Vegetation Dynamics in Response to Climate Change Based on Satellite Derived NDVI in Nepal

Binod Baniya, Qiuhong Tang

Institute of Geographical Science and Natural Resource Research (IGSNRR),Chinese Academy of Science (CAS), Beijing, China

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Presentation Highlight

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   - Research methods
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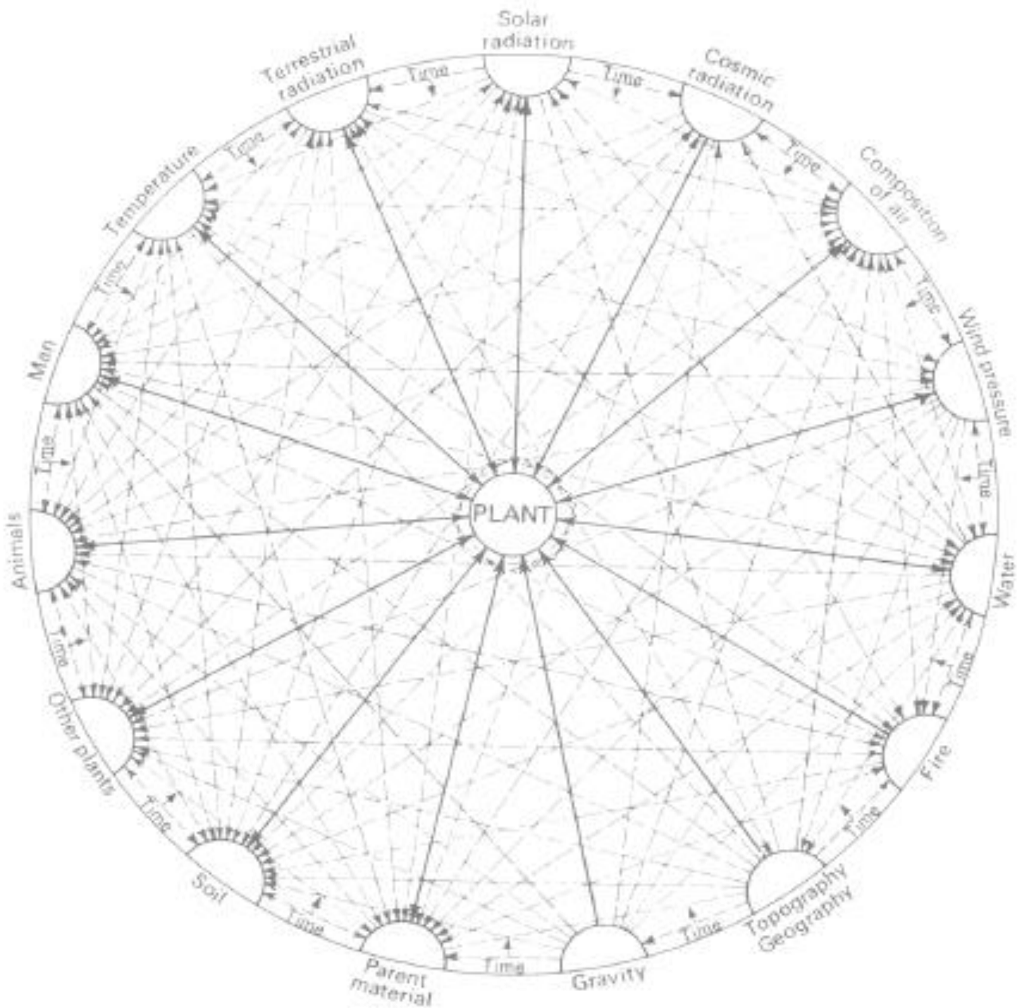
1. Introduction

Billing's Focus on Individual Plant



W.D. Billings 1952;The environment complex in relation to plant growth and distribution; Quarterly review of Biology, 50: 251-265

Environment Complex in Plants	
Climate	Radiation
	Temperature
	precipitation
	Atmospheric gases
Edaphic	Parent materials
	Soil
Geographic	Gravity
	Rotational effects
	Geographic position
	Volcanism
	Diastrophism
	Erosion and deposition
	Topography
Pyric	Fire
Biotic	Plants competition
	Animals
	Man

Principle of Limiting Factor

Liebig's Law of the Minimum (Justus Liebig in 1840)

"Growth of plants depends on the amount of factors presented to its minimum quantity"

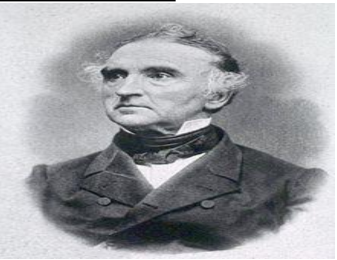


Photo: Justus Freiherr von Liebig (1803 –1873)

Shelford's Law of Tolerance (V.E. Shelford, 1913)

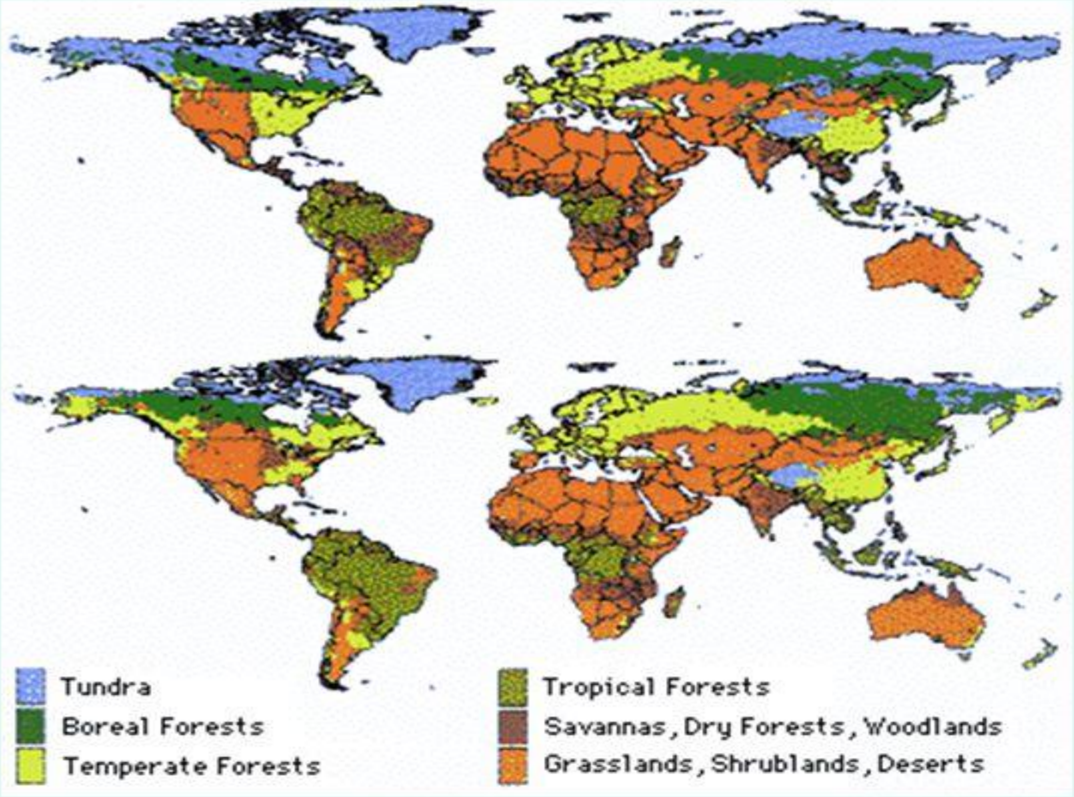
Organism have an ecological minimum and maximum with a range in between which represents the limit of tolerance

Photo: Victor Ernest Shelford

Shifts in Terrestrial Habitat

- It is predicted that at the end of this century there will be large scale shifts in the global distribution of vegetation in response to anthropogenic climate change.
- With man doubling the amount of carbon dioxide entering into the atmosphere the climate is changing more rapidly then plant migration can keep up.

Potential distribution of the major world biomes under current climate conditions



Projected distribution of the major world biomes by simulating the effects of 2xCO_2-equivalent concentrations

www.usgcrp.gov/usgcrp/ seminars/960610SM.html

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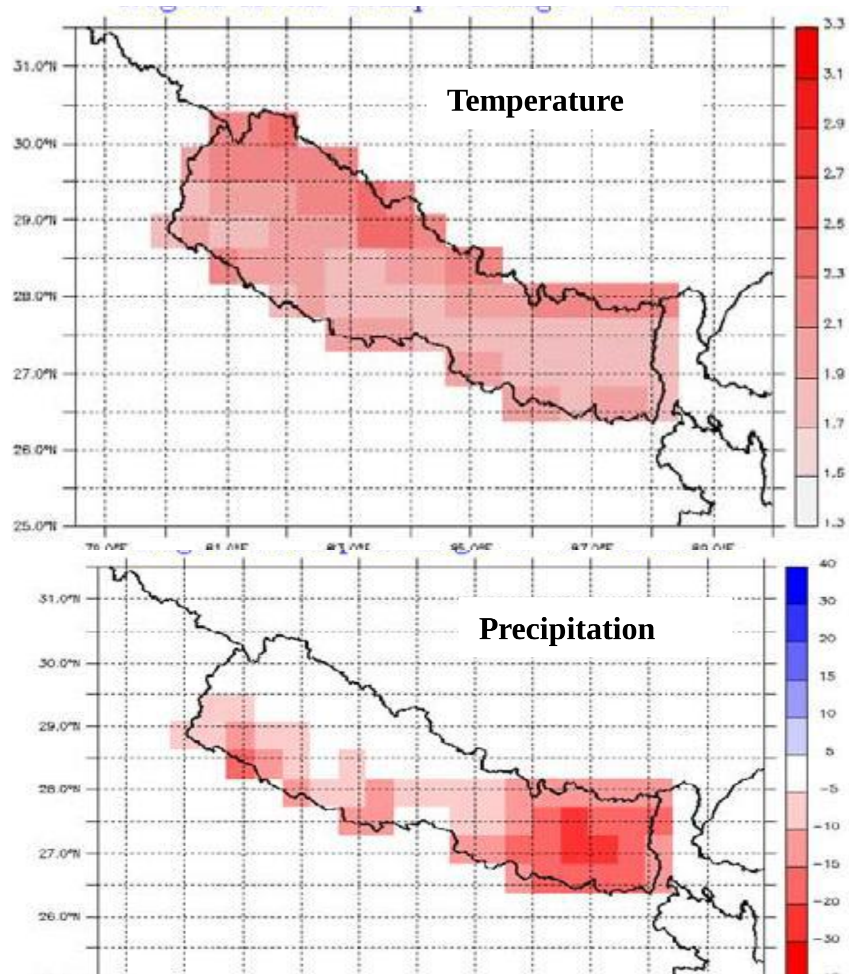
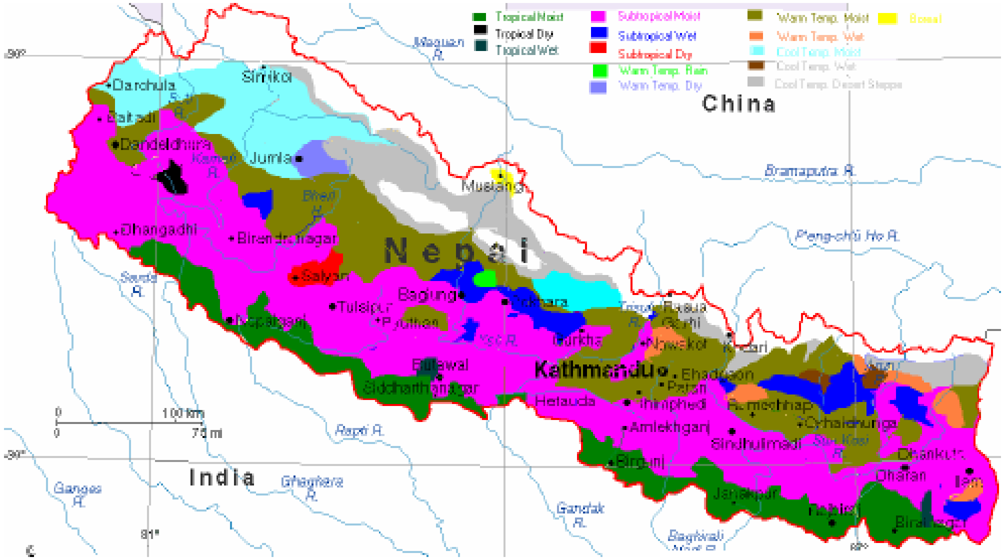
Climate Change in Nepal

- Nepal produces 3.04 million tons of Carbon dioxide per year. It is 0.0126% Co_2 emission share globally (WRI, 2011)
- 0.04°C in period of 1996-2005 (Sharma, K.P., 2009) , 0.06°C from 1977-1994 (Shrestha et al. 1999)
- 0.027°C per decade (IPCC, 2007), Warming occurs over entire the country, 1.7⁰C in the South and 2.5⁰C in the North
- Precipitation decreased in large parts of the country, Mostly decreased in Eastern and Southern part
- Climate : tropical in the South to alpine in the North



Source: Department of Hydrology and Meteorology (DHM),2007

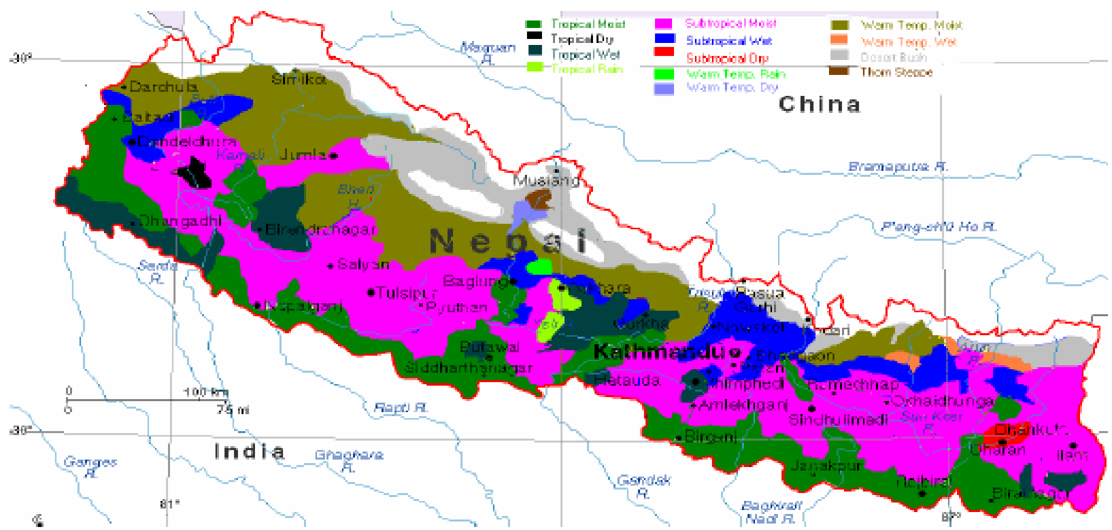


Climatic Zone Shift in Nepal

Bio-climatic Zone of Nepal, Source: Stanton, 1972

- Tropical Climate (below 1000m)
- Sub-tropical climate (1000-2000m)
- Temperate climate (2000-3000m)
- Sub-alpine Climate (3000-4000m)
- Alpine Climate (4000-5000m)
- Nival Zone (above 5000m)

Source: MoSTE, 2010



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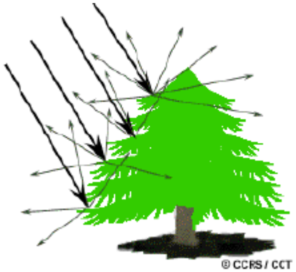
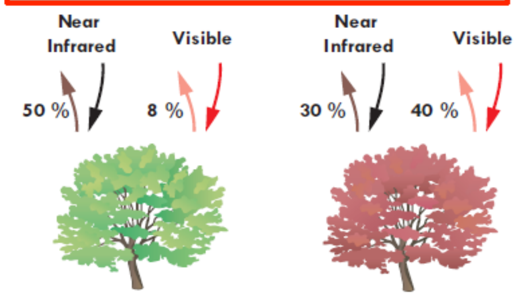


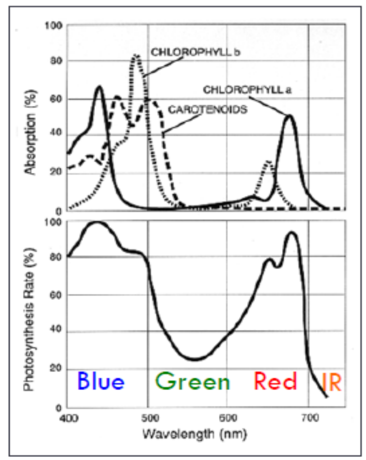
Normalized Difference Vegetation Index - NDVI

NDVI is the normalized ratio of red and near-infrared (NIR) reflectance (Tucker, 1979)

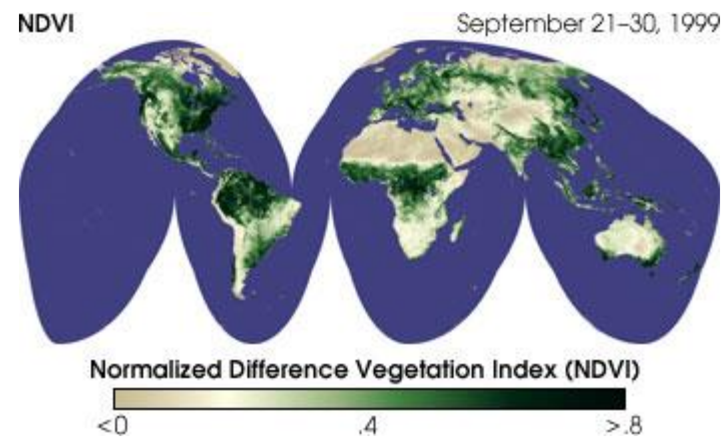
NDVI = (NIR – VIS) / (NIR + VIS)



$$\frac{(0.50-0.08)}{(0.50+0.08)} = 0.72 \qquad \frac{(0.40-0.30)}{(0.40+0.30)} = 0.14$$



Typical PAR action spectrum, shown beside absorption spectra



- The chlorophyll in plant leaves strongly absorbs visible light (from 0.4 to 0.7 μm) for use in photosynthesis. The cell structure of the leaves, on the other hand, strongly reflects near-infrared light (from 0.7 to 1.1 μm).

Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high values indicate temperate and tropical rainforests (0.6 to 0.8).

2. Objective

To study vegetation dynamics in response to climate change based on satellite derived NDVI in Nepal

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3. Methodology

Study Area: Salient Features

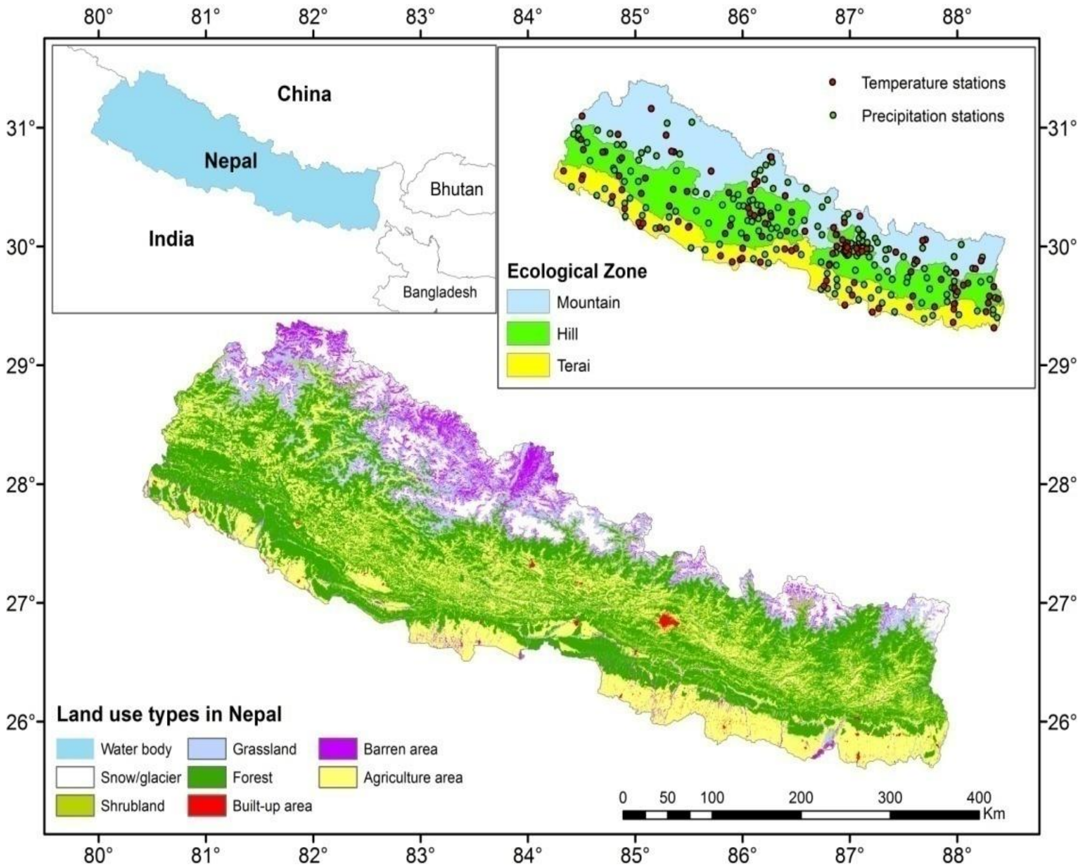
Geographical location

- Latitude: 26º 22' and 30º 27' North
- Longitude: 80º 04' and 88º 12' East

Boundary: Tibetan highland to the north and an Indian foothill of the Himalaya to the south.

Altitude: varies between 60-220m in the South and reaches a maximum of 8,848 m in the North

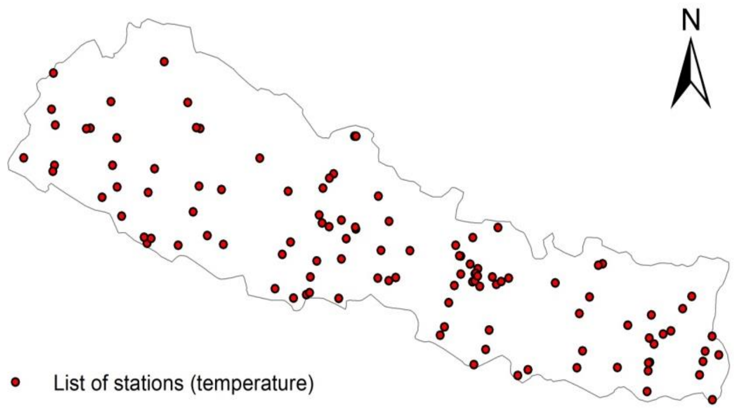
Climate: average temperatures from -18ºC in North to 26ºC in South; average annual precipitation is about 1516 mm

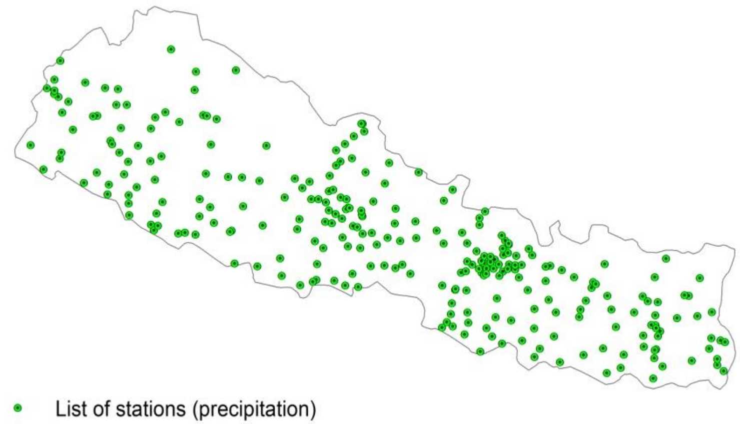


NDVI and Climatic Data Sets

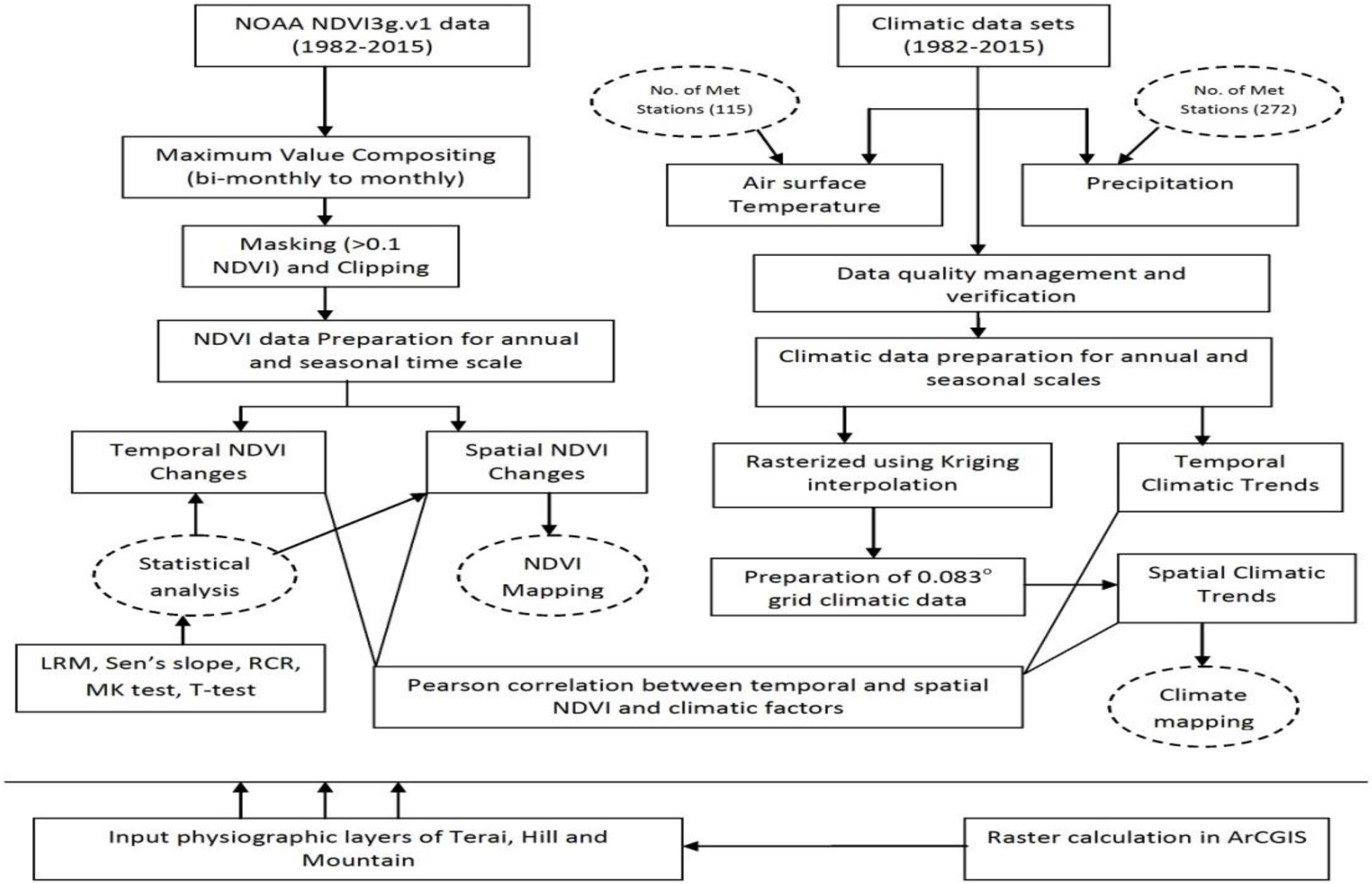
1. **NOAA, AVHRR, NDVI3g, 1981-2015**

2. **Ground based temperature and precipitation data:** monthly precipitation from 272 meteorological station and maximum and minimum air temperature from 115 meteorological station are used for the study





Schematic flow of study method



1. Linear Regression Method

2. Sen’s non parametric slope
3. Relative Change Ratio
4. Pearson Correlation Coefficient
5. Spatial analysis using ArcGIS and Kriging interpolation

Biomass Carbon Density (BCD) estimation model

This model is the satellite based empirical global forest biomass model used by the Piao et al, 2005 using $NDVI_{max,}$ latitude and longitude

$$BCD = 111.521\, ln(NDVI) - 0.452\, lat - 20.034\, lon + 0.08568\, lon^2 + 1278.29 \quad ....(5)$$

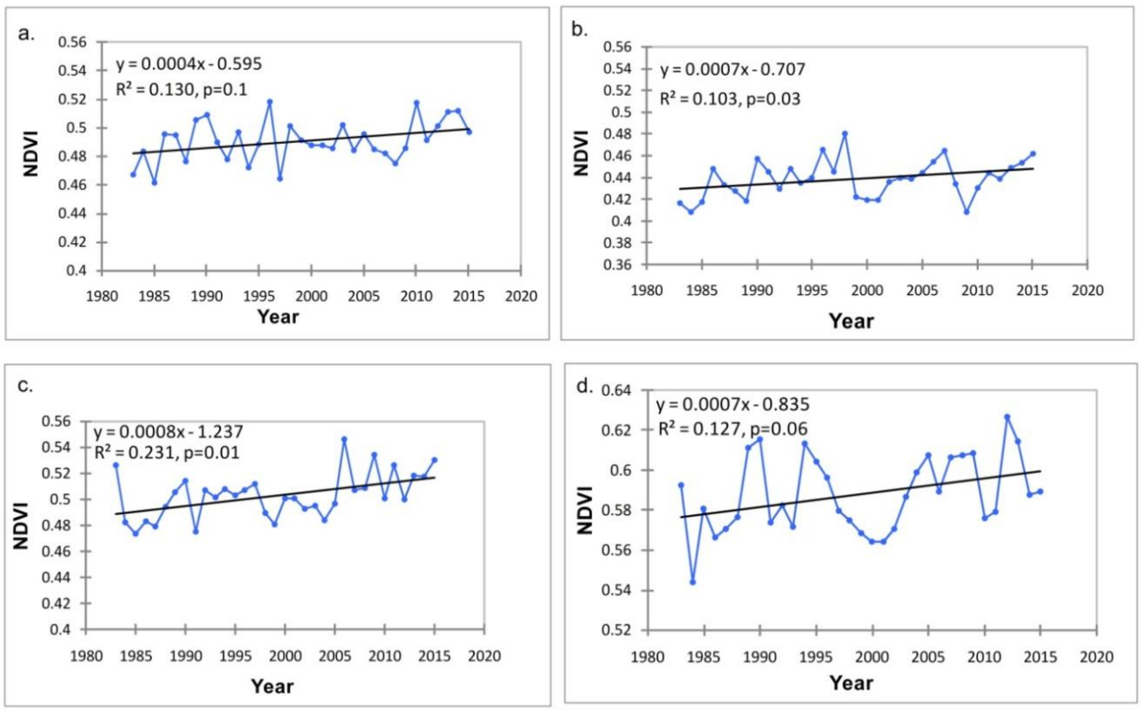
Where,

BCD is forest biomass C density (Mg C/ha), NDVI is the $NDVI_{max}$, and lat and long are the latitude and longitude.

This model was also used by Myneni et al 2001 and Dong et al 2003 based on growing season total NDVI, annual average NDVI and latitude.

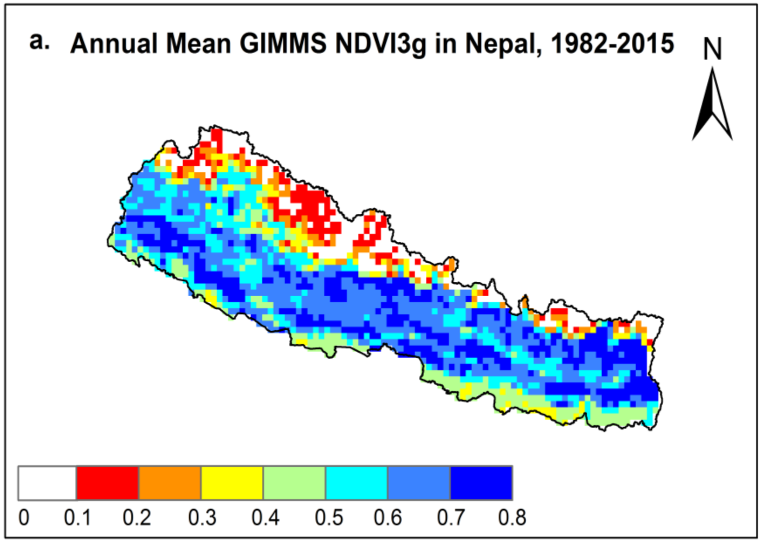
4. Results

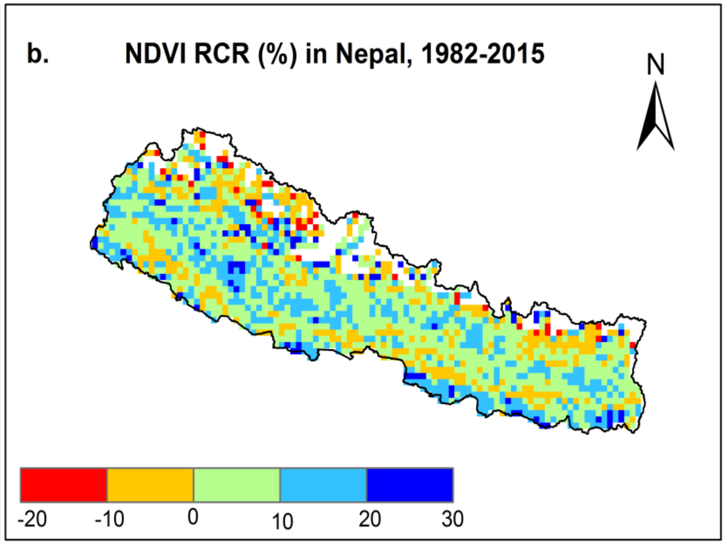
Time Scale	Linear Slope	Sen's slope	Kendall tau	P-value	Test statistic	Mean ±SD	RCR (%)
Annual	$0.0009yr^{-1}$	$0.0008yr^{-1}$	0.45	0.0001	Significant	0.50±0.015	6.29
Winter	$0.0006yr^{-1}$	$0.0004yr^{-1}$	0.20	0.10	Insignificant	0.491±0.015	4.14
Pre-Monsoon	$0.0006yr^{-1}$	$0.0007yr^{-1}$	0.25	0.03	Significant	0.439±0.017	4.89
Monsoon	$0.0009yr^{-1}$	$0.0008yr^{-1}$	0.31	0.01	Significant	0.503±0.017	5.93
Post-Monsoon	$0.0009yr^{-1}$	$0.0007yr^{-1}$	0.22	0.06	Insignificant	0.588±0.019	5.41



The annual, pre-monsoon and monsoon season NDVI has significantly increased with the rate of 0.0008 yr^{-1}(p=0.0001), $0.0007yr^{-1}$(p=0.03) and $0.0008yr^{-1}$ (p=0.01) respectively.

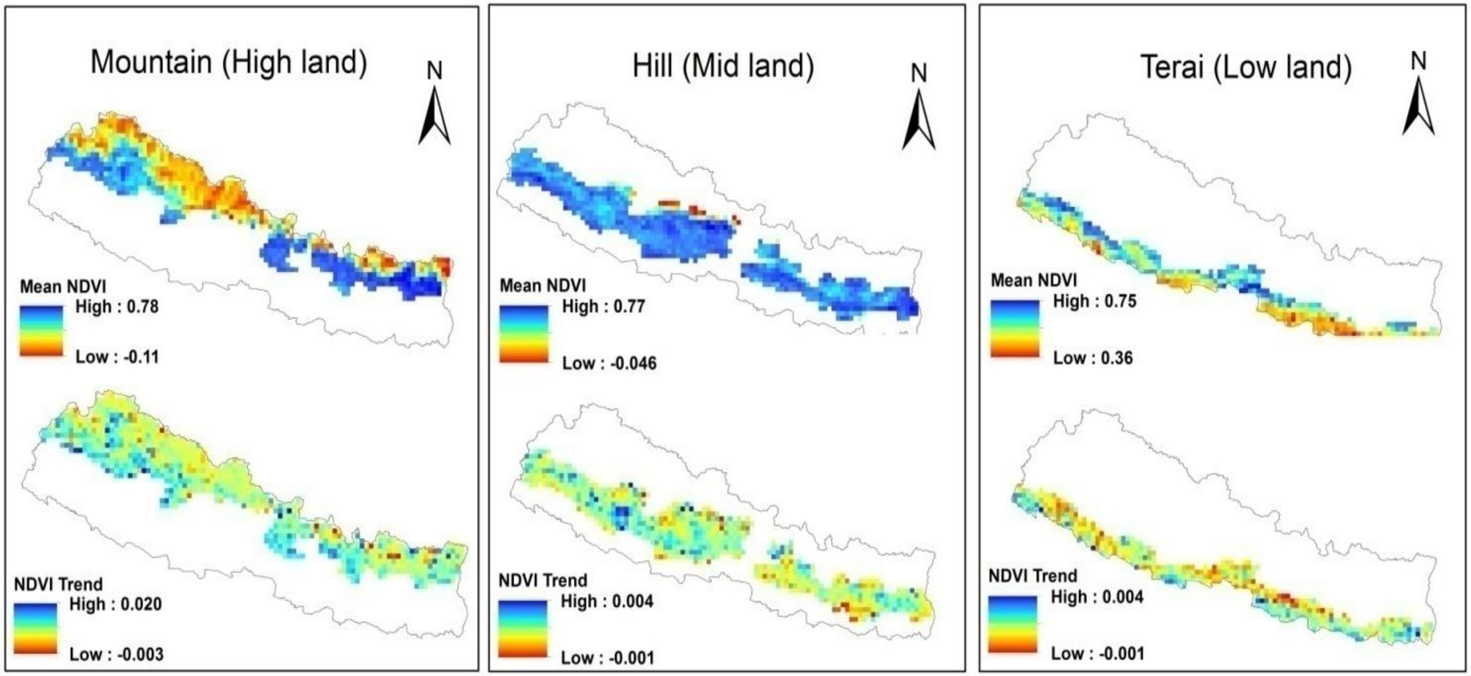
The NDVI in 83.89% (57.35% significant, $p<0.05$) of the study area shows an increasing trend and 16.10% (4.68% significant, $p<0.05$) of the area presents a decreasing trend.





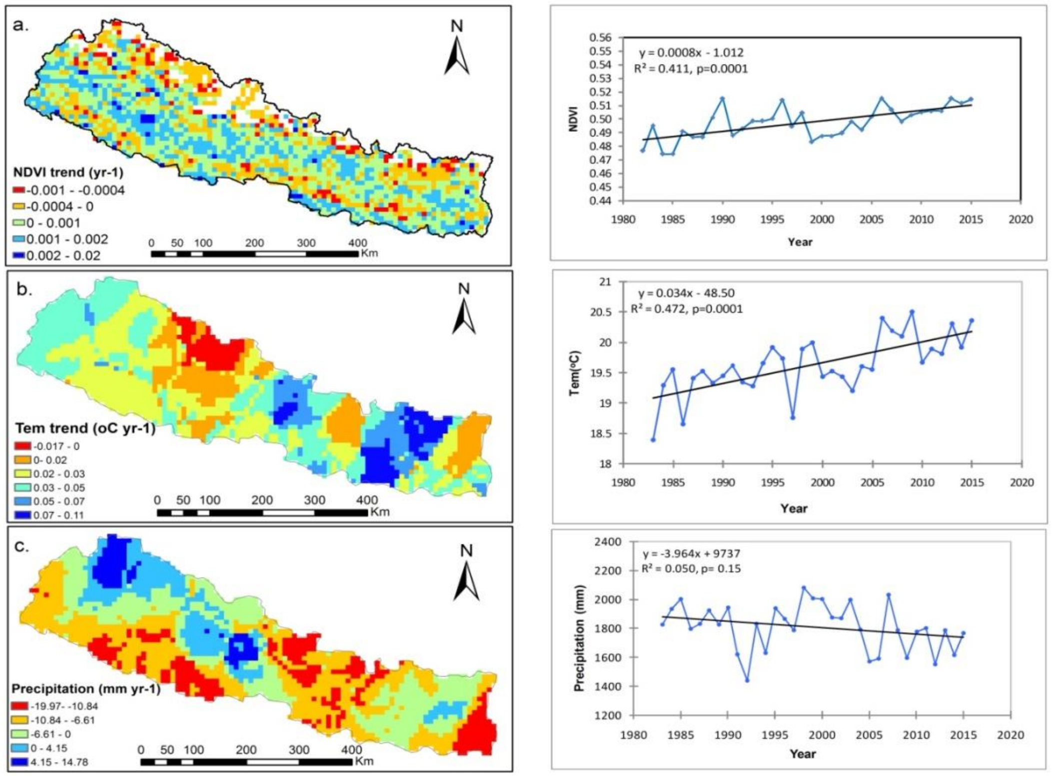
The annual mean temperature has significantly increased at the rate of 0.03°Cyr^{-1} and the maximum temperature has increased by 0.04°Cyr^{-1}. The precipitation has decreased at the rate of 3.96$mmyr^{-1}$ during 1982-2015

Ecological Zone	Mean NDVI	NDVI Slope(yr^{-1})	NDVI RCR (%)	Ave. annual tem (^oC)	Slope ($^oC\ yr^{-1}$)	Ave. annual ppt (mm)	Slope ($mmyr^{-1}$)
Terai	0.56	0.0010	7.16	21.34	0.041	1744.81	-9.20
Hill	0.60	0.0012	7.20	19.40	0.038	1817.24	-5.71
Mountain	0.36	0.0005	5.03	17.52	0.035	1591.21	-3.86



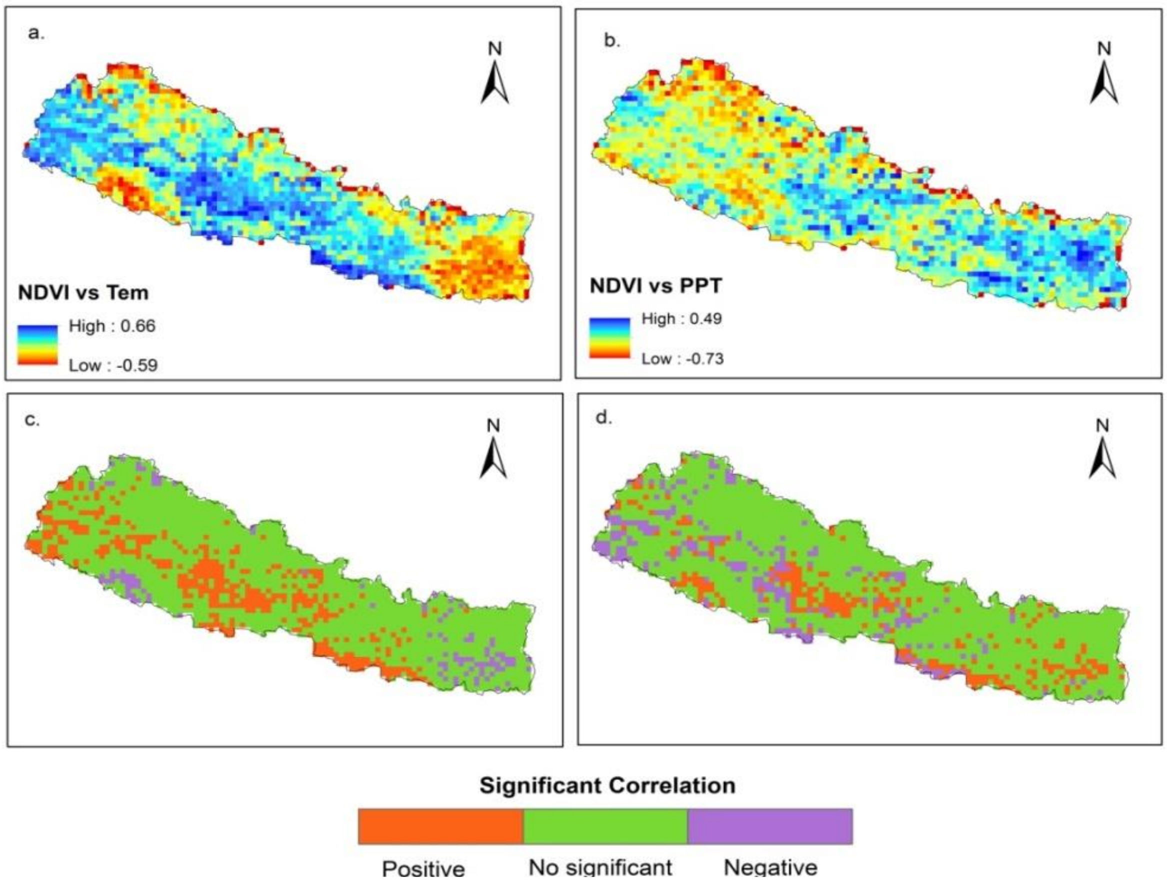
The elevation ranges in Terai is below 1000m altitude, 1000-3000m altitude in hills and more than 3000m altitude represents high lands i.e. the mountain and Himalaya (Gurung et al, 1987)

The spatial and temporal trends of NDVI, temperature and precipitation during 34 yrs study periods in Nepal

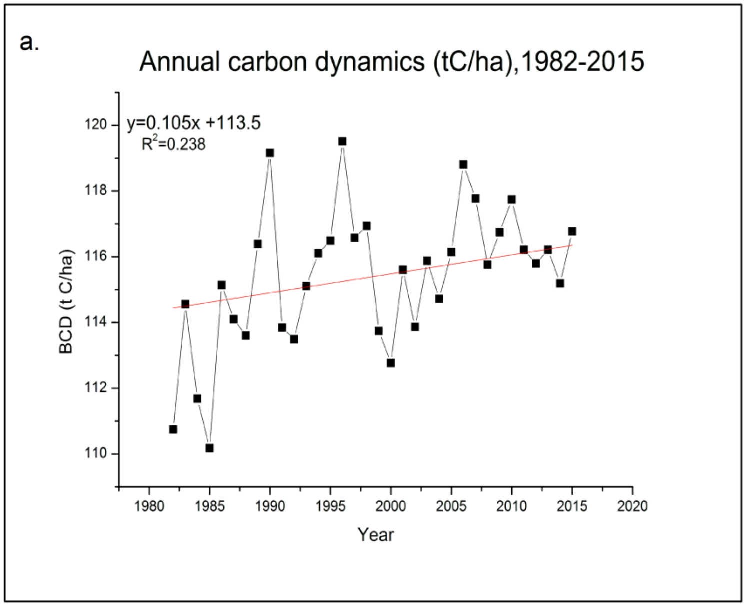


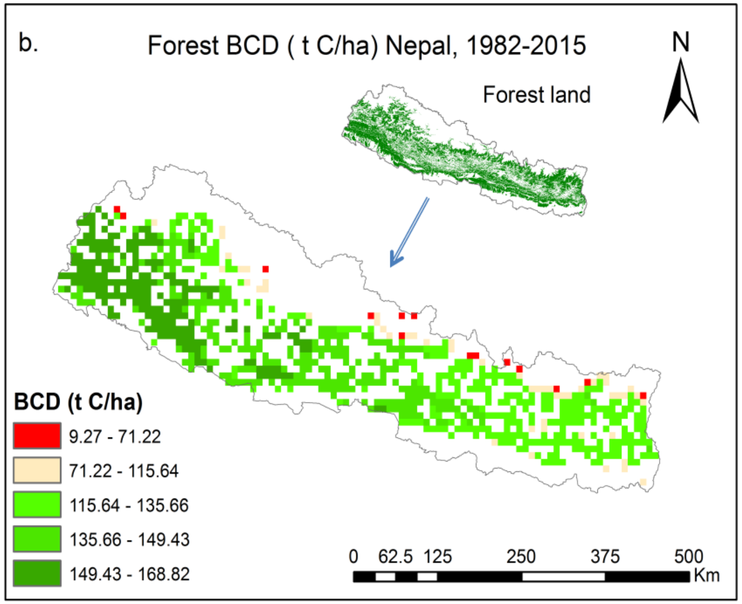
Correlation Coefficient	Winter	Pre-Monsoon	Monsoon	Post-Monsoon	Annual
R_T	0.23(0.2)	-0.07(0.7)	0.58(0.0005)	0.17(0.35)	0.38(0.03)
R_P	-0.01(0.93)	0.09(0.62)	-0.32(0.07)	-0.05(0.78)	-0.13(0.46)

Correlation	Positive	Significant Positive	Negative	Significant Negative
RT	66.42%	19.75	31.43	5.43
RP	53.12	13.05	44.74	12.13



NDVI analysis showed average forest carbon stock in Nepal is 115.392 t C/ha with annual carbon sequestration rate of 0.10 t C/ha during 1982-2015. The total Nepal's forest carbon stock is found 685.45 × 10^6 t C.





The present study indicates an increase of 6.77 t C/ha in average carbon stock difference of 6.23% compared to that of government's inventory data. Government's field based study obtained an average value of 108.62 t C/ha in between 2010-2014

5. Conclusions

- The study provides spatial and temporal NDVI and climatic trends and the implication of NDVI on carbon dynamics during last three decades in Nepal.
- The result indicated that annual and seasonal NDVI experienced an increasing trend overall in Nepal. The average temperature has increased and the precipitation decreased.
- The majority of the areas have experienced significant positive NDVI trends.
- In forest land, the carbon stock has showed increasing in trends with its high spatial heterogeneity.
- The correlation between NDVI and temperature is significantly positive in large areas compared than precipitation but the time series correlation between the NDVI and precipitation is mostly negative.
- It shows that temperature and precipitation is recognized as a more sensitive climatic factor affecting vegetation growth in Nepal.

6. Acknowledgements

- CAS-TWAS President's PhD Fellowship
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Thank you for your kind attention !!

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