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Assessing the Correlation between Aboveground Carbon Stock, NDVI and Tree Species Diversity (A Study of Kailali and Kanchanpur District)

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Abstract

There is limited research to show the correlation between biophysical character and reflectance value of satellite imageries. Thus, this research was conducted to show the relation between the reflectance value (Normalized Differences Vegetation Index: NDVI) and biophysical characteristics (carbon stock and biodiversity) of forest. Kanchanpur and Kailali districts of Nepal were selected as the study sites. Total 184 plots were established to measure the height and diameter at breast height (DBH). The Landsat 8 image of 2022 was downloaded from USGS.gov. Above ground tree biomass was calculated which was further converted into carbon stock. Tree species diversity was assessed using Shannon-Weiner index (H'). Furthermore, Pearson' correlation was performed to show the relation between aboveground carbon stock vs NDVI and biodiversity vs NDVI. The descriptive statistics showed that mean value of above ground carbon with standard deviation was 109.70±64.52 and 96.76±53.79 ton/ha in Kanchanpur and Kailali districts respectively. The mean value with standard deviation of H' index was 1.163 ±0.512 and 1.247 ±0.56 in Kanchanpur and Kailali districts respectively. The mean value with standard deviation of NDVI of the sampled plots was 0.491±0.268 and 0.367±0.192 of Kanchanpur and Kailali districts respectively. The R value of Carbon stock vs NDVI was 0.54 and 0.382 of study sites in Kanchanpur and Kailali districts respectively. Similar results were of Carbon stock vs H' index and H' index vs NDVI of the study sites of these districts. t-test showed that, these equations were significant at 5% since p value was less than 0.05. This study will be useful to understand the application of NDVI to correlate with biophysical characteristics of the forest.

Keywords: Carbon stock; NDVI; Tree species diversity.

1. Introduction

The Reo de Janeiro summit emphasizes on three important global issues. These are climate change, desertification and biodiversity (Adger *et al.*, 2001). No doubt, the issue of desertification is very important in the world but more than that climate change and biodiversity are interestingly significant (Jaikishun *et al.*, 2019). The forest plays a vital to keep the balance among these three issues (Billett *et al.*, 2010; Takeuchi, 2010). Research on these three issues is vital in the world resource, time knowledge limit to conduct the study. This research is importantly focuses on the issues of forest carbon (climate change) and biodiversity the issues. The assessment and monitoring of carbon and biodiversity is another vital issue in global arena.

Application of remote sensing to assess and monitor the carbon and biodiversity is becoming popular methodology. The application of remote sensing supports to evaluate the carbon stock and biodiversity. Several indices are derived based on the reflectance value of remotely sensed imageries (Bustamante *et al.*, 2016). One of the important indices is Normalized Differences Vegetation Index which showed very good correlation with carbon stock and biodiversity (Dung and Kappas, 2017). The application of this index has been used to monitor and evaluate the carbon stock and biodiversity in forest management (Pettorelli *et al.*, 2014; Vihervaara *et al.*, 2015). The monitoring and evaluation of carbon stock is worthful (Hansen *et al.*, 2008) in Reducing Emission from Deforestation and Degradation (REDD+) while biodiversity is important in National Biodiversity Strategy and Action Plan (NBSAP) (Steenweg *et al.*, 2017).

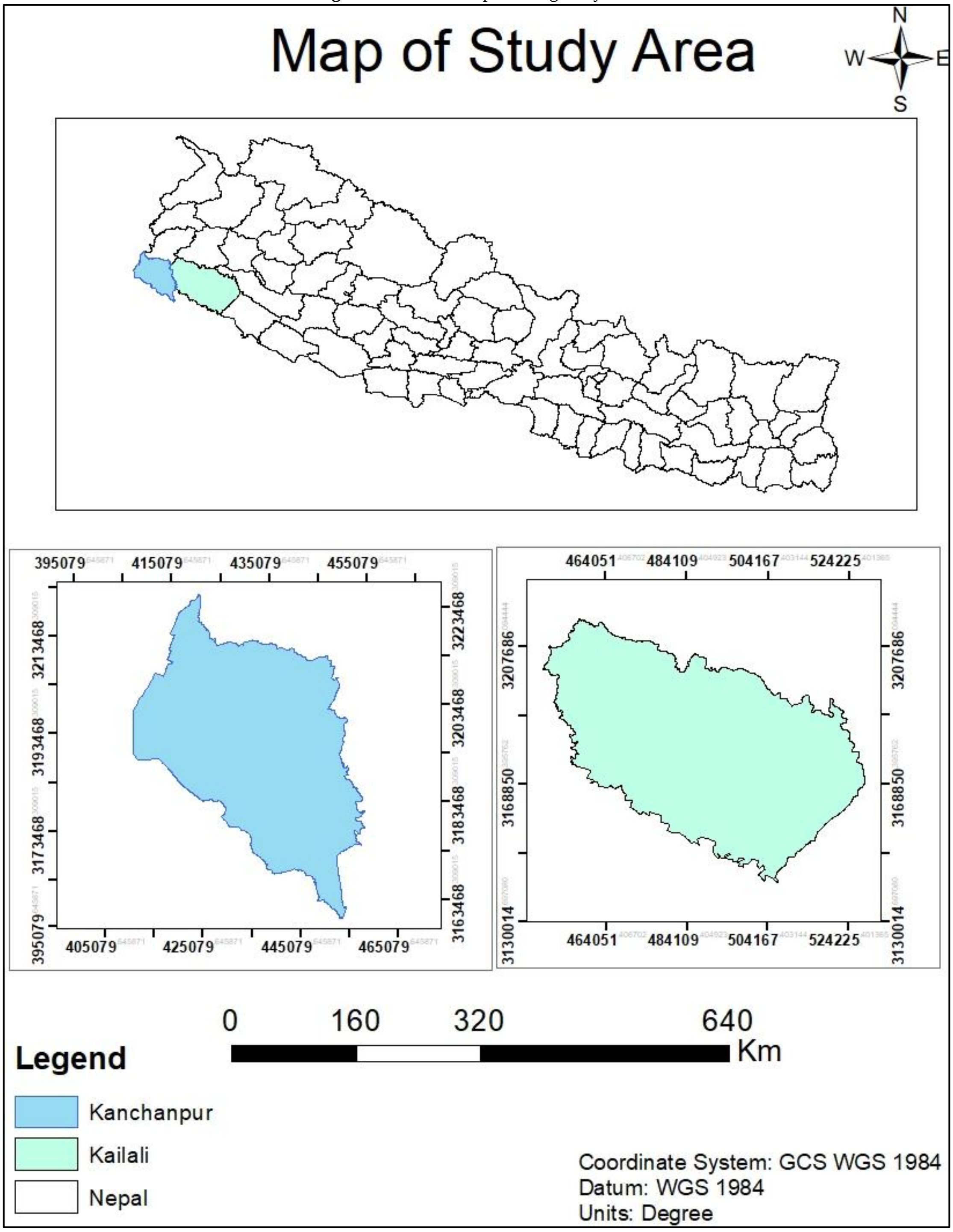
In this context, study on assessment of carbon stock and biodiversity are limitedly done in different part of Nepal. The mapping of carbon and biodiversity is important task in forest science. However, there is very limited study showing thematic map of carbon and biodiversity in Nepal (Aryal *et al.*, 2018). Despite the important relationship between these components the studies related to it are very limited. Thus, this research was objectively conducted to find correlation between carbon stock, tree species diversity and NDVI which helps for the implementation of effective conservation and management efforts.

2. Materials and Methods

2.1. Study Site

Kanchanpur and Kailali districts of Nepal were selected as the study sites. Kanchanpur district is situated between 28.8372° N latitude and 80.3213° E longitude whereas, Kailali district is situated between 28.8314° N latitude and 80.8987° E Longitude in Terai region of Sudurpashchim Province in the western part of Nepal. The elevation of Kanchanpur district is ranging from 160 m to 1528 m above mean sea level and this of Kailali district is ranging from 179 m to 1957 m above sea level (Gautam *et al.*, 1970). The average annual rainfall of Kanchanpur district is 1775mm with average maximum and minimum temperature as 43°C and 3°C respectively. The average annual maximum temperature of Kailali district is 43 °C and minimum temperature is about 5 ^{0}C and 1840 mm rainfall. These districts are mainly dominated by wide variety of Forest types such as Sal Forest, Terai Mixed Hardwood and Sissoo-Khair forest. Kanchanpur Kailali district is rich in biodiversity with 71 species of non-timber forest products (NTFP) and hundreds of species of medicinal herbs with more (figure 1).

Figure-1. Location map showing study area



2.2. Biophysical Data Collection and Analysis

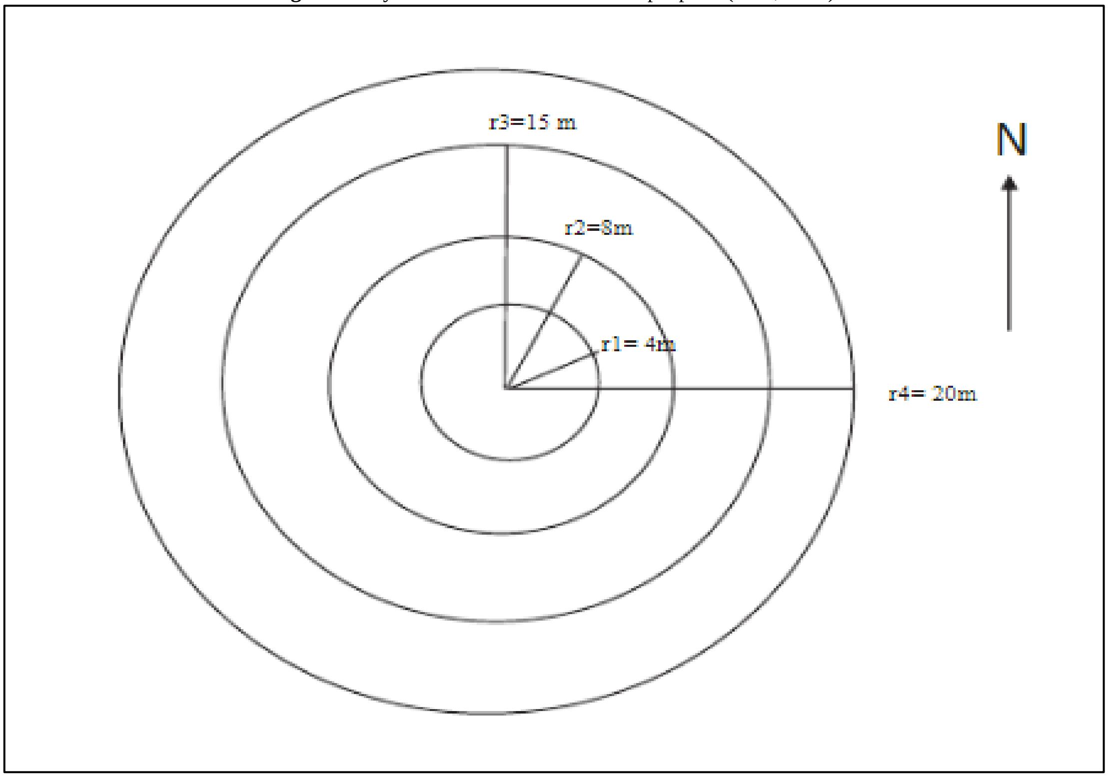
2.2.1. Biophysical Data Collection

Data were collected from total 184 plots distributed across Kailali Kanchanpur.

Two phases cluster sampling method was used for the inventory. At the first phase, a grid of 4 km×4 km was established, and at each grid point/ knot a cluster of plots were established. Each cluster consisted of six concentric circular sample sub-plots laid out and interpreted visually (DFRS/FRA, 2014).

The circles of a Concentric Circular Sample Plot were used to tally trees. The trees (having DBH 30 cm or more, 20-29.9 cm, 10-19.9 cm and 10 to less were enumerated within a 20 m, 15 m, 8m and 4 m radius plot respectively (Figure 2).

Figure-2. Layoutof Concentric circular sample plots (FRA, 2017)



The species of trees were noted and their DBH and height were measured.

2.2.2. Stem Volume and Biomass Estimation: The Tree Volume was Estimated Using the Equation Developed by Sharma and Pukkala (1990).

Equation 1. Tree volume ln (v) = a + b ln(d) + c ln(h)

Where 'ln' is the natural logarithm to the base 2.71828, 'v' is the volume per hectare (m^3 ha^{-1}), 'd' is the DBH (cm), 'h' is the height of the trees (m) and 'a', 'b' and 'c' are coefficients depending on species . From above equation, volume can be derived as:

Volume (v) = Exp [a + b × ln (DBH) + c × ln (h)].

The volume estimates were then divided by 1000 to convert them into m^3.

Equation 2. Tree stem biomass (ton/kg) = Volume × Wood density.

whereas, Volume = Stem volume in m^3 , Density = Air–dried wood density in kg m^{-3}

Species–specific wood–density values were obtained from Sharma and Pukkala (1990).

2.2.2.1. Tree Branch and Foliage Biomass Estimation

The separate branch-to-stem and foliage to- stem biomass ratios prescribed by the MoFSC (1988) for small (DBH < 28 cm), medium (DBH 28– 53cm) and large (DBH >53 cm) trees were used to estimate branch and foliage biomass from stem biomass. Dead trees were not taken into account for this estimate (DFRS/FRA, 2014). Then, total AGB was obtained (Equation.3) by adding the stem biomass, branch biomass, and foliage biomass, i.e.

Equation 3. Total aboveground biomass = Stem biomass + Branch biomass + Foliage biomass

Calculation of Carbon Stock: The above–ground carbon content (t /ha) was calculated by multiplying total aboveground biomass (kg/ ha) by the default carbon fraction of 0.47 (IPCC, 2006).

Equation 4: Aboveground carbon stock = AGB* 0.47

2.3. Tree Diversity Calculation

2.3.1. Shannon-Weiner Diversity Index was used to Calculate Tree Species Diversity Using the Following Equation (DFRS/FRA, 2014).

Equation 5: Shannon Wieners index (H') = - ∑ Pi ln(pi)

Where; H' is Shannon-Weiner diversity index, Pi is the relative abundance of each species, i.e.; the proportion of individuals of a given species relative to the total no. of individual in the community and ln is the natural logarithm.

2.4. Spatial Data Collection and Analysis

A 30 M Resolution Landsat Operational Land Imager (oli) 8 satellite image was used for this study which was downloaded from the united states geological survey (usgs) official website. data with less cloud cover (i.e. less than 10%) was prioritized for this study (table 1).

Table-1. Details of Landsat OLI 8 Image

WRS (Path and Row)	Scene ID/website	Sensor	No. of band	Spatial resolution	Acquired date
Path :144 Row: 040	LC08_L2SP_144040_2022 0609_20220616_02_T1 (website:https://earthexplor er.usgs.gov/)	OLI _TIRS		30m*30m	2022/06/09

2.5. Calculation of Normalized Difference Vegetation Index (NDVI)

NDVI measures the greenness and the density of the vegetation captured in a satellite image which is calculated from the visible and near-infrared light reflected by vegetation, (Habib and Al-Ghamdi, 2021; Tucker, 1979). NDVI have been used widely to examine the relation between Spectral variability and the changes in vegetation growth rate (Gandhi *et al.*, 2015). The NDVI was calculated using following formula (Choubin *et al.*, 2017). The value of NDVI ranges from -1 to +1.

$$NDVI = \frac{NIR-RED}{NIR+RED} = \frac{Band5-Band4}{Band5+Band4}$$

Whereas, NIR =Near Infra-Red band value, RED = Red band value.

Landsat 8 (formerly the Landsat Data Continuity Mission, or LDCM) was launched on February 11, 2013 consisting of two sensors i.e. Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). The OLI measures the visible, near infrared, and shortwave infrared portions (VNIR, NIR, and SWIR) of the spectrum (Table 2). Image processing was done by radiometric corrections for the Landsat image which was then used to calculate NDVI.

Table-2. Information of Band in OLI 8

Band number	Description	Wavelength	Resolution
Band 4	Visible red (RED)	0.634to 0.684	30 meter
Band 5	Near infrared(NIR)	0.846 to 0.886	30 meter

2.6. Statistical Analysis

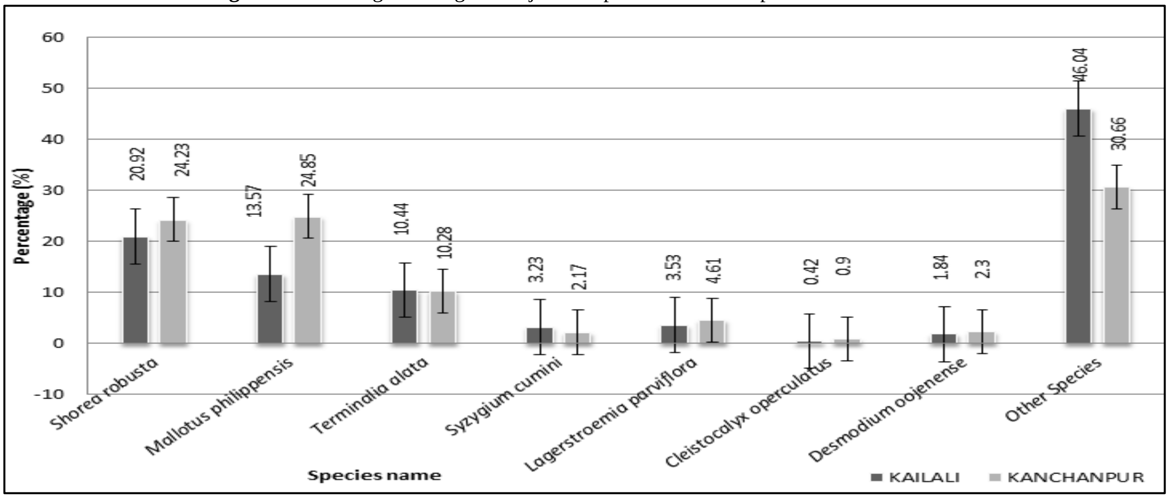
The Pearson product-moment correlation coefficient measures strength of a linear association between any two variables (carbon stock vs. NDVI, NDVI vs. H' index and carbon stock vs. H' index) and is denoted by R. The Pearson correlation coefficient, R value ranges from +1 to -1. A value of 0 indicates that there is no association between the two variables, a value greater than 0 indicates a positive association and value less than 0 indicates a negative association.

3. Result

3.1. Percentage of Tree Species in Study Site of Kabchanpur and Kailali Districts

The percentage of tree species was varying in forest of Kanchanpur and Kailali districts. The dominant tree species was *Shorea robusta* with 24.23% and 20.92% in Kanchanpur and Kailali districts respectively. Other major tree species were *Mallotus philippensis, Terminalia alata , Syzygium cumini, Lagerstroemia parviflora, Cleistocalyx operculatus, Desmodium oojenense etc.* (Figure 3).

Figure-3. Percentage coverage of major tree species in Kanchanpur and Kailali districts



3.2. Descriptive Statistics of Carbon Stock, Biodiversity and NDVI of the Study Site

The descriptive statistics of above ground carbon stock was varying Kanchanpur and Kailali districts. The mean value of above ground carbon stock with standard deviation was 109.70±64.52 and 96.76 ±53.79 ton/ha in Kanchanpur and Kailali districts respectively. The range of carbon stock was 19.14 to 277.97 ton/ha in Kanchanpur district while this was 5.67 to 244.00 ton/ha in Kailali district (Table 3).

The mean value, maximum, minimum values and standard deviation of Shannon- Weiner index was varying Kanchanpur and Kailali districts. The mean value with standard deviation of Shannon Weiner index was 1.163 ±0.512 and 1.247 ±0.56 in Kanchanpur and Kailali districts respectively. The range of Shannon- Weiner index was 0 to 2.15 and 0 to 2.321 in Kanchanpur and Kailali districts respectively (Table 3).

The result showed the descriptive statistics of NDVI of the sample plots in Kanchanpur and Kailali districts. The mean value with standard deviation of NDVI of the sampled plots was 0.491±0.268 and 0.367±0.192 of Kanchanpur and Kailali districts respectively. The value of NDVI was ranging from 0.121 to 0.978 and 0.038 to 0.999 of sampled plots of Kanchanpur and Kailali districts respectively (Table 3).

Table-3. Descriptive statistics of Carbon stock

District	Mean	Standard deviation	Minimum	Maximum value
Carbon stock ton per ha				
Kanchanpur	109.7	64.52	19.14	277.97
Kailali	96.76	53.79	5.67	244
Shannon Weiner index in Kanchanpur and Kailali districts				
Kanchanpur	1.163	0.56	0	2.15
Kailali	1.247	0.512	0	2.321
NDVI of plot of study area				
Kanchanpur	0.491	0.268	0.121	0.978
Kailali	0.367	0.192	0.038	0.999

3.3. Correlation between Carbon Stock vs. Biodiversity, Carbon Stock vs. NDVI and Biodiversity vs. NDVI

The result showed that there was positive correlation between Carbon stock vs. NDVI, Carbon stock vs H' index and H' index vs. NDVI in the study sites. The R value of Carbon stock vs NDVI was 0.54 and 0.382 of study sites in Kanchanpur and Kailali districts respectively. Similar results were found of Carbon stock vs H' index and H' index vs NDVI of the study sites of these district. t-test showed that, these equations were significant at 5% since p value was less than 0.05 (Table 4).

Table-4. Correlations of biophysical variables and NDVI of forest

Variables	R	CI at 95%	t –test	P value
Correlations of biophysical variables and NDVI of forest in Kanchanpur district				
Carbon stock vs NDVI	0.54	[0.35,0.70]	5.16	< .001*
Carbon stock Vs H' index	0.42	[0.20,0.60]	3.69	< .001*
H' index Vs NDVI	0.63	[0.46,0.76]	6.45	< .001*
Correlations of biophysical variables and NDVI of forest in Kailali district				
Carbon stock vs NDVI	0.382	[0.22,0.53]	0.382	$1.8e^{-05}$(p<0.05)
Carbon stock Vs H' index	0.288	[0.11,0.45]	0.288	0.0015 (p<0.05)
H' index Vs NDVI	0.282	[0.11,0.44]	0.282	0.0019 (p<0.05).

The map showed the range of NDVI of the forest. The high value of NDVI was indicated by blue color and low value of NDVI was represented with green color (Figure 4, 5).

Figure-4. NDVI map of Kanchanpur district

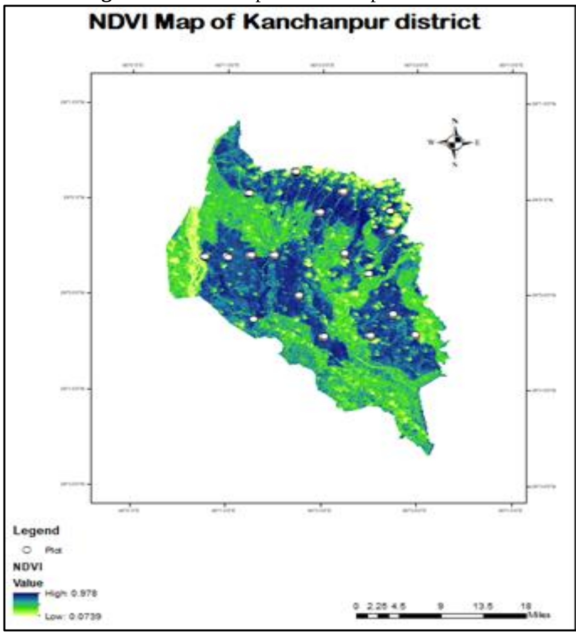
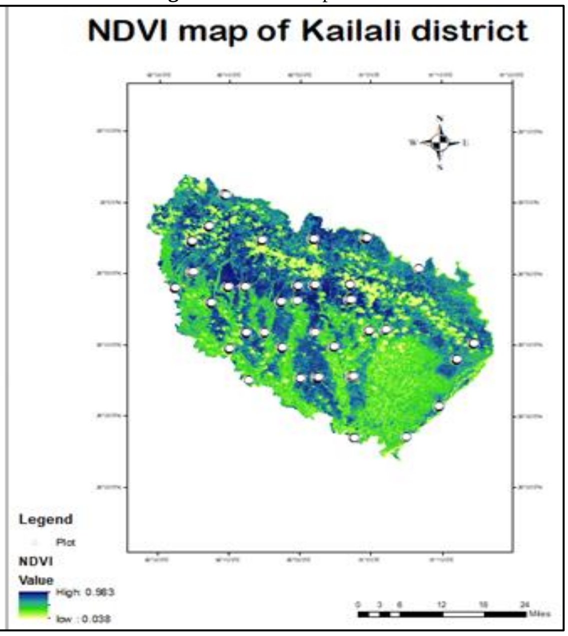


Figure-5. NDVI map of Kailali district



4. Discussion

The mean carbon stock of the study site of Kanchanpur district was about 109.7 ton/ha while this of Kailali district was 96.76 ton/ha. Several studies supports this values of carbon stocks. The study done by Mandal *et al.* (2013) showed that, there was 116.72 ton/ha in Banke Maraha collaborative forest. This value was quite similar with the finding of this research, the study sites were belonging to Terai areas. Study done in Dang district showed that the carbon stock was varying from 99.02 to 143.51 ton/ha (Regmi *et al.*, 2021). The finding was also similar to the finding of this research since Dang district is situated in western Terai region and Kanchan and Kailali districts as well. Besides storing a large amount of biomass, the trees having bigger in both DBH and height size and more carbon stocks (Pokhrel and Sherpa, 2020) .

There was statistically significant linear correlation between above-ground ground carbon stock (t/ha) and NDVI in our study. The finding of this research was quite similar to the study done in Forest of Lembah Seulawah sub-district, Indonesia (Situmorang and Sugianto, 2016). Similar results of research done in Pakistan to show the correlation between above-ground ground carbon stock (t/ha) and NDVI was 0.873) (Wani *et al.*, 2021). The study done in temperate conifer region of Himalaya showed that correlation between NDVI and aboveground biomass carbon for *Cedrus deodara* (R^2 = 0.63), Mixed I (R^2 = 0.61), *Pinus wallichiana* (R^2 = 0.57), and Mixed-II (R^2 = 0.48) (Wani *et al.*, 2021).

Statistically, Pearson correlation showed that there was positive and significant correlation between H' index and NDVI. This result was in line with the study done in Mpumalanga, Limpopo and KwaZulu-Natal (KZN) of South Africa showing the positive and significant correlation between biodiversity and NDVI (Madonsela *et al.*, 2021). A study done in a Savanna ecosystem showed that there was significant correlation between NDVI and Shannon index of diversity (Chapungu *et al.*, 2020). Likewise, a study was conducted in temperate forest of Turkey where the correlation between (H') and NDVI was positive and strong (Arekhi *et al.*, 2017).

There was positive correlations between above ground carbon stock and H' index with (r=0.42, p=0.00047) and (r=0.29, p=0.0015) in Kanchanpur and Kailali districts respectively. The study done in pilot carbon offset projects in southwestern, Uganda showed similar result like a positive relationship between tree carbon stock and species diversity (Nakakaawa *et al.*, 2010). Another study done in Spruce-dominated forest of Uganda also showed the positive correlation between carbon stock and diversity (Wang *et al.*, 2011). Another similar result was study conducted in central African Rainforest (Day *et al.*, 2014). Another study done in collaborative forest of central region of Terai, Nepal showed the positive correlation between carbon stock and biodiversity (Mandal *et al.*, 2013).

5. Conclusion and Recommendation

The value of carbon stock, biodiversity index and NDVI was quite satisfactory in Kanchanpur and Kailali districts. There was positive correlation between carbon stock vs NDVI, Shannon-Weinner biodiversity index vs NDVI and carbon stock vs biodiversity.

Application NDVI to monitor forest carbon and biodiversity is useful for academician and policymaker. This will provide value of carbon stock, biodiversity and NDVI in the forest of western Terai, Nepal. However, further research should be focused on assessment of species wise correlation with NDVI values. It is recommended to use high resolution satellite image for studying vegetation indices.

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