Chapter 6

RESULT:

BIOMASS PRODUCTION ALONG THE ALTITUDINAL GRADIENT

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Biomass is defined as the total amount of dry weight of forest cover per unit area of land at any time, and is expressed in terms of tonnes (Lodhiyal & Lodhiyal, 2003). Also, it can be expressed as above ground biomass and below-ground biomass. It measures the change in forest structure (Schreuder *et al.,* 1997; Husch *et al.,* 2003). Several methods are in use to estimate forest biomass (Ovington 1968; Whittaker 1966): (1) Destructive and Non-destructive techniques (Foody *et al*., 2003; Zheng *et al*., 2004; Muukkonen & Heiskanen, 2005) and (2) Sampled data based using Satellite imagery (Brown *et al*., 1999). The former method is commonly used for biomass estimation.

Non-destructive technique for biomass estimation is widely used technique using field based data (Hunter *et al*., 2013; Garcia *et al.,* 1993). In this method tree specific regression equation were involve *viz*. Tree diameter/circumference, tree height and basal area are used as independent variables. Brown *et al*. (1989) used non-destructive sampling technique to estimate the volume of the tree and then converted into biomass using the specific gravity of individual species. Rana *et al*. (1989) used the field based method for the estimation of biomass for Central Himalaya. Bhattarai *et al*. (2004) performed field study of alpine grassland of the Central Himalayan part of Nepal for the estimation of biomass. Wang *et al*. (2014) saw the variations in the live biomass and carbon pools of *Abies georgei* Hand._Mazz. (*A. forestii* Coltm.-Rog.) along an elevation gradient on the Tibetan Plateau, China. There are several factors which directly control the biomass of the plants; some of those are climate (Wang *et al*., 2014) anthropogenic activities etc. Sundriyal and Sharma (1996) observed the impact of anthropogenic pressure on tree structure and biomass production in the temperate forest of Mamlay watershed in the South district of Sikkim.

The estimates of forest live biomass are still an important source of uncertainty in the carbon balance from local to regional scale, partly due to the scarcity of reliable estimates of live biomass and its variation across landscapes and forest types (Alves *et al*., 2010; Wang *et al*., 2014). Biomass assessment is necessary because forests are affected by various factors like deforestation, fire, uncontrolled harvest of different minor forest produces, pests, silviculture and climatic change (Schroeder *et al*., 1997; Change, I.P.O.C. 2006.) those bring considerable changes in the forest ecosystem.

Many studies have been analysed to understand the forest biomass patterns along elevation gradients in tropical mountains, The use of elevation gradients within the same biogeographic zone (tropical, temperate, boreal) is considered to be particularly powerful tool for improving biomass estimates across spatial variations and environment gradients (Wang *et al*., 2014).

Many environmental factors (e.g. rainfall, temperature, atmospheric pressure, solar radiation, wind velocity, etc.) change systematically with the change in elevation. Therefore, to test the ecological and evolutionary responses of biota to environmental changes the altitudinal gradients are among the most powerful techniques (Korner, 2007)

The above ground biomass and its dry weight decreases with the increasing elevation, and there are significant differences at different elevations (Jia *et al*., 2006). Goward and Dye (1987) opined that the integrated vegetation index can be related directly to the amount of vegetation (above ground phytomass) and primary productivity.

Chhabra *et al*. (2002) studied the average total growing stock volume density in India for the study years 1992 – 1993. Average total growing stock volume density in India was estimated as 74.42 m3 t/ha; with a range of 7.1–224.5 m3 t/ha. The mean biomass density in Indian forests was estimated at 135.6 t /ha and amongst the states it varied from 27.4 t /ha in Punjab to 251.8 t/ ha in Jammu & Kashmir. The total standing biomass (both, above and below ground) was estimated at 8683.7 Mt. The above ground and below ground biomass was estimated at 6865.1 and 1818.7 Mt; contributing 79 percent and 21 percent to the total biomass. The study has also highlighted state level differences in forest biomass density in India (Chhabra *et al*., 2002). The total above and below ground forest biomass in all states and union territories were estimated as 6865.1 and 1818.7 Mt, respectively. Sikkim contributes 48.1Mt. Total above ground biomass and below ground biomass has been calculated as 12.3Mt and 60.4Mt (Chhabra *et al*., 2002). Estimation of forest biomass is the key for understanding the exchange of energy flow, primary production and fluxes of nutrients in a forest ecosystem (Thakur, 2014).

Similarly, Sundriyal and Sharma (1996) recorded 8.32 t ha-1 for wood biomass and 1.80 t ha-1 for floor phytomass during their studies in the temperate forest of Mamlay watershed in South Sikkim.

The effect of adjusting plot placement to include large diameter trees over estimates forest biomass because biomass per tree increases geometrically with increasing diameter (Haripriya, 2002) The minimum diameter of sampled trees in India is more than 10 cm, reflecting the dominant interest in inventories of commercial volumes (Brown *et al.*, 1989). Though the smaller trees may have less volume than larger trees, they often contain relatively more trees than larger size classes and in certain cases they may contain important proportions of the total stand volume per biomass (Haripriya, 2002).

The above-ground biomass is mainly the largest carbon pool and it is directly affected by deforestation and forest degradation. Estimating the forest carbon stocks is mainly important to assess the magnitude of carbon exchange between the forest ecosystem and the atmosphere. Assessment of the amount of carbon sequestered by a forest will give us an estimate of the amount of carbon emitted into the atmosphere when this particular forest area is deforested or degraded. It will also help us to quantify the carbon stocks which in turn will enable us to understand the current status of carbon stock and also derive the near-future change in the carbon stock (Vashum & Jayakumar, 2012).

Sun *et al.* (2013) and Khan *et al.* (2014) studied the alpine meadow area, they found that elevation and soil moisture are strongly negative effects on above ground biomass (AGB) where as abundance, and soil nitrogen content was positively related to the AGB distribution. This study has confirmed that the average shrub biomass declined with increasing altitude.

This chapter records the estimation of biomass along the altitudinal gradient of Sikkim Himalayas. As has already discussed in the previous chapter the altitudinal range of the study area is spreading over from 500 m to 3300 m in the east district of Sikkim. The present study has estimated the total above ground biomass of this district using growing stock assessment field inventory method. Biomass was estimated using the tree volume formula and tree volume equation developed by FSI (1996). The methodology used for the calculation of biomass in East Sikkim has been detailed in the methodology chapter.

6.1. Biomass Productivity

Amongst others, the two type of non-destructive method for estimation of above Ground biomass is used in this study are (1) using the field sampled data like species number, tree height, CBH etc. and (2) Using the satellite based data.

6.1.1. Field data

Field productivity of East district of Sikkim Himalaya estimated, using the field sample plots data. There are 224 quadrats laid while collecting the field data from where a total 664 plant species collected from 28 elevation steps (500 – 3300 m). The biomass of the study area has been estimated using the volume equation of FSI (1996). The estimated biomass is ranging from 6.3 t/ha at 3150 m and 68.6t/ha at 2650 m in different elevation range in the East district. In an average 38t/ha biomass estimated from our field data.

6.1.1.1. Circumference at Breast Height (CBH): The CBH of above 10 cm of plants are taken as trees to estimate the biomass. *Lithocarpus pachyphyllus* is the biggest tree with CBH of 557 cm. The other big trees were *Castanopsis tribuloides*, *Quercus lineata*, *Quercus lamellosa* etc. Those contributed more than 500 cm CBH. The Diameter at Breast Height (DBH) is calculated using the recorded CBH, which, in turn, used for further volume calculation.

6.1.1.2. Tree height: the tree height collected from the field using range finder for 6 – 7 trees, than for other ocular estimation applied to estimate the tree height. The highest tree observe in the study area was *Artocarpus lacucha* and *Schima wallichii* with upto 37 m height followed by *Quercus lamellosa*, *Lithocarpus pachyphyllus* and *Magnolia lanuginosa*.

6.1.1.3. Basal area: It is similar to CBH and the *Lithocarpus pachyphyllus* found to possess the largest basal area in the study area.

6.1.1.4. Volume Estimation

Volume of the tree is a major component for the biomass/productivity estimation; first the individual tree volume was calculated in Microsoft excels using Volume equation formula of FSI, 1996 (*Annexure IV*). The volume is also correlated with CBH and basal area. *Lithocarpus pachyphyllus* found the largest one. The list of top 10 volume contributing trees are shown in Table 6.1.

Table 6.1. List of top ten volume contributor tree species from the East District of Sikkim

Sl. No	Plant Species	Volume contribution of the study area in M^3
1	*Castanopsis hystrix*	780.69
2	*Schima wallichii*	702.90
3	*Quercus lamellosa*	586.91
4	*Lithocarpus pachyphyllus*	507.66
5	*Alnus nepalensis*	350.93
6	*Acer campbellii*	328.92
7	*Engelhardtia spicata* var. *integra*	283.42
8	*Engelhardia aurifolia*	152.63
9	*Castanopsis tribuloides*	152.26
10	*Abies densa*	107.78

6.1.1.5. Biomass estimation

Biomass (Productivity) of the study area calculated using the volume and specific gravity of trees (*Annexure IV*), the *Quercus lamellosa* contributed the highest biomass followed by *Castanopsis hystrix* the detail of top 9 species is given in the Table 6.2.

Table 6.2. List of tree species as per their contribution of biomass

Sl. No.	Plant name	Contribution of Biomass by individual species t/ha.
1	*Quercus lamellosa*	410.249
2	*Castanopsis hystrix*	402.053
3	*Schima wallichii*	349.343
4	*Lithocarpus pachyphyllus*	261.446
5	*Acer campbellii*	163.471
6	*Engelhardtia spicata* var. *integra*	140.860
7	*Alnus nepalensis*	111.947
8	*Castanopsis tribuloides*	78.414
9	*Engelhardia aurifolia*	75.858

6.1.1.5.1. ***Along 100 m elevation step:*** It was seen in 100 m elevation gradient the biomass production increases with altitude up to the limit of tropical forests. The negative pattern was observed in sub-tropical forests between 900 – 1400 m elevation section, the major human habitation areas also fall in this region. Then, the biomass t/ha suddenly increase and reach to about 60 t/ha at around 1700 m elevation. It again decreased to about 30 t/ha at around 2000 m elevation. As we observed the overall pattern of biomass production along the altitude increases along the elevation in the temperate forest zone. After that, the production decreases with the increased elevation.

As shown in figure 6.1 the relation between biomass and elevation, as the elevation increases the tree biomass decreases. Similarly, the number of trees in the sample area also decreases with increased elevation.

Result was found significant at $p<0.10$, it shows that there was a poor relation of biomass along the elevation gradient of 100 m in the east district of Sikkim (Fig. 6.1).

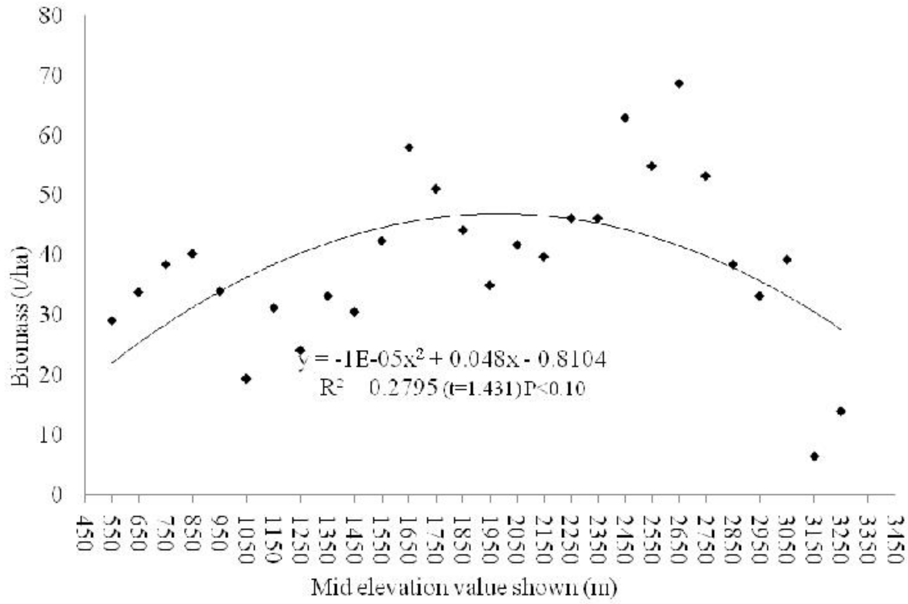


Fig. 6.1. Relationship between biomass and altitude along 100 m elevation step

6.1.1.5.2. ***Along 200 m elevation step*****:** The relation of biomass along the 200 m elevation gradient has been evaluated as shown in figure 6.2. In this step the relation of biomass and elevation $R^2=0.410$, it shows that there is 41 % chance to be a good relation of these two parameters.

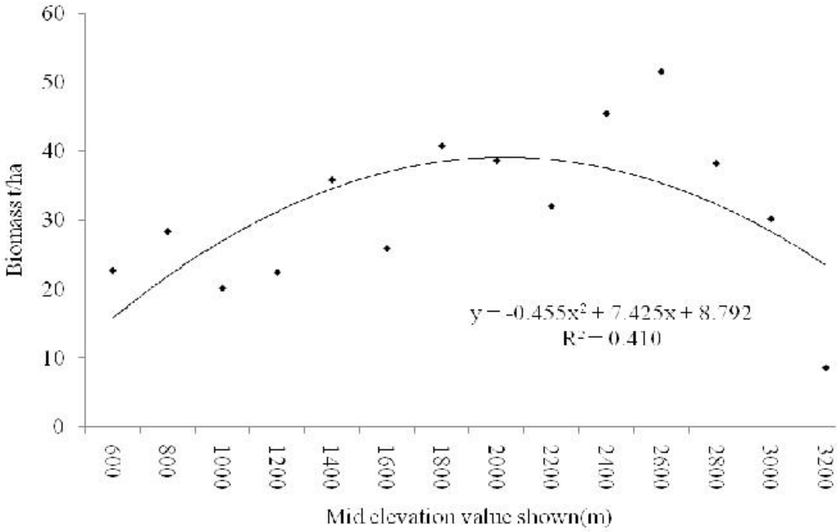


Fig. 6.2. Relationship between biomass and altitude along 200 m elevation step

6.1.1.5.3. ***Along 300m elevation step:*** The relation of biomass along the 300 m elevation gradient has been shown in figure 6.3. The R^2 at 0.58 is the expression of a good relation with altitude in 300 m elevation band. Here, a hump-shaped relation of biomass along the elevation gradient peak at around the 2500 m elevation is clearly visible.

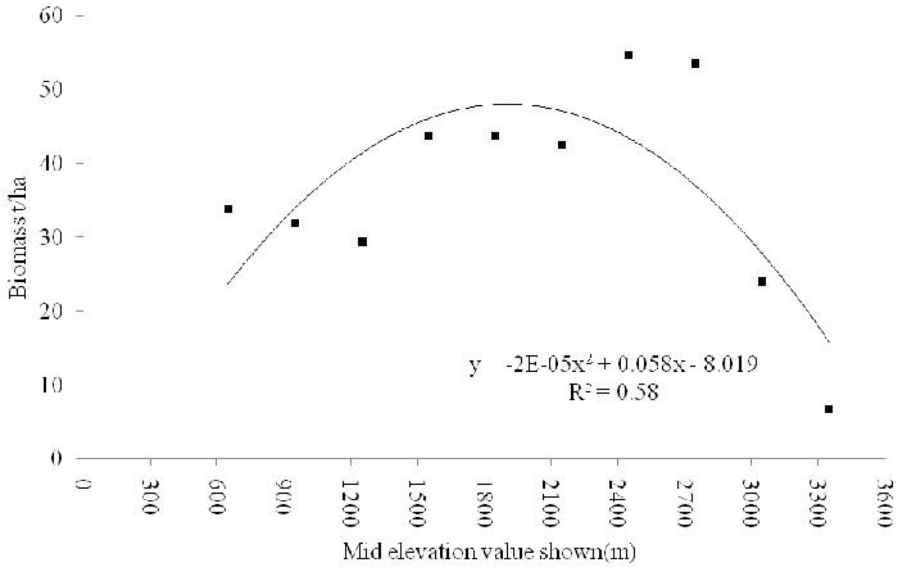


Fig. 6.3. Relationship between biomass and altitude along 300 m elevation step

6.2. Satellite based relation of Biomass

Several works has been conducted with remote sensing imageries and their utility in the field of plant biomass. The remote sensing satellites are equipped with sensors looking down to the earth. They are the “eyes in the sky” constantly observing the earth as they go round in predictable orbits. There are different types of remote sensing satellite data, *viz*. Optical, Microwave, Infrared Radar, etc. This elucidate the relation between the satellite based plant productivity NPP with the field derive biomass. Zhang *et al*. (2009) observed the Global pattern of NPP to GPP ratio derived from MODIS data, they observed that geographically, the NPP/GPP ratio increased with altitude but in the Southern Hemisphere, the NPP/GPP ratio decreased along latitude. MOD17 product, are limited by the spatial resolution. Sims *et al*. (2006) shown that a model based solely on EVI provided as good or better estimates of productivity for most of the sites than did the much more complex MOD17 model . MODIS data inputs are best suited to assessments of large forested tracts of land where stand ages are relatively uniform (Potter *et al*. 2007).

6.2.1. Landsat-8 NDVI and EVI: Similarly, the range of NDVI values observed -0.053 to 0.488 this shows that the NDVI values was saturation up to 0.488 only on the other hand, the EVI2 derived value range shows 0.07 to 0.90 in different month data (Fig. 6.4).

Further there is a limitation of optical satellite data (Landsat imagery) is that fewer cloud-free dates are typically available that can be collected over the course of a growing season in most temperate and humid climate zones as compared to MODIS composite images. In contrast, MODIS composite images provided regular bimonthly time series

6.2.2. Relation between biomass and satellite EVI: Satellite remote sensing provides consistent and systematic observations of vegetation and ecosystems, and has played an increasing role in characterization of vegetation structure and estimation of productivity (Prince & Goward, 1995; Rai, 2006).

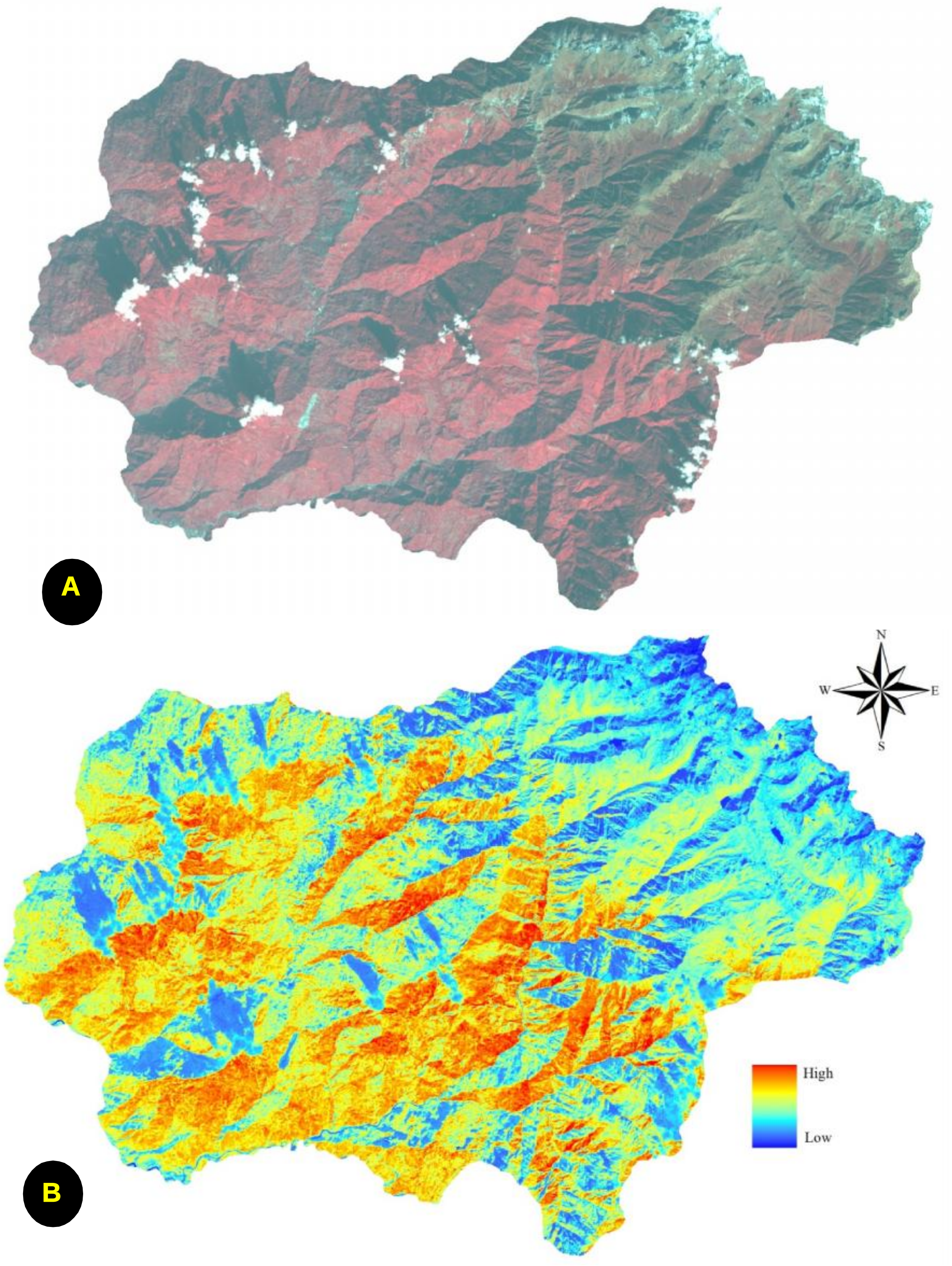


Fig. 6.4. Landsat satellite imagery of 6th December 2013 (A) and NDVI of same period (B)

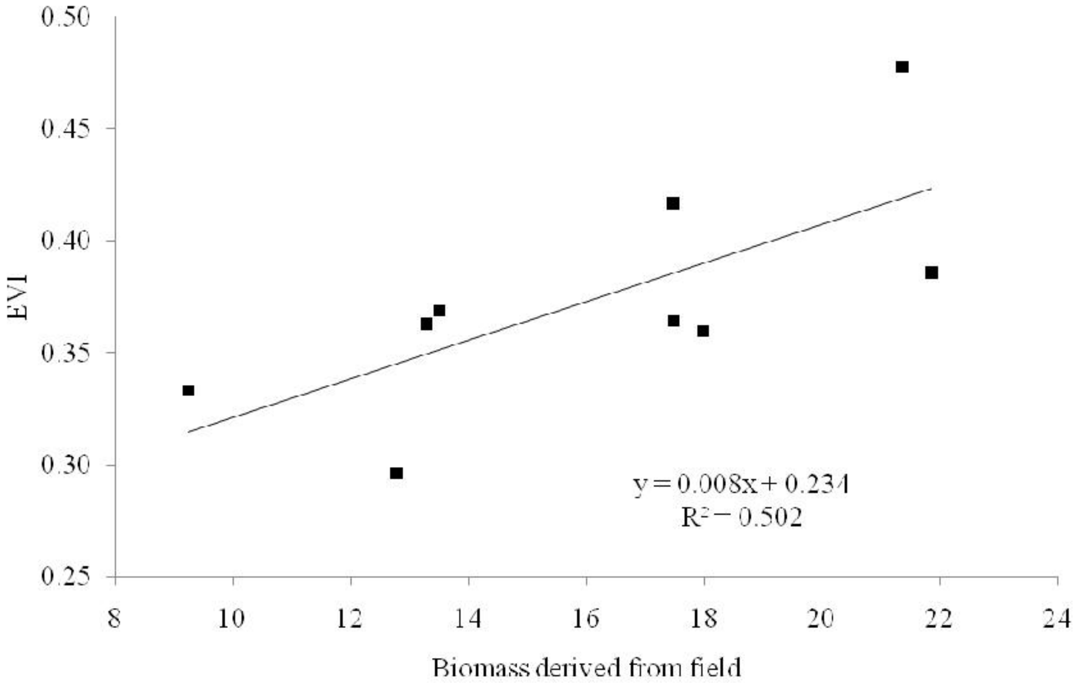


Fig. 6.5. Relation between Biomass vs Landsat EVI in 300m steps

The productivity predicted from Landsat satellite data of 30-meter resolution and has been correlated with the field biomass which shows the significant correlation of R^2 at 0.50, in 300 m elevation steps when the result tested in linier equation (Fig. 6.5).

Further the field biomass and EVI tested using the polynomial regressions between EVI and field biomass were computed along the 100 m elevation steps of Sikkim Himalayas from 500 to 3200 m elevation range. The result is shown in figure 6.6. It was observed R^2 at 0.322.a in second order polynomial.

The second order regression polynomials between EVI and field based biomass along the100 elevation steps of subtropical to sub alpine forest (1200 – 3000 m) of the study area was also performed. Correlation was seen R^2 at 0.31 for EVI values and field values along the elevation (Fig. 6.7a). Further segregate of procured data for temperate and sub-alpine area (2300 – 3000 m) and tested in second order of regression polynomials. A better correlation between field biomass and satellite based EVI along the elevation was observed in (Fig. 6.7b). It is due to may be the moisture contain in the temperate and sub-alpine forest area of Sikkim Himalayas.

Though the derived result also shows the relation with biomass is not quite satisfactory it may due to the following factors:

i. *Data acquisition date*: The data collection date from the field and date of acquisition of satellite imagery may not be the same.

ii. *Sample and Pixel sizes*: The sample size for trees is 20 x 20 m and the pixel size of satellite imagery is 30 x 30 m which may mismatch with other pixels.

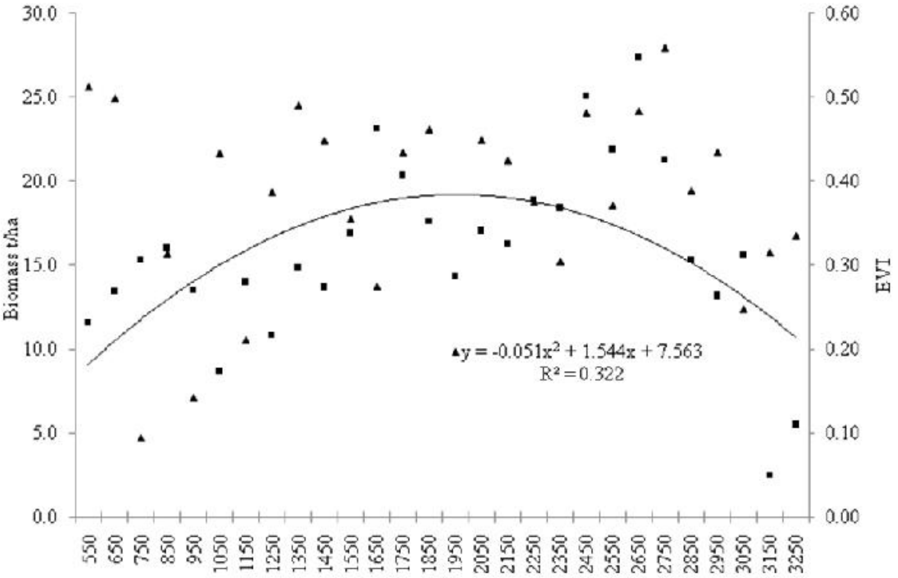


Fig. 6.6. Relation between field biomass vs EVI2 values along the100 m elevation steps from 500 to 3300 m of Sikkim Himalaya

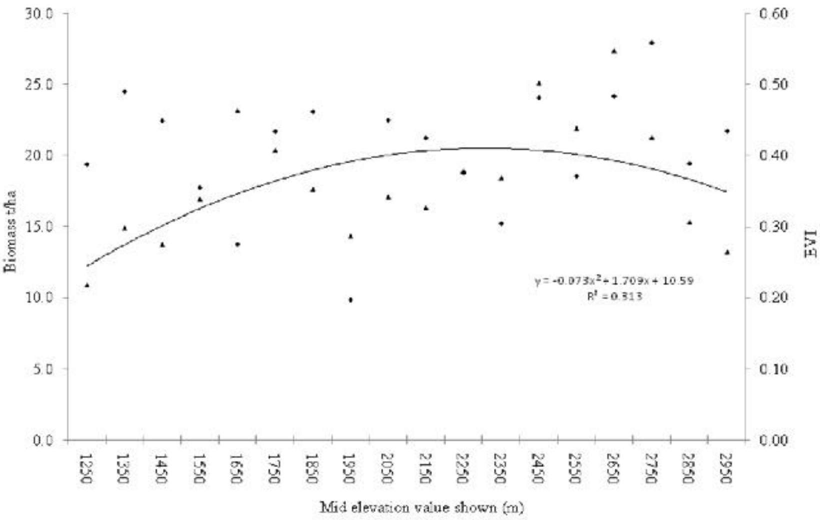


Fig. 6.7a. Relation between field biomass vs EVI2 values along the elevation steps from (A) 1200 – 3000 m and (B) 2300 – 3000 of Sikkim Himalaya

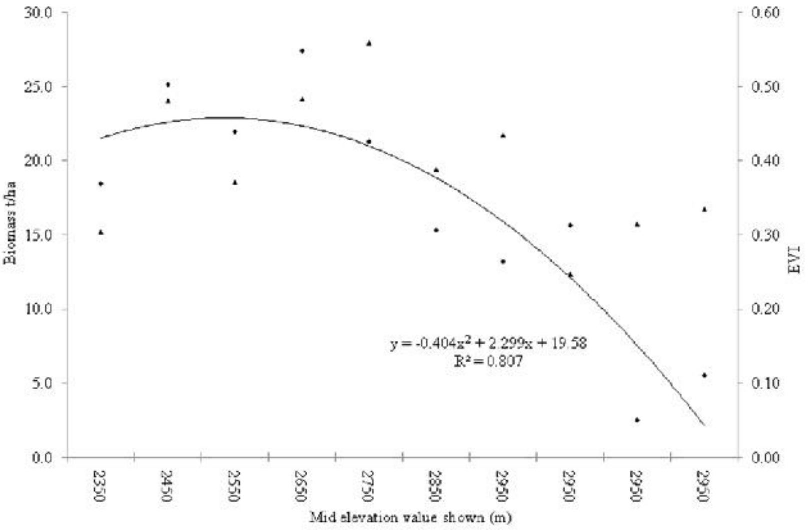


Fig. 6.7b. Relation between field biomass vs EVI2 values along the elevation steps from (A) 1200

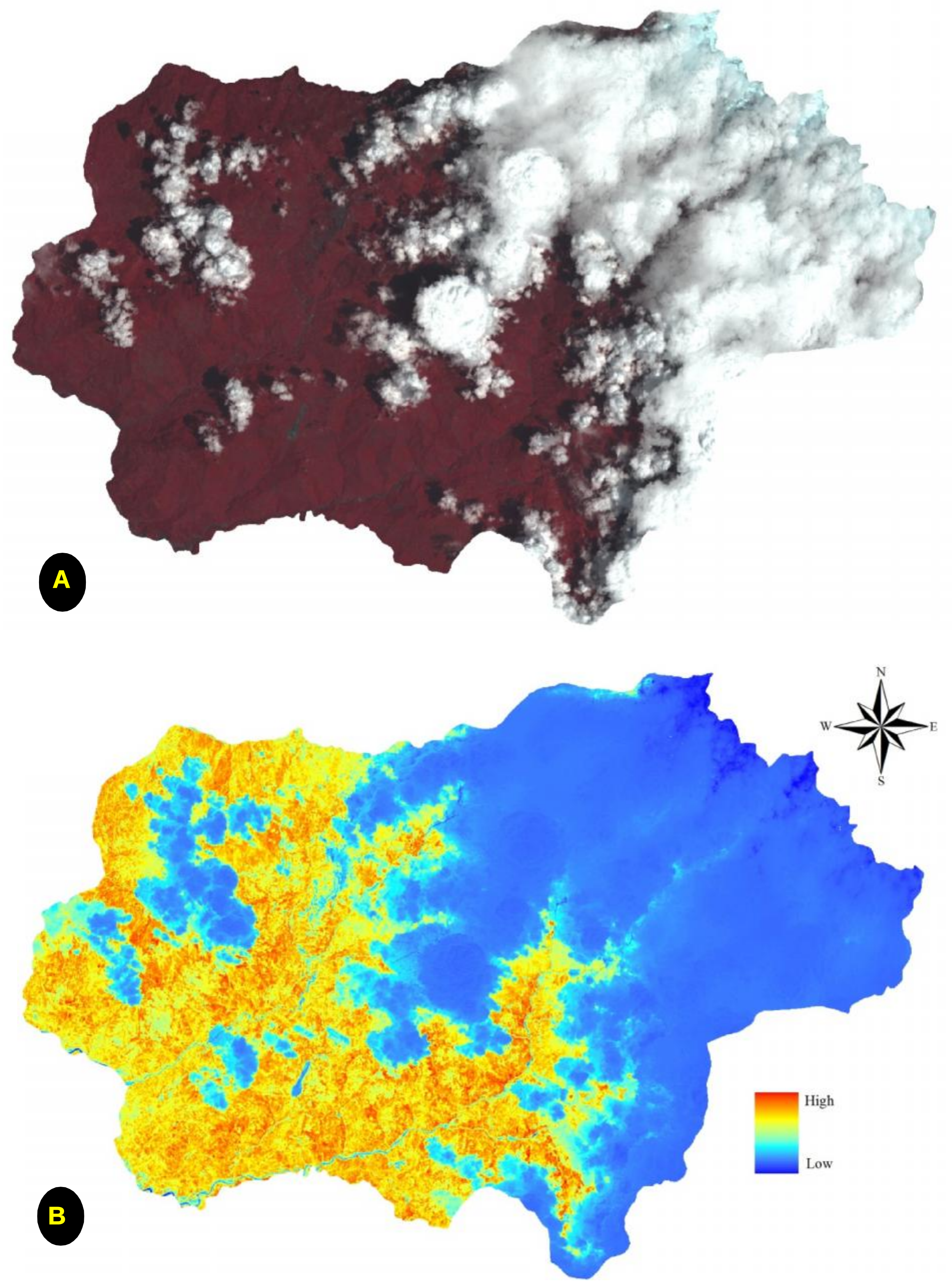


Fig. 6.8. Landsat satellite imagery of 26th April 2013 (A) and (B) EVI of same period indicate the presence of more than 40 % cloud cover.

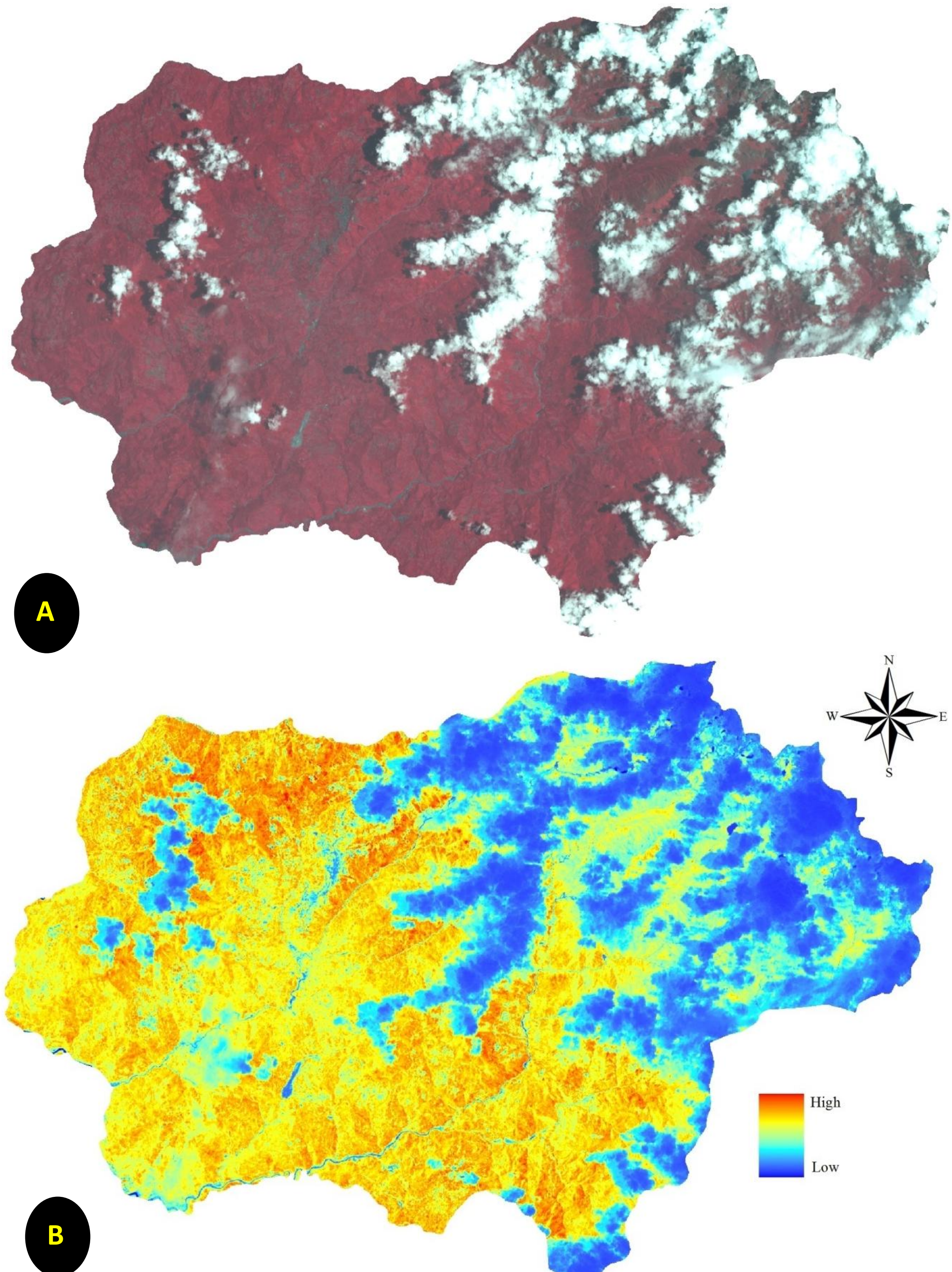


Fig. 6.9. Landsat satellite imagery of 13th June 2013 (A) and (B) EVI of same period

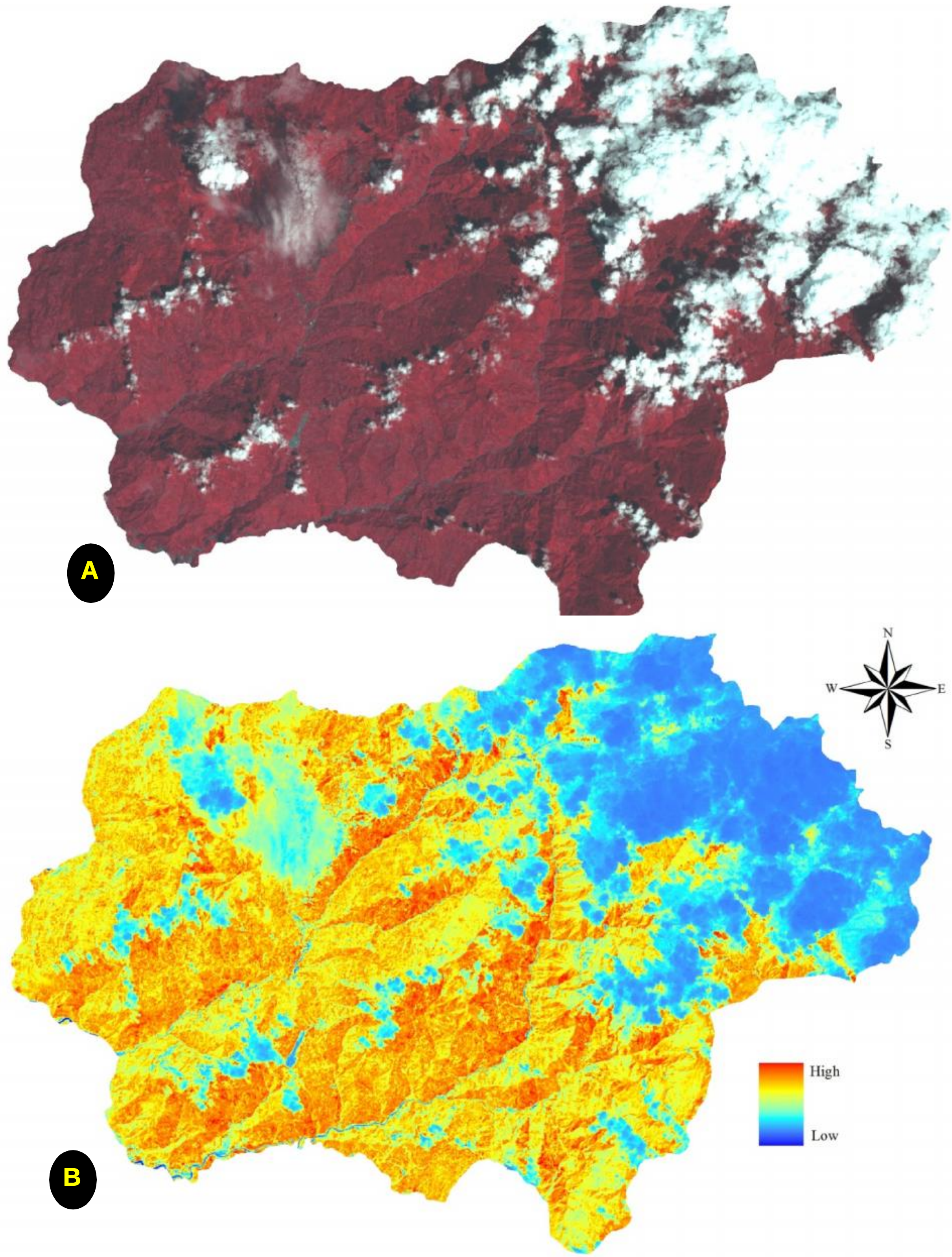


Fig. 6.10. Landsat satellite imagery of 17th September 2013 (A) and (B) EVI of same period

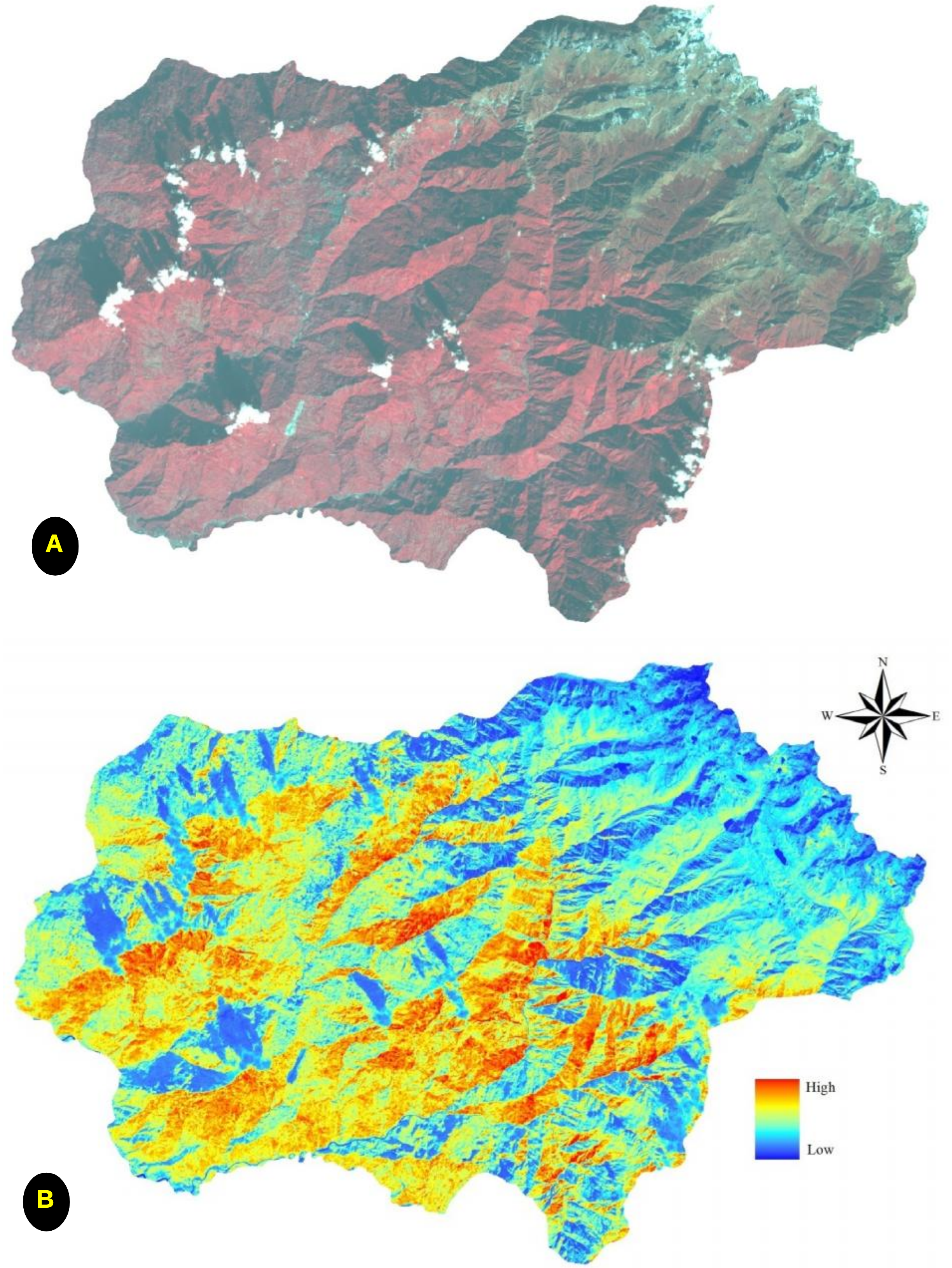
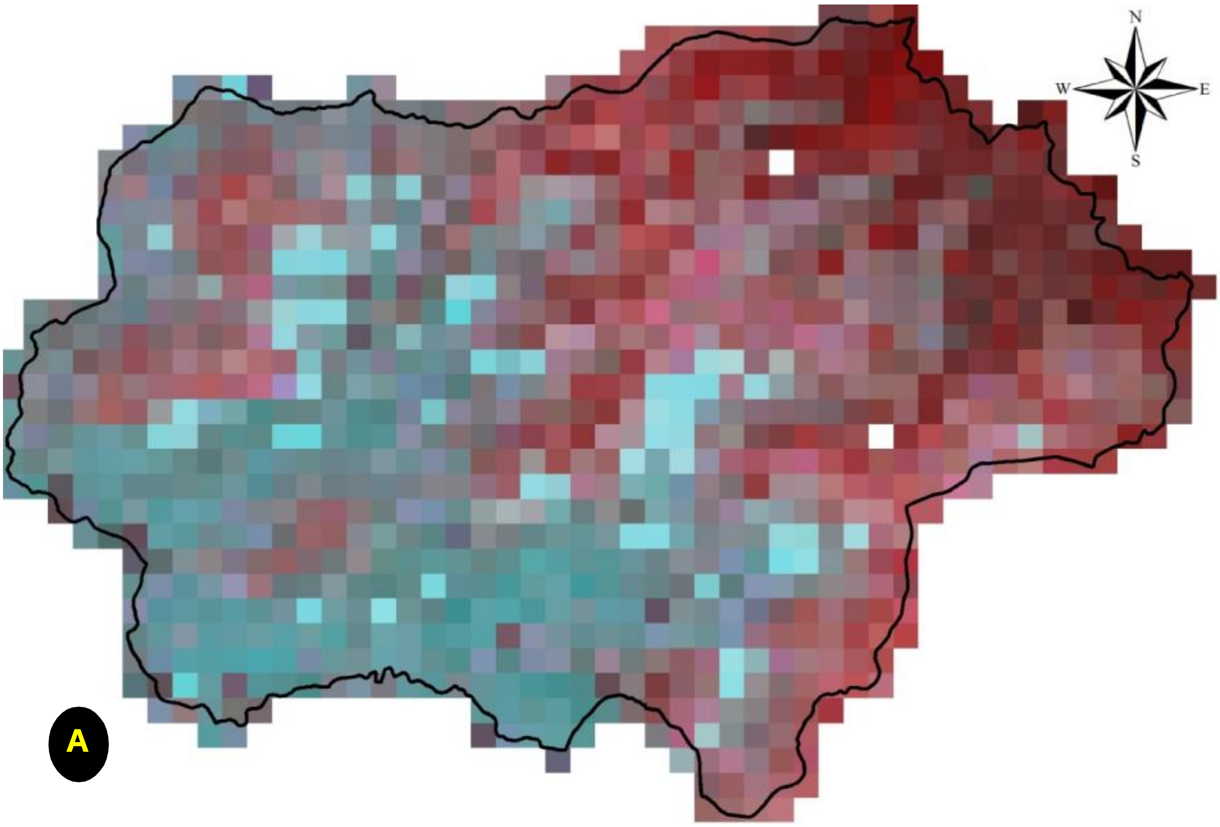


Fig. 6.11. Landsat satellite imagery of 6th December 2013 (A) and (B) EVI of same period



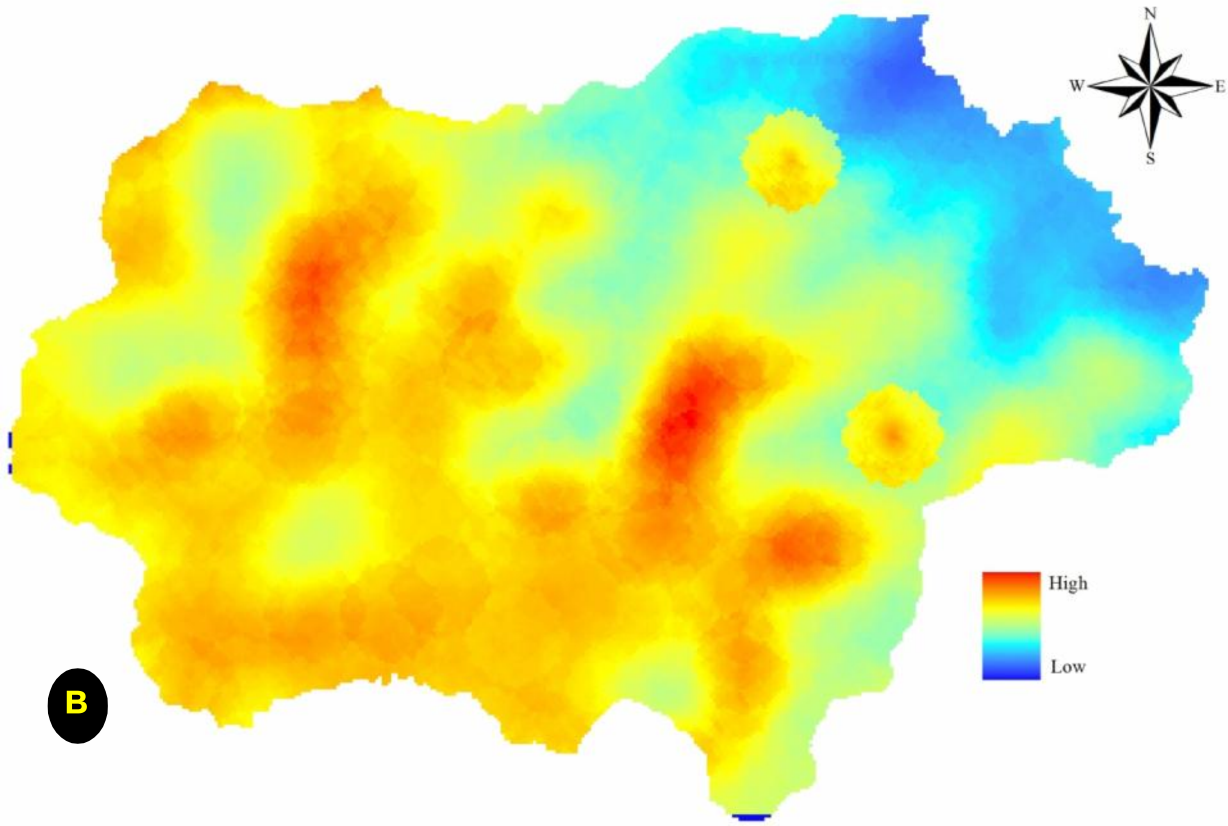


Fig. 6.13. MODIS Productivity imagery (A) and (B) MODIS NPP derive after interpolation

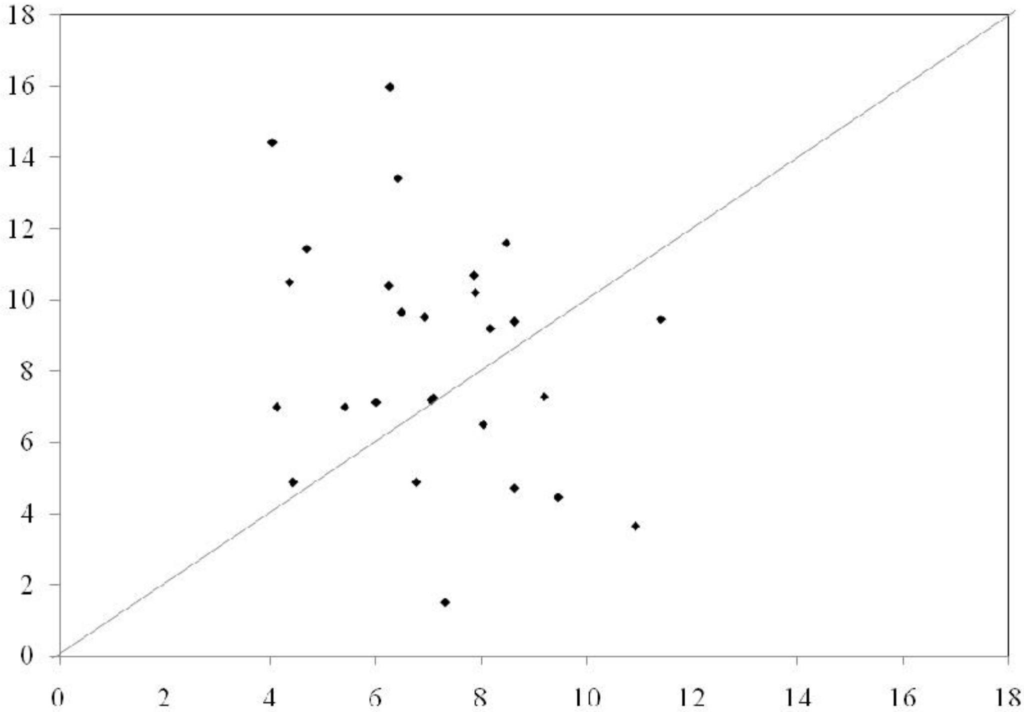


Fig. 6.12. Relation between MODIS NPP and Field derived biomass

iii. Anthropogenic disturbances: There are very less correlation in the tropical and temperate forest, it may be due to more anthropogenic disturbances.

The EVI's utility in satellite-driven primary production modelling has previously been demonstrated for several different biome types (Xiao *et al*. 2004) and the highly linear relationship observed in GPP can be estimated through a linear regression model for similar environments with relatively high accuracy, using only EVI as independent variables.

6.2.3. MODIS Productivity: At first the MODIS NPP were downloaded and compared with the field derived biomass. Then, tried to fit the MODIS NPP product in local scale of Sikkim Himalaya (Fig.6.12 & 6.13). This product is also prone to be complicated by the mismatch in scale between ground-based NPP derived from the field and the coarse resolution (1 km) of the MODIS NPP product.

6.2.4. Relation MODIS Productivity with Biomass: The values of MODIS Productivity was not satisfactory as compared to other satellite products. The MODIS (1 km x 1 km) data is not suitable for the estimation of productivity in local scale of study.