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Net Primary Productivity Estimation of Eastern Ghats using Multispectral MODIS Data

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ABSTRACT

Javadhu Hills is one of the natural bio-reserves of Eastern Ghats, Tamil Nadu, India. This hill lies between 78°35" and 79°35" East longitude and 12°24" and 12°55" North Latitude with an area of 2405 square km. MODIS Satellite data is used to map local scale NPP for Javadhu Hills in Tamil Nadu, India. NPP maps for four different seasons namely (Southwest Monsoon, North East Monsoon, winter and summer season were generated for the years 2008-2009 using MODIS 09A1 surface reflectance products. "Micrometeorological approach" of Monteith's equation and "Production efficiency approach" by Goward and Ruimy were also attempted. Best of both the approaches were used in this study for NPP estimation of Javadhu hills. This study explains the temporal variation of NPP between different seasons. NPP and NDVI values are higher for the North east and South west monsoons comparatively lower for winter and lowest for the summer season. Thus this study gives an insight to identify the significance of Micrometeorological parameters affecting seasonal NPP values.

Keywords: NPP, MODIS data, Jhavadhu Hills, Production Efficiency Approach, Seasons.

1.Introduction

Net primary productivity (NPP) is a key component of the carbon budgeting in the event of the Global Climate Change. NPP estimates vary from regional to global scale, as the carbon storage by terrestrial ecosystem play an important role in limiting the increasing rate of atmospheric CO_2. In situ NPP ground measurements are costly, involves more time, labor-intensive nature and tedious and therefore. Available ground measurements are insufficient to account for spatio-temporal variability of NPP at regional and meso-scales. It is, therefore, necessary to calibrate and derive NPP estimates in combination with remote sensing and other datasets to quantify the spatio-temporal variability of NPP.

Micrometeorological approach of makes use of Light Use Efficiency (LUE) and Absorbed Photosynthetically Active Radiation (APAR) to derive NPP. Light Use Efficiency (LUE) based models are easily amenable to remotely sensed data to widely map primary production of the terrestrial biosphere over large areas. Gross Primary Production (GPP) and annual net primary production (NPP) at the 1-km spatial resolution are now produced operationally for the global terrestrial surface using imagery from the MODIS sensor.

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Recently, validation of annual global MODIS (Moderate Resolution Imaging Radiometer) NPP (net primary production) at 1 km spatial resolution posed a great challenged and this issue has been seriously discussed by many researchers . The development of these series of model revealed that the validation of annual MODIS NPP is an essential step which provides a means of evaluating spatial patterns in productivity as well as inter-annual variation and long term trends in biosphere behavior. The Indian subcontinent has diverse vegetation with the climate varying from monsoonal in the south to temperate in the north. The biological productivity of vegetation cover is, therefore, largely controlled by water and temperature stresses. Estimates, at country-level NPP by incorporating satellite-derived vegetation indices into LUE based models by have reported low annual NPP in the range of 0.4 to 0.6 Pg C over the country during late 1980s, whereas have reported relatively large NPP budget of 2.18 Pg C for the country during the agricultural year: June 1998–May 1999. Mapping of NPP at local scale with season variation of biological productivity is attempted in this study.

The present study has been carried out with the following main objectives:

(1) To map local scale NPP for an area of about 2405 sq.km. of Javadhu Hills of Tiruvannamalai district, Tamil Nadu, India using low resolution MODIS satellite data.

(2) To estimate spatio-temporal patterns of NPP corresponding to four major seasons (winter, summer, south west and north east monsoon) over the Javadhu hills using input datasets derived from the remote sensing and other sources.

(3) To identify favorable parameters that promotes phonological growth of the forest cover.

2.Materials and Methods

2.1 Location and Climate

Javadhu Hills is one of the natural bio-reserves of Eastern Ghats. This hill lies between 78°35” and 79°35” East longitude and 12°24” and 12°55” North Latitude with a total area of 2405 square km. The location of the study area is depicted in Fig -1. Javadhu hills, the soil are derived basically from feldspar and hornblende and the soil is fairly loamy. The hills comprise (77.2 percent of the area is under gross cropped area nearly 7.9 percent of the area (2219 ha) is under gross cropped area. 61.08 percent of the area (3297 ha) is under forest *(Status report, 2001)*. The forest produce are Sandalwood, Eucalyptus, Bamboo, Tamarind, etc. The Javadhu hills have an elevation of 762 meters. The highest points in these hills are pattimals Vellanda Ponmalai and Pudur Nadu which have an elevation of 1094 meters. This region enjoys an equable climate. During the cold season there is a substantial amount of dewfall which generally benefits the vegetation. The mean maximum temperature is 36.6*C Minimum temperature ranges from 20.7°C to 26.0°C, The mean annual rainfall for Javadhu hills is 1100.85 mm with 480mm in south

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west monsoon (June - September) and 429mm in North east monsoon (October - December). Depth of ground water level below ground level in meters, of pre monsoon and post monsoon were of 8.43 and 5.33 respectively (CGWB Report, 2003). Ground water levels are in the range of 2-5 m in the major part of the district.

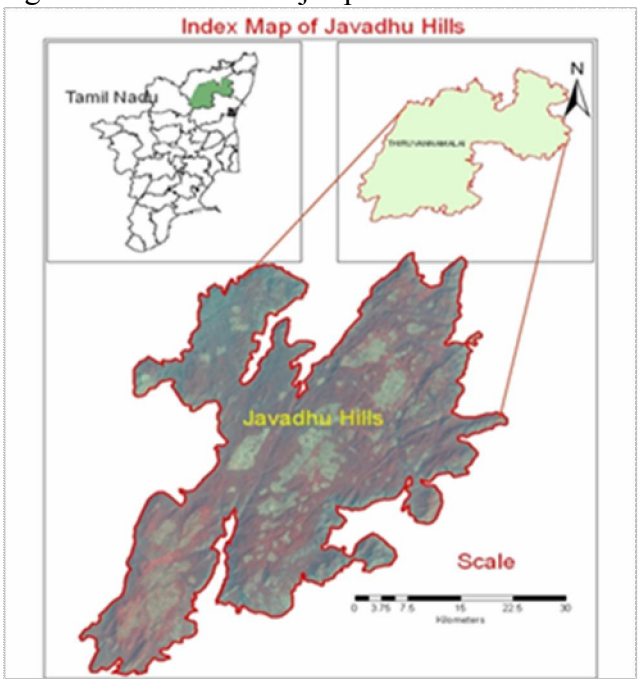

Figure 1: Index map of the study area

2.2 Database used

The MODIS surface reflectance data of MOD09 A1 product provides Bands 1-7 at 500 meter resolution in an 8 day gridded level 3 products in sinusoidal projection has been acquired from http://mrtweb.cr.usgs.gov/. Each MOD09A1 pixel contains best possible L2G observation during 8 day period as selected on the basis of high observation coverage, low view angle, absence of clouds or cloud shadow and aerosol loading. The Quality Accuracy (QA) information from the HDF-EOS file of MODIS surface reflectance was verified for the consistency in the data set. Dataset pertaining to the period of Julian day 041 of the year 2008, and days of 137, 161, 249 and 289 of the year 2009 with minimum cloud cover have been selected using quick look menu provided in the free download website are used in this study. Each of the data set corresponds to winter; summer, south west and north east monsoon are used here. Due to frequent and incessant rain during north east monsoon periods two data sets of 249 and 289 are employed for the assessment of NPP. Ancillary data like Survey of India toposheets with respect to Tiruvannmalai district are used for positional accuracy for ground control points.

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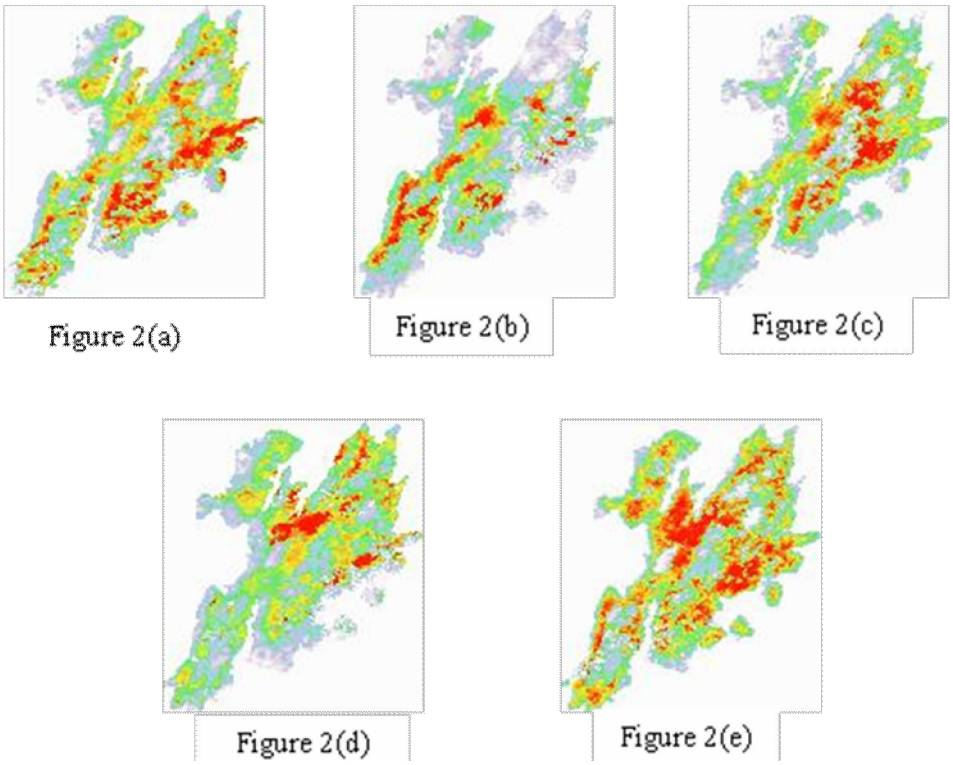

Figure 2: MODIS NDVI Images of Javadhu hills on Winter season, Summer season, South West monsoon season and North East monsoon season for 2008-2009

Table 1: The range of MODIS Seasonal NDVI estimates for the Javadhu Hills.

Sl.No.	Seasons	Julian DOY	NDVI			NDVI St.dev
			NDVI Min	NDVI Max	NDVI Mean	
1	Winter	041_2008	0.076	0.860	0.674	0.114
2	Summer	137_2009	0.055	0.781	0.483	0.115
3	SW Monsoon	161_2009	0.026	0.901	0.624	0.134
4	NE Monsoon	249_2009	-0.073	0.908	0.620	0.145
5	NE Monsoon	289_2009	0.167	0.896	0.750	0.097

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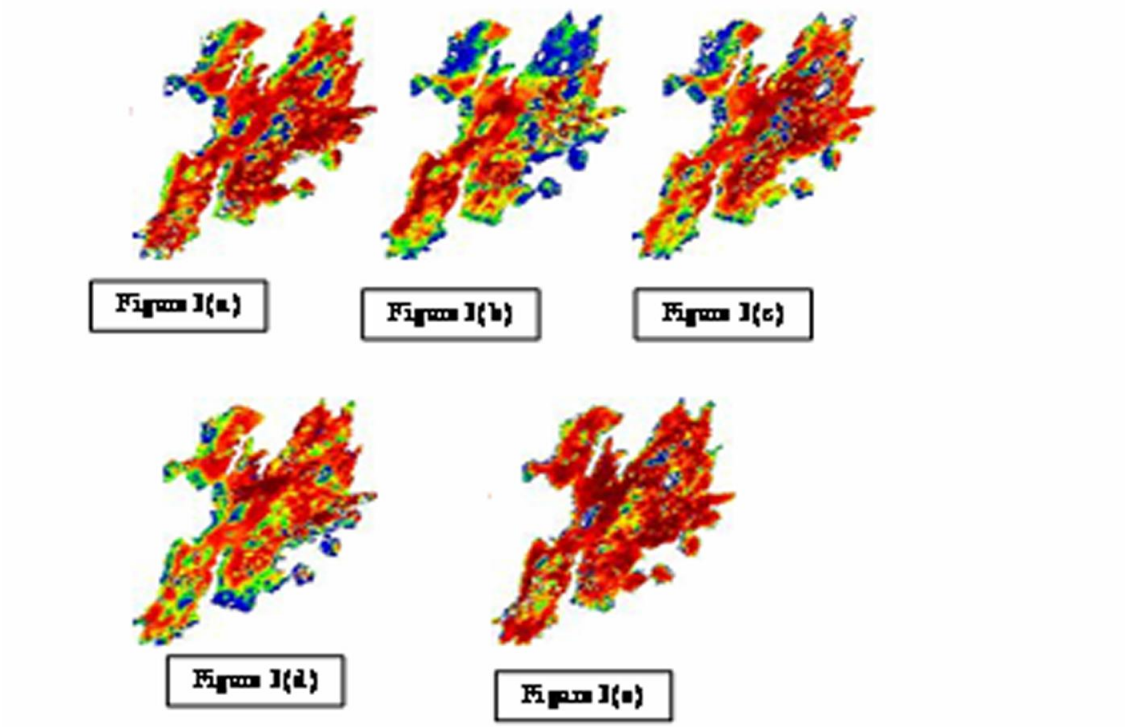

Figure 3: MODIS seasonal NPP images

Table 2: The range of MODIS Seasonal NPP estimates for the Javadhu Hills.

Sl.No.	Seasons	Julian DOY	NPP (gCm^2y^{-1})			NPP St.dev
			NPP Min	NPP Max	NPP Mean	
1	Winter	041_2008	0.002	16.58	10.23	3.30
2	Summer	137_2009	-0.026	13.54	5.18	2.56
3	SW Monsoon	161_2009	-0.031	18.25	8.86	3.69
4	NE Monsoon	249_2009	-0.034	18.58	8.81	3.85
5	NE Monsoon	289_2009	0.380	18.05	12.64	3.14

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2.3 Model Description

The study has been carried out using the micrometeorological approach according to the Monteith's equation as follows:

NPP = LUE * APAR [4] ……[Eq. 1]

Where, LUE – Light Use Efficiency and APAR- Absorbed Photosynthetically Active Radiation

Net Primary Productivity (NPP) can be estimated using NDVI and PAR data by "production efficiency approach" proposed by Goward (1998) and Hooda (2003).

NPP = eò APARdt where: e:efficiency[g/MJ] APAR = fPAR*PAR ……[Eq. 2]

The calculation of Normalized Difference Vegetation Index (NDVI) using band1 and 2 is given as

NDVI = (b2-b1)/(b1+b2) ……[Eq. 3]

Subsequently, the NDVI values are utilized to calculate the fraction of Photosynthetically Active Radiation (fPAR) absorbed by vegetation using the following equations:

fPAR = -0.08+1.075 NDVI ……[Eq. 4]

The PAR values are actually restricted to just a portion of electromagnetic spectrum from 0.4 to 0.7 micrometers (µm) which is comparable to the range of light of human eye can see. Therefore, this value was assumed to be approximately 0.5 of the incoming solar radiation [6]. Therefore, value of PAR for each pixel as defined by [6] was utilized in this study.

Therefore, $NPP\,(g\,Cm2\,y-1) = \sum\,(fPAR(NDVI) * PAR)$……[Eq. 5]

3. Result and Discussion

NPP of Javadhu hills especially for four seasons namely- winter, summer, South West and North East Monsoon for an area of approximately 2405 sq.km. have been produced from MODIS surface reflectance data using production efficiency approach. NDVI, fPAR, PAR and APAR are the indices that are derived from the visible and near infra red bands of the MODIS surface reflectance product. Photosynthetically active radiation (PAR) is the solar radiation reaching the canopy in the wavelength region of visible light (0.4 - 0.7 micrometers). This is typically derived from meteorological datasets, but may also come from satellite products. Therefore, this value was assumed to be approximately 0.5 of the incoming solar radiation [6]. The fraction of absorbed PAR (FAPAR) is defined as the fraction of PAR absorbed by green vegetation. FAPAR is difficult to measure directly, but is inferred from models describing the transfer of solar radiation in

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plant canopies, using remote sensing observations as constraints. The Eq [4] is implied to derive fPAR.

Total above ground NPP of the study area have been estimated using the all the indices using ENVI software. NPP map with respect to four seasons are derived from MODIS product was of 8 days Maximum Value Composite (MVC). Thus NPP value generated from each scene has been aggregated to annual NPP. The NDVI and NPP maps and values for Javadhu hills have been derived are shown in Figure 2(a, b, c, d & e) & 3(a, b, c, d & e) and Table 1 & 2.

NPP and NDVI values are low for the period of summer (5.18, 0.483) respectively. Low values of NDVI and NPP during summer were due to high temperatures coupled with higher evapotranspiration rate that lead to less deciduous foliage cover over the Eastern Ghats caused by summer season. Similar observations are reported by [3] for the Indian subcontinent. Higher values of NPP and NDVI are observed for north east monsoon (12.64, 0.750) respectively was resultant of medium to moderate rainfall associated with higher solar radiation both the seasons. Similar conclusions were also drawn by [1].

4. Conclusion

This study has shown the use of low resolution MODIS satellite data for the estimation of NDVI and NPP for different seasons of Javadhu hills, Tamil Nadu. Four seasons corresponding to the winter, summer, south west and north east monsoon have been used to determine the temporal distribution of NPP in Javadhu hills. The pattern of NPP distribution seems to less during the winter seasons and higher during the north east monsoon season. The model developed by Goward and Ruimy through production efficiency approach was used in this study. Production Efficiency approach used in this study seems to fit with Indian condition. Results from this study can be used to provide very useful basic information related to forest productivity mapping of Eastern Ghats as well as to improve the estimation of the spatial and temporal NPP at global scale. The derived NPP from MODIS data could not be validated due to the lack of in situ data from the study site.

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