCC type I, LUTi is the area of LUCC type I and T denotes the year within the research period.

RESULTS AND DISCUSSION

Land Use Land Cover Change Analysis

The LULC Maps of each study period were prepared by using Landsat satellite images 7 and 8 using GEE. Four LULC classes were analysed i.e., Forest, Agriculture, Waterbodies and other land. The LULC Maps for the years 2000, 2010 and 2020 are presented in Figure 2, 3 and 4.

From 2000 to 2020, the dominant LULC types in Chure were forest followed by agricultural land, Otherland and Water bodies. In 2000, Forest (68.46%) was the major land cover class followed by agriculture (16.50%), otherland (10.59%) and water bodies (4.44%). In LULC 2010, Forest (65.58%) followed by agriculture (18.21%), otherland (13.30%) and water bodies (3.89 %) and in 2020, Forest (71.17%) followed by agriculture (16.21%), other land (8.82%) and water bodies (3.79%)

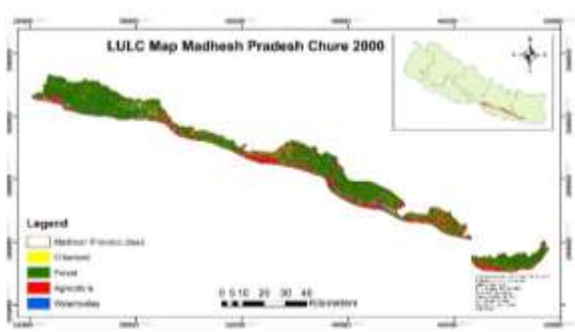

Figure 2. Land use land cover Map of 2000

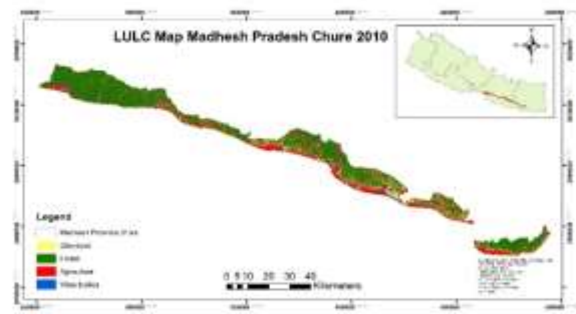

Figure 3. Land use land cover Map of 2010

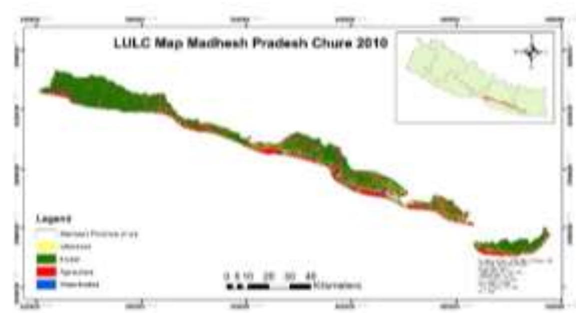

Figure 4. Land use land cover Map of 2020

Land use Land Cover Area from 2000 to 2020

The result of LULC change from 2000 to 2010 indicated that there was a decrease in the forest, and waterbodies by 3.87%, and 0.54% and agriculture and other land increased by 1.7% and 2.71% respectively. Similarly, from 2010 to 2020, agriculture, waterbodies, and other land decreased by 1.99%, 0.10% and 4.48% whereas Forests increased by 6.58%. From 2000 to 2020 the area of the forest increased by 2.70% whereas agriculture, waterbodies and other land decreased by 0.28%, 0.65% and 1.76%.

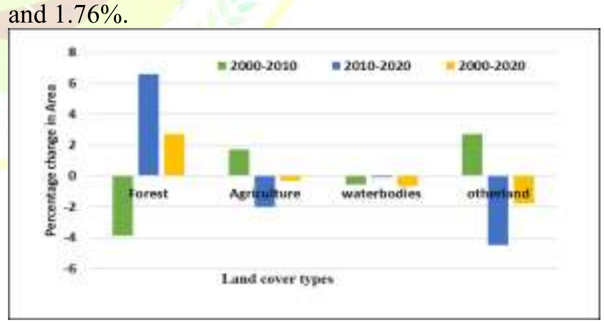

Figure 5. Land use land cover change from 2000 to 2020

Estimation of Ecosystem Services value and its changes

The total ecosystem service value of the Siwalik region was estimated at USD 28 million per year in 2000, USD 26.84 million per year in 2010 and USD 28.97 million per year in 2020. It was found that in 2020, 71 % of the land was covered by forest and delivered USD 26.39 million per year which was the highest value whereas agriculture was delivered for USD 2.57 million per year. Similarly, in 2010 forest delivered USD 23.94 million per year, i.e., 65% of the landscape was covered by forest and agriculture delivered USD 2.89 million per year. Similarly, in 2000, forest delivered USD 25.38 million per year whereas agriculture delivered USD 2.62 million per year. Ecosystem services which were included Forest products, Biodiversity and pharmaceuticals, Hydrological services, and food production. These are the major ecosystem services provided by the cure region (Acharya et al., 2019)

Impact of LULC on spatially explicit ESVs

To understand the impact of LULC change on the total ESV and their relationship, we have calculated the elasticity of ESV in response to LULC changes. The elasticity in the repose of LULC change was calculated using Equation 2 and is presented in Figure 6. It shows the elasticity of ESV in response to LULC change was 0.47, 0.27 and 0.63 during the period 2000-2010, 2010-2020 and 2000-2020 respectively. The elasticity implies that a 1% transition of LULC would result respectively in on average 0.47%, 0.27% and 0.63% chance of total ESV during the study period. The fluctuation trend of ESV is illustrated in Figure 6. The elasticity of ESV declined from 0.47 to 0.27 during the period 2000 to 2020. The decreasing trend of ESV implies that ESV is less sensitive to LULC change during this period. The higher value of ESV during 2000-2020 indicates that the greatest change in ESV occurred during this period due to LULCC.

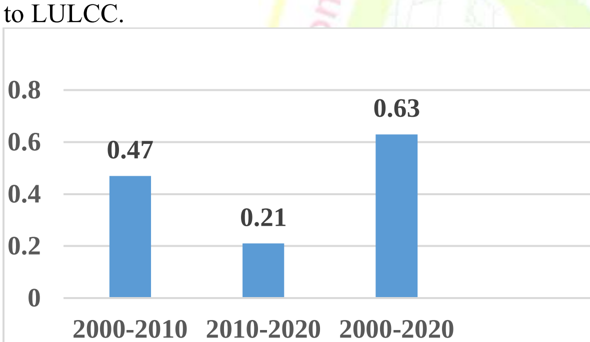

Figure 6. Elasticity of ESV in response to LULC change

For effective natural resource management, detailed LULC research is crucial(Uddin et al., 2015). A Landsat image was extracted, and a land use land cover map was prepared for the years 2000, 2010 and 2020. In this study, we use GEE to classify the LULC by using RF algorithm in the Siwalik region of Madhesh province. Cloud masking, shadow masking, Bidirectional reflectance distribution function correction, and topographic correction were used to improve the accuracy of the classification. The overall accuracies of the LULC classification in 2000, 2010 and 2020 were 88.17%, 89.69 % and 90% respectively indicating the good performance of our methods. Based on LULC we further estimated the ESVs of the chure and the relationship between ESVs in response to LULC change.

Land Use Land Cover Change

Total of four major land cover classes were included i.e., Forest, Agriculture, waterbodies, and other land. The results here presented show that in 2000 forest cover and agriculture in chure region occupied 68.46% and 16.50% of the area. Due to insufficient regional LULC literature, results agree with Bhuju, Yonzan, and Badiya (2007), who quantified that 61.2% of the eastern chure hills were covered by forests by 1992 and agriculture represented 8.5%. In 2010, the forest cover occupied 65.58% (a decrease of 3%) of the total area. Similarly, the report authored by FRA/DFRS (2014) indicates the region has experienced deforestation at a rate of -0.8% from 1995 to 2010. Likewise, Ghimire (2017) also found deforestation in the chure hills and inner terai valley from 1954 to 2015. The LULC of Nepal reports that agricultural land occupied 10.74% of the chure by 2010, while the study found 18% in the study area. In 2020, there were almost 71.17% of the total land is covered by forest. The national land cover monitoring system(NLCMS) 2019 (FRTC, 2022) showed 41.69% of land in Nepal is covered by forest, (Sharma et al., 2019) showed 44% of the land is covered by forest in TAL. The chure land use land cover has been gone through nominal change over twenty years. LULC changes are dynamic and nonlinear, which means that due to a variety of natural and artificial reasons, the transition from one land cover to another does not follow a consistent pattern throughout the year. From 2010 to 2020, there was a decrease in agriculture (1.99%) and an increased in the forest (6.58%). NLCMS showed forests increased by 1.70%, agriculture decreased by 2.10% from 2000 to 2019 (FRTC, 2022). GDP contribution from agriculture drastically decreased in 2018. There was a decrease in other lands from 2000 to 2020 which asserts with the result (Pandey 2022) shows a decrease in other lands due to conversion into forest. The finding showed the decreasing trend of waterbodies in the chure which complies with the finding (SAWTEE, 2016)due to increasing deforestation and extraction of water materials from rivers. The increase in the forest cover after 2010 might be due to Chure Terai Madhesh Conservation Programme (2010), the declaration of Chure as EPA under the Environment Protection Act (1997) on July 14 2014, and the Forest policy (2015) which might act as a boon policy for the forest in Nepal. The study showed that from 2000-2010 most of the forest was converted into other land and agriculture whereas from 2010 to 2020 most of the other land was converted into forest. In the Chure region, maximum land conversion has been found from agriculture to forest and forest to agriculture from 2000 to 2014 (Aulestia, 2019).

Valuation of Ecosystem Services and comparison between ESV coefficients

Costanza et al. (1997) have provided the global ecosystem valuation which is used by researchers since valuing the global ecosystem services. Based on LULC change, research quantified the ESV of the chure region during the period from 2000 to 2020 at a 10-year interval. The research finding identified that LULC causes a change in ecosystem services value. In each year ESV coefficient, our study envisioned decreasing trend of ESV of 1.16 % from 2000 to 2010 and an increasing trend of 2.13% from 2010 to 2020. For the temporal comparison of changes in ESV better to include the ESV which is adjusted to the base year rather than adjusted inflation ESV for a different period (Shrestha et al., 2019). In ESV coefficient, showed an increasing trend of ESV from 2010 to 2020 due to an increase in forest cover through the agriculture area decreases by 1.99%, which implies that ESV is mostly dependent upon the forest because it provides a wide variety and high-value ecosystem services. The other studies also revealed a decrease in ESV due to a decrease in forest cover (Sharma et al., 2019).

The loss in global ecosystem services due to LULC change was about $4.3-20.2 trillion from 1997 to 2011. In the Tibetan plateau, ESV increased at the rate of 67.10× 108 between the years 1985 to 2000 however between 2000 to 2010 the ESV decreases at the rate of 49.30 × 108. In the Gandaki river basin, the ESV increased from 50.16 × 108 USD/year to 51.84 × 108 USD/year between 1990 and 2015 (Rai et al., 2018). The increase in ESV is due to enhancement in cropland, forest, waterbodies, wetland and barren land. Similarly, in the Karnali river basin, the ESV increased from 45.87 × 108 USD/year to 45.89× 108 USD/year between 2000 and 2017 (Shrestha et al., 2019). The slight increase in ESV is due to a slight increase in grassland, agriculture and barren land. However, the Koshi river basin showed a decreasing ESV from $91.60 × 108 and $89.55 × 108 between 1990 to 2010 (Zhilong et al., 2017). The loss is due to human interferences such as urbanization, deforestation and land reclamation in the Koshi river basin(Zhilong et al., 2017). Similarly, in TAL the ESV decreased from 1275 million USD to 1264 million USD between 2001 to 2016(Sharma et al., 2019. The loss is primarily due to a decrease in forest cover, and cropland in the TAL area (Sharma et al., 2019). Here, other land and water bodies derived no ecosystem services value due to a lack of ESV coefficient considering the local context. There was very less increment in ESV of Madhesh Province as compared to Gandaki and Karnali river basin because the study used limited ecosystem services of land cover forest and agriculture only and it considers the local ESV coefficient Rai (2017) rather than Xie's (2003). Research findings on the elasticity of ESV in response to LULC change showed that the change of ESV due to LULC change is elastic. The elasticity during the period 2000 to 2010 was 0.47 implies that the conversion of 1% of the land area would result in an average change of 0.47% of ESVs. It decreases because of the increase (6%) in forest cover. The elasticity from 2010 to 2020 was 0.21 which implies that the conversion of 1% of the land area would result in an average change of 0.21 % of ESVs. High elasticity indicates that even small LULC changes would have serious effects on ESV. The elasticity of KSL-China was 5.27, KSL- Nepal 4.34 and KSL-India was 1.57 between 2000 to 2015, Nepal shows the second highest 4.34 due to loss in forest cover (394.47 km2) during the 15 years (Gu et al., 2021).

CONCLUSION

In this study, the LULC study was conducted on the entire Siwalik of Madhesh Province and further quantified the change in ESV between 2000 to 2010 and 2010 to 2020. During the study period, the Madhesh province Siwalik experienced significant LULC change, forest (3.87%) and waterbodies (0.54%) decreased, whereas agriculture (1.7%) and other lands (2.71%) increased. Between 2010 to 2020, agriculture (1.99%), waterbodies (0.10%) and another land (6.58%) decreased, whereas forest (6.58%) increased. The overall finding from 2000 to 2020 shows condition of Madhesh province Chure is improving due to an increment in the forest due to the major conversion of other lands (Grassland, shrubland, built-up areas) and agriculture into the forest. Meanwhile, which also indicates that there was an abandonment of agriculture in the Madhesh province of Chure. Between 2000 and 2010, the total ESV in the study area decreased by 1.16 million USD/ year. This decrease was mainly due to a decrease in forest cover (2.88%). Between 2010 to 2020, the ESV increased by 0.9 million USD/ year due to an increase in forest cover. In the ESV coefficient based on base year, the decrease and increase of ESV in forest cover contributed most to the loss and gain of total ESV and the high elasticity. This study revealed that even small LULC changes could cause relevant high ESV changes in the Chure.

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