NDVI Based Assessment of Land Use Land Cover Dynamics in A Rainfed Watershed Using Remote Sensing and GIS

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ABSTRACT - Assessment of Land use/ Land cover dynamics is critical for conservation, sustainable use and development of natural resources in rainfed regions. In the present study Kaddam watershed, G-5 sub basin of Godavari River, India, a typical rainfed watershed characterized by acute annual rainfall of 715 mm and dry land crops has been considered for the evaluation of land use/land cover changes. Normalized Difference Vegetation Index (NDVI), an indicator of vegetation growth and coverage, has been employed to describe the spatiotemporal characteristics of land use land cover, including percent vegetation coverage. using multi spectral remote sensing. The Land use/Land cover (LULC) classification was done based on Normalized Difference Vegetation Index (NDVI) using four IRS-P6 LISS-III satellite imageries each of Kharif and Rabi seasons for 2004 and 2005. The LULC assessment based on NDVI for Kharif and Rabi seasons of 2004 and 2005 has resulted that crop land has been decreased by drastically by 148.23 sq km and fallow land has been increased by 150.32 sq km from 2004 to 2005. Changes were noted in the aerial extents of water bodies and bare soil classes, change in forest class was nominal. The ranges of NDVI values are stressed for kharif season imageries and bounds of NDVI values of different LULC classes are subject to change from Kharif to Rabi in the same year. It can be concluded of all the available methods of image classification with regard to vegetation and LULC, NDVI formed the basis for a better classification especially suitable in such cases where the analysis was carried out using either past imageries or present imageries with no ground truth data.

Key words: GIS, Land Cover, Land Use NDVI, Remote Sensing

1.0 Introduction:

Land use/Land cover inventories are essential for the optimal utilization and management of resources in a watershed/sub-basin. Land cover refers to different features covering the earth's surface including vegetation cover, water bodies, open scrub etc. (IGU, 1986).It integrates the sum of human activities having an influence on the environment. With the development of Geographic Information System (GIS) and Remote Sensing technologies and its applications facilitates the adoption of new methodologies which prove to be highly efficient in mapping and visualizing Land use/Land cover inventories(Digregorio and Jansen, 2000), (Jansen and Di Gregorio, 2002). From the remote sensing data, the USGS has devised a land use/land cover classification system (Anderson et al., 1986).

The spatial data sets such as land use and land cover maps are derived through Remote Sensing data using image classification methods. Digital image classification is the process of categorizing of all pixels in an image into land cover classes or themes. Usually, multi-spectral data are used for these purposes (Lillesand and Kiefer, 1979). The spectral pattern within the data for each pixel is used as the basis of categorization. Different feature types show different combination of digital numbers (DNs) based on their inherent spectral reflectance and emittance properties. Digital image classification techniques are used to classify the image into different land uses; commonly supervised and unsupervised classification techniques are employed. In recent years, Normalized Difference Vegetation Index (NDVI), an indicator of vegetation growth and coverage, has been widely employed to describe the spatiotemporal characteristics of land use land cover, including percent vegetation coverage (Kaufmann, 2003). The visible and near infrared bands on the satellite multi spectral sensors allow monitoring of the greenness or vigor of vegetation (Burrough, 1986). Vincent and Pierre (2003) used time-series high resolution SPOT images to create a NDVI profile of each pixel and classified them into 4 land class viz. bare soil, herbaceous crops, trees on bare soil and trees along with herbaceous crops. Doraiswamy et al., (2006) studied the 8 date composite data from MODIS in a three year time series. Long duration vegetation like trees, shrubs and grasses were identified using the year long data based on NDVI. Joshi et al (2008) of ISRO and Forest survey of India explored the potential of multi-temporal IRS LISS –III and Wide Field Sensor (WiFS) data for mapping of vegetation cover types in India using vegetative indices. Panigrahy et al., (2009) used multi-date data AWiFS data for classifying different vegetative clasess based on NDVI, their growing season and their difference in growth calendar. Ying et al., (2010) used four temporal MODIS NDVI product images to create a vegetative mask on TM image to distinguish

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agriculture crops from other vegetative types. Cunyong et al (2011) employed Normalized Different Vegetation Index (NDVI), an indicator to estimate percent vegetation cover in heterogeneous topographical features and vegetation cover at Muus sandy land, mid west china. This paper presents the land use and land cover dynamics based on Normalized Difference Vegetation Indices (NDVI) at temporal pattern using multispectral IRS P6 LISSIII remote sensing data for the study region.

2.0 Study Region:

The study region, Kaddam reservoir catchment lies in the central part of middle Godavari (G-5) sub-basin of Godavari river basin, which lies between latitudes 17°04' – 18°30' North and longitudes 77°43' – 79°53' East. The G-5 sub-basin has a catchment area of 35723 km², which constitutes 11.38% of the total Godavari river basin area and entirely lies in the state of Andhra Pradesh (Watershed Atlas of India, 1998).

The study area of Kaddam reservoir catchment lies between latitudes 19°05'– 19°35' N and longitudes 78°10' – 78° 55' E and the location of study area is shown in Fig. 1. The areal extent of the study area is 2617.56 km², which constitutes 7.4% of the sub-basin area. The climate in the study area is semi-arid with an average annual rainfall of 715 mm and is a typical rainfed watershed characterized with dry land crops, i.e., cotton (majorly) and pigeon pea. It is observed that the monthly minimum and maximum average temperature recorded in summer ranges from 26°C to 42.5°C and the monthly average temperature recorded in winter ranges from 16°C to 29°C. Daily mean relative humidity ranges from 10 to 100%. The highest wind speed is 136 km/hr.

The study area is drought prone and regional government (Government of Andhra Pradesh) has declared the administrative boundaries of the watershed as drought prone in the years 1994-1997, 2000, 2003, 2005, 2006 and 2009 (APWALMTARI 2010). Various developmental activities (schemes) are initiated in the study region by local and central governments for rehabilitation of watersheds. In this context, identification of landuse/land cover dynamics within the watershed is having high importance to formulate appropriate strategies for suitable conservation and management practices.

2.1 Data used

The study region comprises 10 survey of India toposheets 56-I 3, 56- I 6, 56- I 7, 56- I 8, 56-I 10, 56-I 11, 56-I 12, 56- I 14, 56-I 15 &56- I 16 on a scale of 1:50,000 which were collected from Survey of India (SOI), Hyderabad, India.The satellite imageries of Indian Remote Sensing Satellite (IRS) P-6, Linear Imaging and Self Scanning Sensor (LISS –III) with a resolution of 23.5m are used for the generation of NDVI for the study area. The details of imageries are given in the Table 1.

3.0 Methodology:

3.1 Normalized Difference Vegetation Index

Green vegetation is highly absorptive in the visible part of the spectrum, mostly owing to the presence of chlorophyll. Beyond a wavelength of about 700 nanometers, the absence of absorbing pigments and leaf structure results in high reflectivity for green vegetation. In contrast, other features such as bare ground, water, snow and clouds have similar reflectance in visible channel compared to near infrared channel. Stressed vegetation is less reflective in the near infrared channel than non-stressed vegetation and also absorbs less energy in the visible band. Thus, Plant tissue absorbs much of the red light band and is very reflective of energy in near infrared ("NIR") wavebands. The ratio of these two bands is referred to as the 'vegetation index' (VI).

The VI is a simple ratio of digital values of two spectral bands.

$$VI = Band\ 1 / Band\ 2$$

Out of the various vegetation indices available, NDVI is very widely used as it minimizes the effect of change in illumination condition and surface topography. The NDVI is defined as the ratio of difference between the near infrared and red reflectance to their sum. The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands.

$$NDVI= (NIR-RED) / (NIR+RED)$$

Normalized Vegetation indices are generally calculated by ratioing, differencing, summing, linearly combining, etc. data from two or more spectral bands. They are dimensionless and radiometric measures that are intended to minimize the solar irradiance and soil background while enhancing the signal from vegetation. The use of vegetation index can normalize the effects of differential illumination of features in an area and can also help in extracting specific vegetation classes in an area. The advantages of using vegetation indices (Jensen 2009) as follows;

a) It maximizes the sensitivity to vegetative biophysical parameters,
b) Consistent spatial and temporal comparisons can be made due to normalizing or modeling of sun angle, viewing angle effects and atmosphere,
c) Canopy background, topography and soil variations, etc. can be normalized
d) It reduces the dimension of the multispectral data for temporal analysis studies

The main principle of detecting vegetation using NDVI is the high absorptivity of vegetation pigments (chlorophyll) in the red spectral region and high reflectance in the near infrared spectral region. NDVI is highly correlated to the photosynthetic activity and indicates the greenness of the vegetation and NDVI can significantly separate various spectral classes of LULC. The NDVI image enhances the vegetation class in the images and helped in distinguishing it from other non-vegetation classes. After the spectral assignment of the classes, which are functions of spectral wave lengths of remote sensing sensors. The assigned spectral classes which are function of NDVI are evaluated to assign into suitable Land Use / Land Cover classes. The NDVI based LULC analysis were carried out for 2004 and 2005 kharif and rabi seasons for study area and in detail results were discussed in section 4.

3.2 Generation of NDVI

Pre-processing of remote sensing images is necessary for reducing the noise due to atmospheric conditions and to increase the interpretability of information from the data. Especially when conducting vegetation studies using temporal images, the images need to be spatially and spectrally compatible. The idea behind pre-processing the temporal images is to reduce the noise introduced into the data because of atmosphere and to make the images spatially compatible to each other. Thus the available temporal images of LISS-III are pre-processed with respect to image registration and atmospheric corrections for its use in the temporal study.

Image to image registration technique is carried out for registering the temporal images with each other. The standard mosiaced SOI toposheet (56-I_3, 56- I_6, 56- I_7, 56- I_8, 56-I_{10}, 56-I_{11}, 56-I $_{12}$, 56- I_{14}, 56-I_{15} &56- I_{16}) was selected as reference and all other temporal images of LISS-III were registered with it. The ERDAS Auto Sync module was used for this purpose and the RMSE (Root mean Square Error) was kept under 0.5. This is done so that when the temporal images are stacked over each other the corresponding class on the temporal images lies over each and there was near perfect correspondence of the pixels. This is a pixel based un supervised classification where the changes in a pixel are tracked over the time and hence perfect correspondence of the pixels in the temporally stacked images is of great importance. A nearest neighborhood resampling technique was used during the image registration exercise as it retains the original Digital Number (DN) values and doesn't average them as done by other resampling techniques (ERDAS Inc., 2010). Since this vegetative discrimination study was carried out over a temporal period, there is a need to normalize the effects of the changes in the atmospheric conditions on the temporal images. In order to account for these temporal atmospheric conditions and the atmospheric disturbances like haze, aerosol etc. Atmospheric corrections are applied on all the images of LISS-III. For this purpose of atmospheric corrections, the ATCOR module of ERDAS Imagine software was used. This atmospheric correction module (ATCOR) used calibrated files for specific sensor (IRS-P6's LISS-III) for correcting the effects of the atmospheric disturbances. The aerosol effect is also removed using the atmospheric model for temperate-rural conditions.

4.0 Results and Discussion:

4.1 NDVI and Temporal LULC Profile

After carrying out the initial pre-processing steps, the next step was to generate NDVI outputs for the temporal LISS-III images. The NDVI is generated for four individual LISS-III temporal images using the Spectral enhancement option of ERDAS Imagine. The NDVI images enhanced the vegetation class in the images and helped in distinguishing it from other non-vegetation classes. After the spectral assignment of the classes, which are functions of spectral wave lengths of LISS-III. The assigned spectral classes which are function of NDVI are evaluated to assign into suitable Land Use / Land Cover classes. The Study area has been classified into six classes viz., Water bodies, Crop land, Bare soil, Fallow land, Forest and Settlements. The Classified NDVI Images are shown in Fig.s 2, 3 and 4. The area wise Land use and Land cover details (LULC) are presented in Table 3.

The areal extent of water bodies in Rabi season is estimated as 13.58 sq km and 16.29 sq km for the years 2004 and 2005 respectively. The increase in water spread area from the year 2003 to 2004 may be due to corresponding increase in rainfall in the study area from 780 mm to 849 mm. Similarly, the areal extent of water bodies in Kharif season is estimated as 12.25sq km and 13.24 sq km for the years 2004 and 2005 respectively.

The areal extent of crop land is computed as 821.35 sq km and 844.75 sq km for the years 2004 and 2005 respectively in the Rabi season; 610.58 sq km and 758.85 sq km for the years 2004 and 2005 respectively in the Kharif season. The areal extent of cropland has decreased by 23.40 sq km and 148.23 sq km in Rabi and Kharif seasons respectively. While the decrease in Rabi is not considerable, but the decrease in Kharif season can be attributed to delayed monsoon and corresponding delay in sowing of crops. The date of pass of satellite image being july 02 for 2004 Kharif season the land to be sowed might be classified into fallow land.

The areal extent of bare soil is computed as 65.25 sq km and 58.25 sq km for the years 2004 and 2005 respectively in the Rabi season and 97.85 and 77.48 sq km for the years 2004 and 2005 respectively in the Kharif season. Bare soil is decreased by 7.00 sq km in rabi season and decreased by 20.37 sq km in Kharif season.

The areal extent of fallow land is computed as 72.85 sq km and 63.35 sq km for the years 2004 and 2005 respectively in the Rabi season; and 289.57 and 139.25 sq km for the years 2004 and 2005 respectively in the Kharif season. Fallow land decreased by 9.50 sq km in rabi season and increased by 150.32 sq km in Kharif season.

The areal extent of forest land is computed as 1640.35 sq km and 1631.25 sq km for the years 2003 and 2004 respectively in the Rabi season; and 1603.50 and 1625.35 sq km for the years 2004 and 2005 respectively in the kharif season. Forest Land decreased by 9.1 sq km and increased by 21.85 sq km in Rabi and Kharif seasons respectively. This indicates that the forest area did not register much difference. The geographical area of settlements also did not register much difference. The ranges of NDVI values are stressed for kharif season imageries, as it may be noted that forest (which is of high vegetative index) has a high value of 0.428 for kharif with during summer . The bounds of NDVI values of all LULC classes are changing from Kharif to Rabi in the same year, this may be due to dynamic behavior of vegetative vigor with respect to season.

5.0 Conclusions

The study illustrates the application of Normalized Differential vegetative Indices to measure the vegetative vigor and assess land use/land cover in the study region. The study revealed that,substantial changes in cropped and fallow lands for kharif season 2005. It can be concluded of all the available methods of image classification with regard to vegetation and LULC, NDVI formed the basis for a better classification especially suitable in such cases where the analysis was carried out using either past imageries or present imageries with no ground truth data.

References

1. Anderson, J.R., 1976. A Land use and land cover classification system for use with Remote Sensing Data., USGS professional paper 964, U.S.Gov. Printing Office, Washington, D.C., 1976
2. Burrough, P.A., 1986. Principals of geographical information systems and land resources assessment. Clerandon Press, Oxford, England, 194 pp.
3. Cracknell, A. P., Hayess, L. W. B., 1993. Introduction to Remote Sensing. Taylor and Francis, London, United Kingdom, 540 – 567 pp.
4. Cunyong Ju, Tijiu Cai, Xiaohui Yang, 2011.Topography-based modeling to estimate percent vegetation cover in semi-arid Mu Us sandy land, China. Computers and electronics in agriculture ,6 4, 133–139.
5. FAO, 1984. Guidelines: Land Evaluation for Rainfed Agriculture. Soils Bulletin 52. FAO, Rome.
6. Digregorio, A. and Jansen, L.J.M., 2000. Land Cover Classification System (LCCS): Classification Concepts and User Manual. FAO, Rome.
7. Doraiswamy, N., Camberlin, P., Richard, Y., Philippon, N., 2006. Compared regimes of NDVI and rainfall in semi-arid regions of Africa. International Journal of Remote Sensing, 27, 5201 - 5223.

compared to 0.682 of rabi season this may be due vegetation status before monsoon and can be attributed to weathering

8. IGU, 1986. World land use survey. Report of the Commission to the General Assembly of the International Geographic Union. Geographica Helvetica 1, IGU, Paris.
9. Jansen, A. and Digregorio,R.L., 2002, Parametric land cover and land-use classification as tools for environmental change detection Agriculture, Ecosystems and Environment, 91 (1-3) , 89-100.
10. Joshi, P.K., Roy , P.S.,Sarnam Singh, Shefali Agrawal and Deepshikha Yadav, Vegetation cover mapping in India using multi-temporal IRS Wide Field Sensor (WiFS) data. Remote Sensing of Environment , 103(2) , July 2006, 190–202.
11. Kaufmann, R.K., Zhou, L.-M., Myneni, R.B., Tucker, C.J., Slayback, D., Shabanov, N.V., Pinzon, J., 2003. The effect of vegetation on surface temperature: a statistical analysis of NDVI and climate data. Geophys. Res. Lett. ,30, 21–47.
12. Lillesand, T. M. and Kiefer, R.W., 2000, Remote Sensing and Image Interpretation (4th ed.)Wiley, New York, USA
13. Panigrahi, M., Das, S., Mishra, P., 1999. Remote Sensing based water resource management plan for watershed development – a case study on Bajupur Watershed, Orissa. Proceedings of ISRS National Symposium, Jan. 19-21, Bangalore, pp. 97-102.
14. UNEP/FAO, 1994. Report on the UNEP/FAO expert meeting on harmonizing land cover and land use classifications. Geneva, 23–24 November 1993. GEMS Report Series No. 25. UNEP, Nairobi.
15. USGS, 1998. A Land use and land cover classification system for use with Remote Sensing Data., USGS professional paper 124, U.S.Gov. Printing Office, Washington, D.C., 1998.
16. Watershed Atlas of India, 1998. Central Ground water Board, Ministry of Water Resources, Government of India, New Delhi, India.
17. Ying, J., Ge, J.-P., Guo, Q.-X., 2010. The relation between the change of NDVI of the main vegetational types and the climatic factors in the northeast of China. Acta Ecologica Sinica , 21, 522–527.

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Table 1 Details of Satellite Imageries used in the study

Date of pass	Path, Row, Shift and Scanner	IRS	Season
04-12-2003	99, 58, 50% SHIFT, LISS-III	P6	Rabi
02-07-2004	99, 58, 50% SHIFT, LISS-III	P6	Kharif
22-12-2004	99, 58, 50% SHIFT, LISS-III	P6	Rabi
28-07-2005	99, 58, 50% SHIFT, LISS-III	P6	Kharif

Note: The wave lengths of bands (LISS-III) are 0.52-0.59 (green) 0.62-0.68 (red) 0.77-0.86(NIR).

Table 2 Albedo Values for Different Cover Types as measured by NOAA (USGS, 1998)

Sl. No	**Cover Type**	**Planetary Albedo**		
		CH1	**CH2**	**NDVI**
1	Dense green leaf vegetation	0.050	0.150	0.500
2	Medium green leaf vegetation	0.080	0.110	0.140
3	Light green leaf vegetation	0.100	0.120	0.090
4	Bare soil	0.269	0.283	0.025
5	Clouds	0.227	0.228	0.002
6	Snow and Ice	0.375	0.342	-0.046
7	Water	0.022	0.013	-0.257

Where, Red= NOAA channel 1; Near Infrared = NOAA channel 1

Table 3 Area wise Land use Land cover details with respective to satellite images and season

S.no	LULC Descrption	Area (km^2)			
		Rabi	Kharif	Rabi	Kharif
		04-Dec -2003	02-July -2004	22-Dec-2004	28-July-2005
1	Water Bodies	13.58	12.25	16.29	13.24
2	Bare soil	65.25	97.85	58.25	77.48
3	Fallow land	72.85	289.57	63.35	139.25
4	Forest	1640.35	1603.58	1631.25	1625.35
5	Agriculture	821.35	610.58	844.75	758.85
6	Settelments	6.73	7.02	6.82	6.78

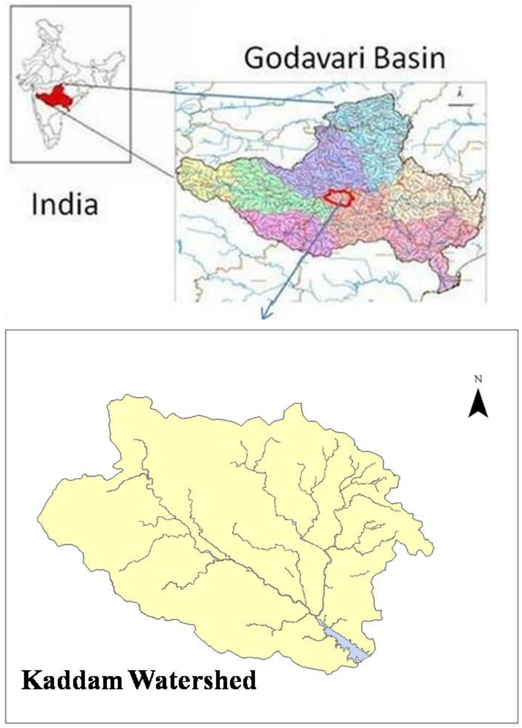
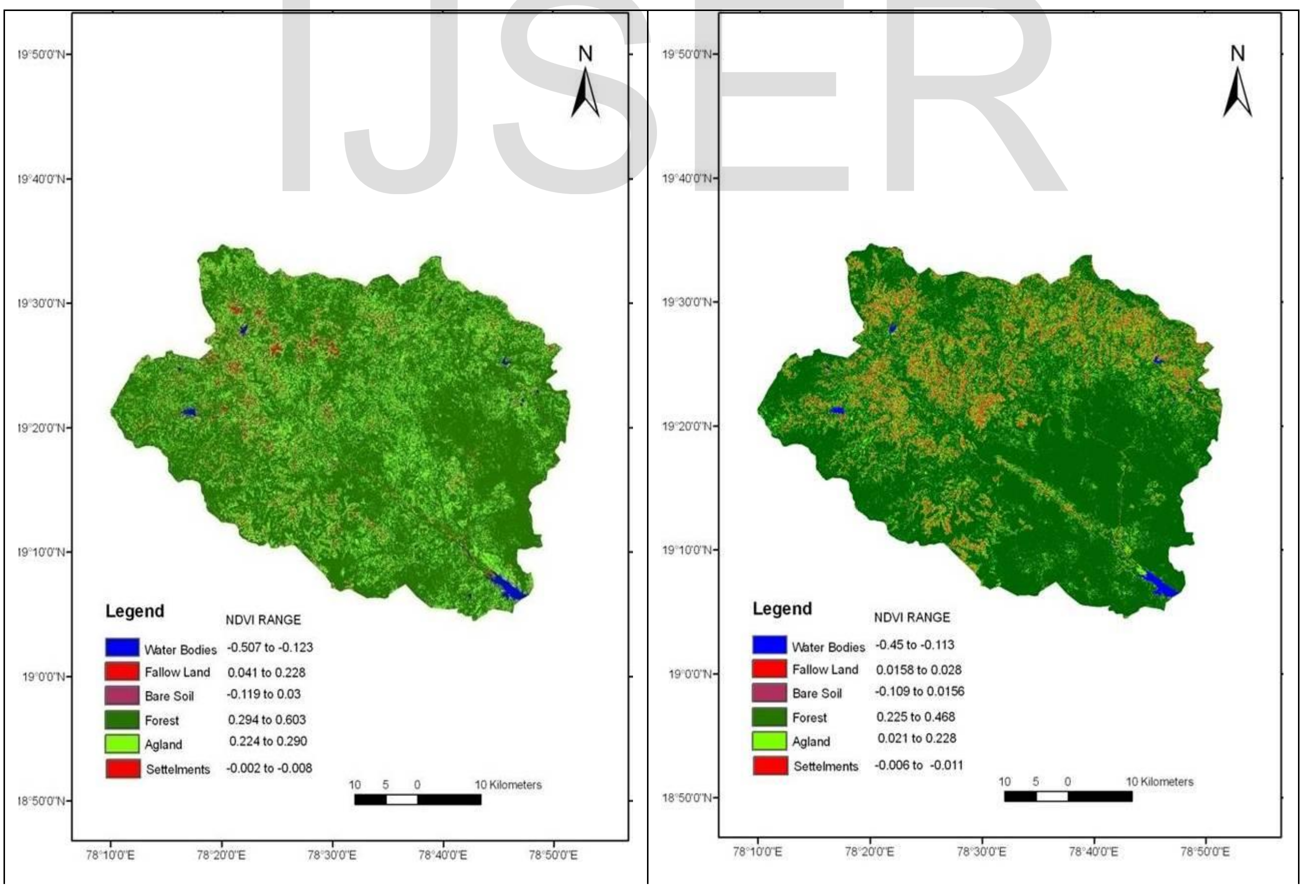


Fig.1. Location map of the study region



(a) (b)

Fig. 2 Land use/Land cover map based on NDVI date of imagery: 28-July-2005 (b) date of imagery: 22-Dec-2004

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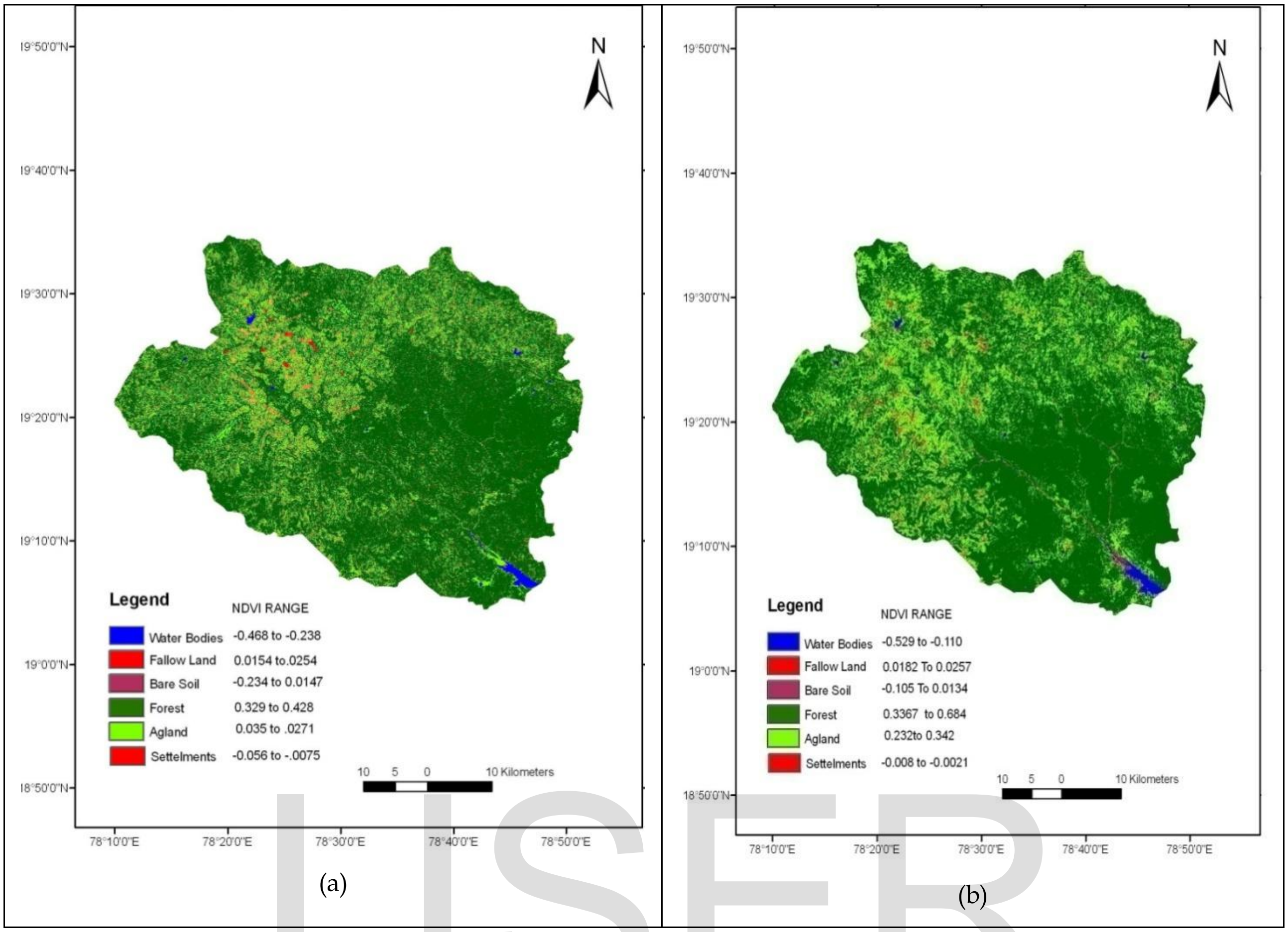

Fig. 3 Land use/Land cover map based on NDVI (a) date of imagery: 02-July-2004, (b)04-dec-2003