Asian Journal of Multidisciplinary Studies

ISSN: 2321-8819 (Online)
2348-7186 (Print)
Impact Factor: 1.498
Vol.4, Issue 8, July 2016

Integration of geospatial technology and sustainable indicators in monitoring environmental resources: Special emphasis on forest environment

L.Prasanna Kumar
Research Scholar,
Ravenshaw University, Cuttack - Odisha

ABSTRACT: The 2012 United Nations Conference on Sustainable Development (Rio+20) had set Millennium Development Goals (MDGs) in order to create a new global development. It was decided at Rio+20 conferences that Sustainable Development Goals (SDGs) will be integrated which will encompass all dimensions of sustainable development: economic, social and environmental. In order to achieve the goals, different sustainable indicators which act as a management tool helps to develop implementation and monitoring strategies for achieving the sustainable development goals. In this paper an attempt is made to integrate the potentiality of geospatial technologies and environmental indicators in achieving the environment related MDGs with special focus on forest environment. The geospatial technology is used in forest cover mapping, forest biomass estimation and forest change detection using the spatio-temporal satellite images. The study will be helpful for the decision makers in monitoring the environmental resources for sustainable development.

Keywords: Sustainable indicators, geospatial technology, sustainable development, forest.

1. Introduction

With the ever increasing population, demand for basic needs has been steeply rising during the past five decades in most of the developing countries. Over 60-70 percent of people in India are living in rural areas that neither have adequate land holding nor alternate service opportunities to produce or procure the need like food, clothing, shelter, fuel, fodder etc. The rural people don't have adequate employment opportunities, in order to generate enough wages to sustain their livelihood. Presently, all the important natural resources like land, water, forest vegetation and livestock play a pivotal role in the social development, economic development and environmental protection. Therefore, the strategy for sustainable development is to improve the productivity of the natural resources and develop the capabilities of the local communities to make optimum use of these resources for their livelihood.

Over exploitation of available natural resources for meeting the growing demand led to serious environmental degradation (Rao 2000). To study and mitigate against further environmental degradation, as well as monitor progress to sustainable development, indicators of environmental status are required (Hall 2001). More recently, efforts have been made to construct indicators in different dimensions and domains to keep track of sustainability i.e. the progress towards the goal of sustainable development (Dhakal, 2002). For any system, to evaluate and monitor the progress towards sustainable development set of indicators were developed, known as Sustainable Development Indicators (SDIs). Many important cities have developed their own set of sustainable indicators. Indicators are adjusted over time to fit the specific conditions, priorities and capabilities (UNCSD, 1996). These indicators would also serve as useful tools for the evaluation of the effectiveness of policies designed to protect the environment as well as provide as early warning of unsustainable practices (Callens and Tyteca 1999, Walz 2000). Becker (1997) has listed sustainability indicators under the headings of Economic, Environmental, Social and Composite. Hart (1999) has shown a new approach in SDIs which includes the interconnection between the three pillars of sustainability i.e. ecological (environment), social and economic. She has described that large number of indicators covers different aspects of human activity, including production, energy, transport, education, health, recreation, ecosystem, landuse, resource use and many more.

However, different environmental information is needed to the decision makers to make some final policies or to take decisions on the environmental development. In this sphere, to gather different level of environmental information, space based technology is used. Space based applications plays an important role in assisting, in understanding, in monitoring, in measuring the impact of development on environment. Remote sensing technologies provides a wealth of environmental data over a range of spatial and temporal scales and play an important role in the provision of indicators of environmental condition that may inform sustainable development and associated decision-making (Schultink 1992, Rao 2001, Rao and Pant 2001, Chen 2002). In the last two decades satellite remote sensing techniques were employed for generating information on forest. Adequate monitoring and management of forest resources is necessary in order to meet the livelihood. Foody

(2003) states that remote sensing technologies can provide a wealth of environmental data over a range of spatial and temporal scales, and so may play a major role in the provision of indicators of environmental condition, that may provide information on the sustainability of development and associated decision making. Several types of remote sensing data, including Aerial photography, Optical Multispectral Scanner, Radio Detection and Ranging (RADAR), and Light Detection and ranging (LIDAR) data have been used by different research and operational agencies for monitoring and assessing the environment.

This paper attempts to study the integration of geo-spatial technology and environmental Indicators in monitoring and assessing the environmental resources for sustainable development with emphasis on forest environment. The Sustainable management of forest resources has become key agenda of the century. In the recent past, the space organizations were successful in providing coarse spatial resolution image to high resolution image in monitoring and assessing the forest resources. In the present work, LANDSAT Thematic Mapper (TM) and Indian Remote sensing Satellite- LISS-III satellite image is used in generating the forest cover maps, land use and land cover maps, change detection maps, forest biomass estimation etc. High resolution satellite image with spatial resolution of 0.6 meters is used for validation of results.

1.1 Sustainable Indicators: Environmental Perspective

Sustainable indicators act as a management tool that helps to develop implementation and monitoring strategies for achieving the sustainable development goals. Constructive efforts have been made to develop different Sustainable Development Indicators (SDI) at global, national and local level. The United Nations defines indicators as not datasets, rather models which simplify a complex subject to a few numbers that are easy to understand and grasp by policy makers. Subsequently the International Institute for Sustainable Development (IISD) has been formed and many research and review papers have been published on SDIs.

In this paper, the major focus is to study the application of remote sensing technologies in environmental sustainability indicators. There are many potential indicators of environmental condition that may be a value in developing a system to monitor sustainable resource use (Foody 2003). The 2012 United Nations Conference on Sustainable Development (Rio+20) had set Millennium Development Goals (MDGs) in order to create a new global development. It was decided at Rio+20 conference that Sustainable Development Goals (SDGs) will be integrated which will encompass all dimension of sustainable development: economic, social and environmental. The MDGs with 10 major priority goals with 30 targets and 100 core indicators is put forward and that is to be achieved by the end of 2015. Among the list of indicators, many of these have potential to be remotely sensed, directly or indirectly. In table 1, subset of the environmental indicators suggested in United Nation Conference on Sustainable Development is shown with significance to forest environment and which remote sensing may have a role in their measurement.

Table 1: Few Millennium Development Goals suggested in the United Nations Conference on Sustainable Development (Rio+20) that are of significance to the environment and which remote sensing technologies have a major role in measuring.

SL No	Priority Goals	Goal Statement	Potential Remote Sensing input
1	Settlements, infrastructure and transport	Settlements and their infrastructure are livable, green and well managed.	Monitor land use and land cover changes with special emphasis on urban spatial growth, Settlement growth, built-up features etc.
2	Food security, sustainable agriculture and fisheries	Sustainable agriculture, food security and universal nutrition are achieved.	Monitor land use and land cover changes. Monitoring the Agricultural changes, vegetation mapping, forest mapping, landuse planning, natural resource monitoring etc.
3	Water availability and access	Safe and affordable water is provided for all and the integrity of the water cycle is ensured	Monitor land use and land cover changes. Monitoring the water bodies.
4	Biodiversity and ecosystems	Biodiversity and ecosystems are healthy and contribute to human well-being.	Monitor land use and land cover changes. Biodiversity mapping, monitoring the forest cover changes, estimate the moisture content etc.

These environmental issues have different sustainable indicators and with the help of remote sensing various applications can be developed for sustainable livelihood. Apart from the above mentioned goals, other issues that are mentioned in the MDGs like Poverty and inequality, Health and population, Education and learning, Quality of growth and employment, SCP and economic sectors, Energy and climate change, has been put forward and various attempts has been made to use the remote sensing technologies directly or in directly.

1.2 Integration of Geospatial technology with Sustainable Indicators

Remote sensing plays a major role in measuring different sustainable development indicators. In this paper, attempt is made to show the inter connection between few environmental indicators that are used to achieve the MDG and remote sensing technologies with special emphasis on forest environment. In order to explain the potential of remote sensing as a source of indicators on sustainable practices it may be helpful to briefly review a case study on the forest environment.

2. Study area

Lanjigarh block of Kalahandi district in Odisha is taken as the sample study area as it is rich in forest resource. The latitudinal extent is 19°32’43’’ N to 20°01’32’’ N and longitudinal extent 83°09’56’’ E to 83°30’54’’ E. The Niyamgiri hill is one of the gifts of natural forest resource to the local people. The 428 Ft. high summit of the Niyamgiri hills situated just on the district border overlooks a narrow valley to its North of which Lanjigarh forms the apex.

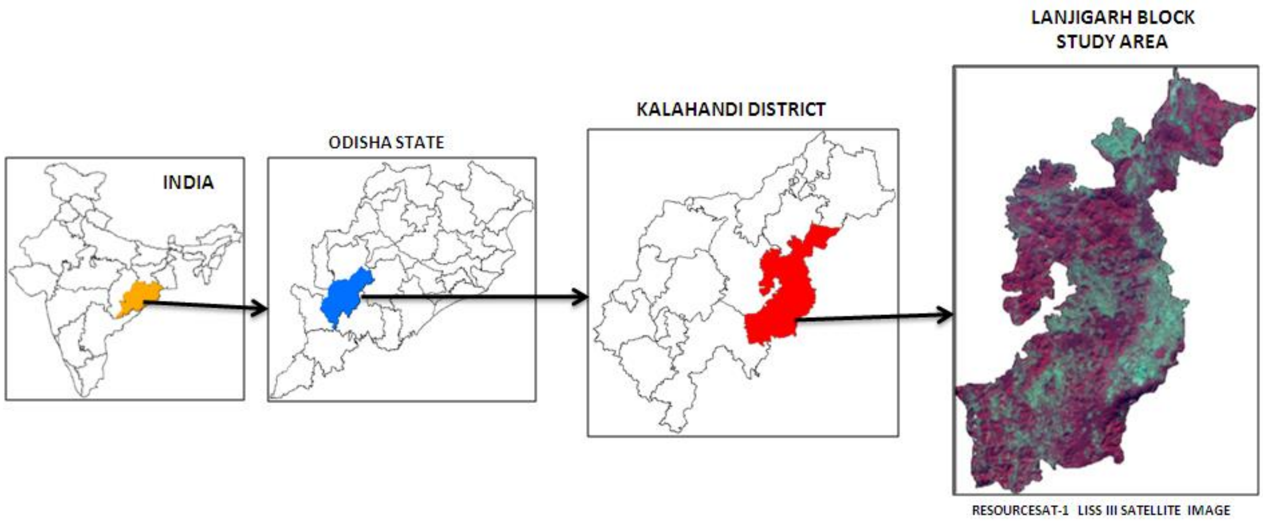

Figure 1: Location of Study area

3. Satellite Data Used

The data used in the study includes satellite remote sensing products in the form of Imageries. Landsat Images and Resourcesat 1 images are used for the above study. The Landsat images are downloaded from the (http://glovis.usgs.gov) website over the year 1973 to 2005. The Indian Remote Sensing (IRS) satellite is downloaded from the Bhuvan website (http://bhuvan.nrsc.gov.in/). Apart from the satellite images, Survey of India (SOI) toposheets are procured for georeferencing the satellite images. The satellite images are georeferenced and WGS-1984_UTM_Zone_45N Projection is assigned. High resolution Spot/GeoEye images are used for the validation of results. The details of the images in table 2.

Table 2: Satellite data used

Satellite	**Landsat 1**	**Landsat 5**	**Landsat 5**	**IRS-P4**
Year	1973	1989	2005	2012
Sensor	MSS	Thematic Mapper (TM)	Thematic Mapper (TM)	LISS-III
Resolution	80 meters	30 meters	30 meters	23.5 meters

A: Landuse and Landcover change monitoring

In this paper, multi-temporal and multi spectral satellite images are used in land use and land cover classification and mapping. In table 1, it is mentioned that land use/land cover (LU/LC) mapping is one of the major output derived from the satellite images and that can be used to achieve few priority goals of MDG. The LU/LC dataset is used in monitoring the natural resources.

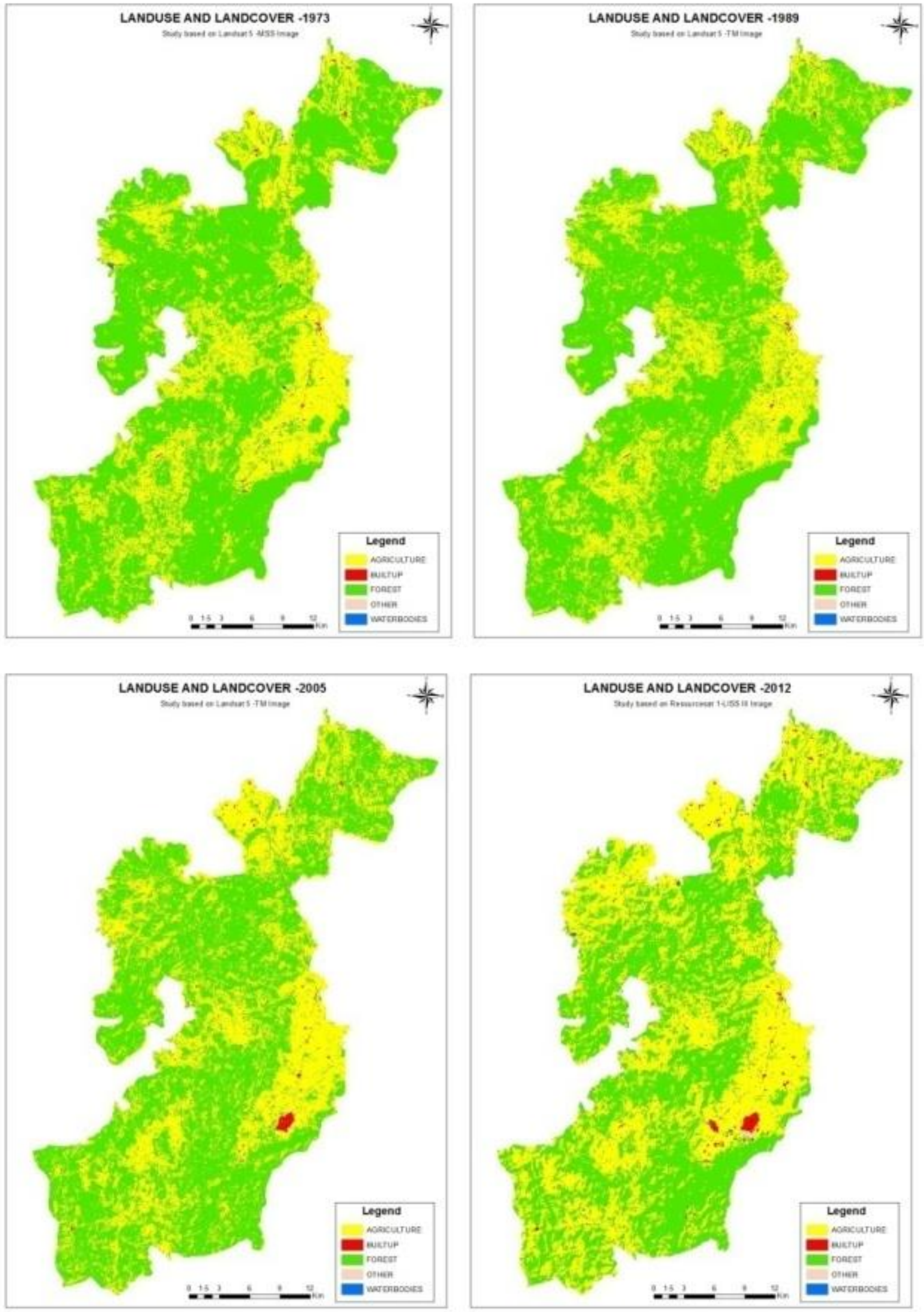

Figure 2: Landuse and Landcover map of the study area. (a) 1975, (b)1989, (c) 2005, (d) 2012

Different natural features like forest cover, water bodies, vegetation can be interpreted from the satellite images. Presently, in this paper five major classes are derived, i.e. forest, vegetation, water bodies, built-up land and others. Figure 2 shows the landuse and landcover map of different years. It includes for the year 1973, 1989, 2005 and 2012.

In table 3, it is indicated that there are major changes in all the classes of landuse and landcover. As compared to that base year 1973, the agricultural land has increased to 13500 hectares where as the built-up land has increased to 867 hectares. The water bodies and other classes, even show the rise in the area. The major change that is observed is the loss of forest cover. The trend of forest cover shows the degradation of forest area over last 40 years

Table 3: Landuse and Landcover Statistics year wise (Area in Hectare)

YEAR→ CLASS	1973	1989	2005	2012
Agriculture	34993.74	33846.89	39183.57	48500.52
Built Up	270.28	324.25	679.58	1138.08
Forest	63910.68	64913.85	58946.89	49012.56
Others	186.56	272.89	540.89	691.80
Water bodies	58.86	62.24	69.19	77.16

B: Forest cover mapping and change monitoring

Accurate estimation of the forest extent and ideally a range of forest types, are required for a complete understanding of forests and their sustainable use (Foody 2003). Forest identification and mapping through remote sensing technologies is one of the major challenges. Coarse spatial resolution helps to map the forest cover at global level, whereas the high resolution satellite image will be more suitable for mapping forest at large scale (local level). In the present state of space science technology, the scientists are even capable to provide the forest work plan, which helps the forest department for clear monitoring and managing the forest resource.

In figure 3, Bengbhata reserve forest of the study area is shown, where it is noticed that over time period the forest cover area is changing drastically. As compared to the 2005 year image with 2012, it is observed that there is forest degradation. In the year 1973 the forest cover was 1487 hectares, whereas in the year 1989 the forest area reduced to 1425 hectares. In the present condition the forest area has drastically reduced to 1107 hectares. Figure 4 shows the detail statistics of the forest cover change. There may be different factors that are responsible directly or indirectly. Few factors like shifting cultivation, increase in the population growth and dependency on the forest for livelihood etc.

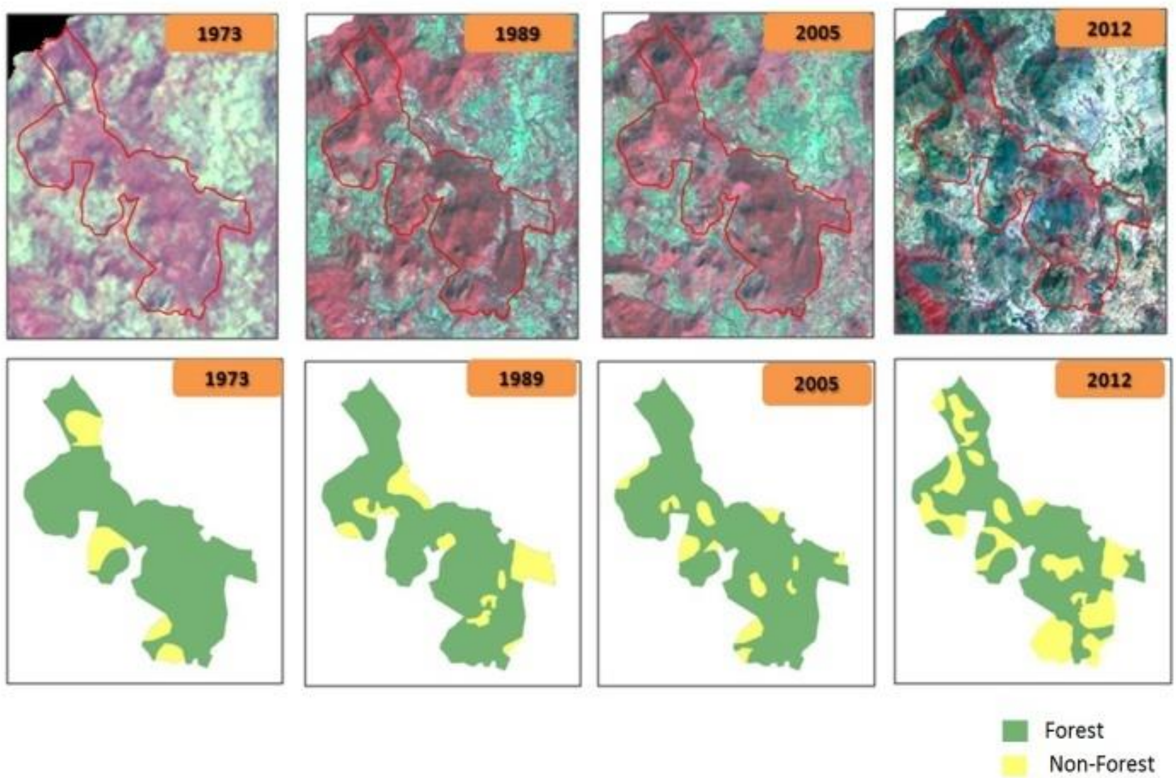

Figure 3: Bengbhata reserve forest of the study area

Table 3: Forest Cover area of Bengbhata reserve forest (Area in Hectare)

YEAR	1973	1989	2005	2012
Forest	1487.09	1426.92	1516.08	1107.5
Non- Forest	194.97	255.14	165.98	574.56

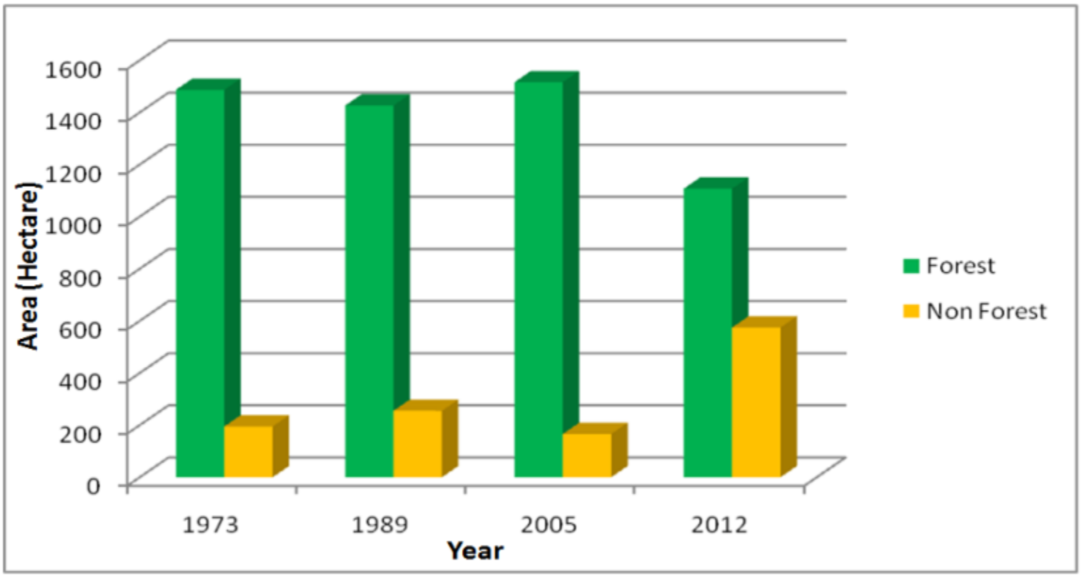

Figure 4: Forest Cover Change

C: Biomass Estimation.

Estimates of the biomass are required to aid the understanding of the role of forests in environmental processes and sustainable use. Reliable biomass data are required for the quantification of the biomass emissions associated with land cover change (Brown and Gaston 1995). The uncertainties about forest biomass are a larger limit to understanding the role forest in carbon cycle than those associated with forest area change (Houghton et al. 2000) Remote Sensing has considerable potential as a source of biomass data. To date, basic vegetation indices such as Normalized Difference Vegetation Index (NDVI) have been used widely in the estimation of biomass. NDVI is used to identify the presence of green vegetation and has been successfully used in numerous regional and global applications for studying the state of vegetation. Forest cover estimation was done by comparing the NDVI values of forest pixels for different date's data. NDVI was calculated as (NDVI=NIR–R/NIR+R), where NIR and R are uncorrected reflectance values Near Infra Red and Red wavelength regions respectively. However, as the spectral response of a forest is strongly influenced by its biophysical properties other approaches may be more appropriate. Figure 5 shows the NDVI map of the study area, where it is shown that the biomass is reduced gradually. In the year 1973 the biomass was estimated to be 74609 hectare where as it got reduced to 40297 hectare in the year 2012. It is monitored that during the year 2005 to 2012, there is decrease of 13000 hectare of vegetation cover.

D: Monitoring the resources through remote sensing technology

By using the satellite image interpretation skill and relevant field information, it is able to classify different features and monitor the changes of natural features from the satellite image. Apart from the forest cover monitoring, other classifications are also useful for achieving the priority goals of sustainable development. For example, monitoring the agriculture cropping pattern, change in settlement growth pattern, change in water-bodies etc. In figure 6, change in forest area, built up feature and water-bodies in the satellite image are shown over a time period.

Table 4: NDVI statistics of the study area (Area in Hectare)

YEAR	1973	1989	2005	2012
NDVI	74609	67993	53284	40297

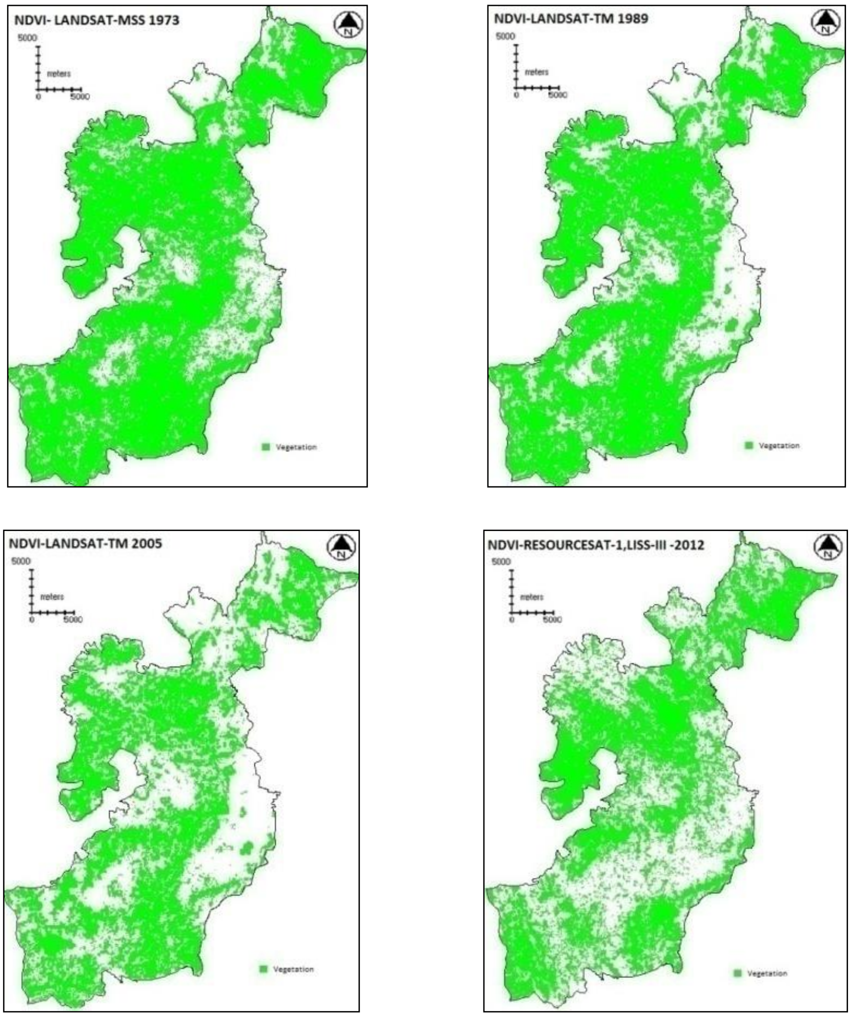

Figure 5 : Normalized Difference Vegetation Index Map

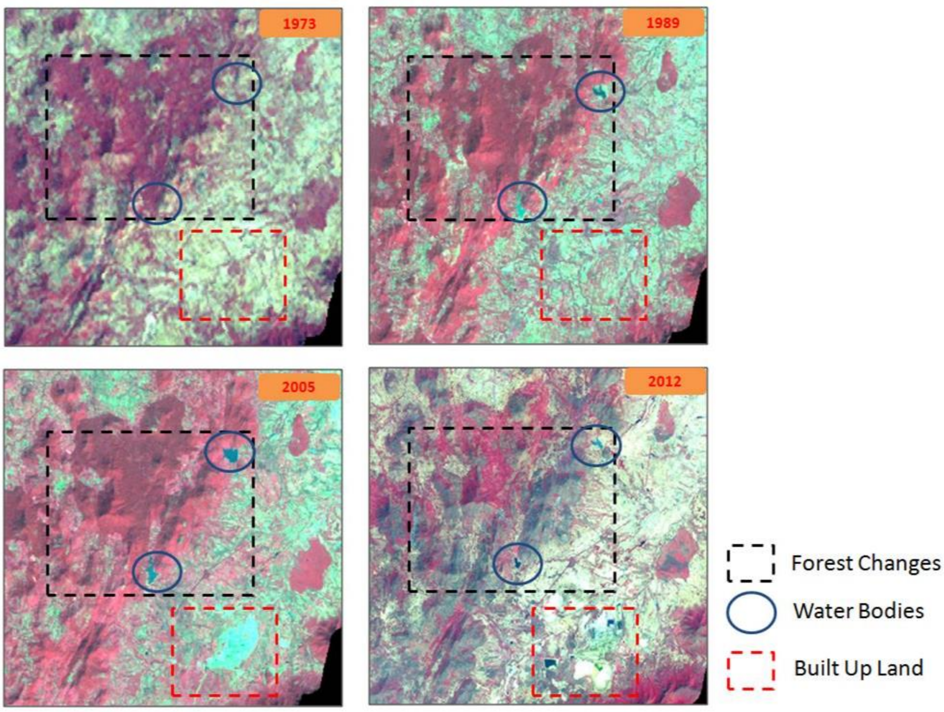

Figure 6: Multi-temporal satellite images in monitoring the changes of forest cover, water bodies and built-up land

4. **Potential of high resolution satellite images in change monitoring**

The validation of the result is done using the high resolution optical data on 25th January 2014 from Google earth. The image is downloaded from the Google Earth and it is georeferenced with the master satellite image. The images are compared with the other multi-spectral images. Figure 7 shows the patch which changed from general land to industrial land. The red circle in the image shows the change detection and validated with optical image.

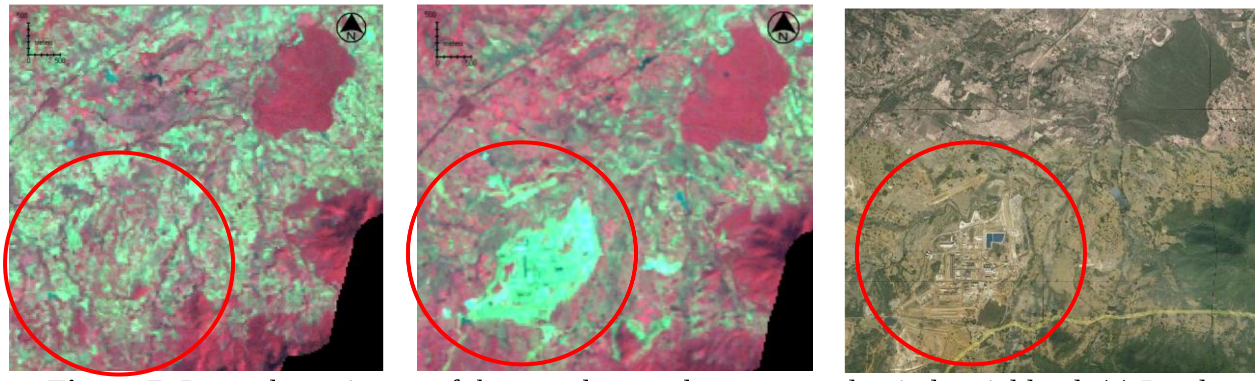

Figure 7: Pre and post image of the sample area that converted to industrial land. (a) Landsat 1989, (b) Landsat 2005 (c) Spot/ GeoEye Image 2014

5. Conclusion

In this paper an attempt is taken to present the potential of remote sensing technologies in achieving the sustainable development goals with special emphasis on environment. Multi-spatio-temporal satellite images are used to monitor the changes of natural and manmade features. The remote sensing technologies have the capabilities to provide information from the global level to local level. Landuse and landcover classification, forest cover assessment, NDVI are few applications that are used to study the priority goals of United Nations Conference on Sustainable Development (Rio+20). Further, different approaches and applications will be carried out to study environmental indicators and other sustainable indicators with the help of space borne technologies.

Acknowledgements

I wish to acknowledge National Remote Sensing Centre (NRSC)-India, for providing IRS-Satellite Image through the Bhuvan website (http://bhuvan.nrsc.gov.in/) and would like to thanks Global Land Cover Facility at the University of Maryland (http://glovis.usgs.gov) from where the Landsat Images were downloaded. The authors also acknowledge "Google Earth" platform for providing access the high resolution satellite images.

References:

Becker, B. (1997) 'Sustainability Assessment': A review of Values, Concepts and Methodological approaches, Issues in Agriculture 10, CGIAR, The World Bank, Washington, USA.

Brown, S., and Gaston, G., (1995) Use of forest inventories and geographic information systems to estimate biomass density of tropical forests: application to tropical Africa. Environmental Monitoring and Assessment, 38, 157-168.

Callens, I., and Tyteca, D., (1999) Towards indicator of sustainable development for firms- a productive efficiency perspective, Ecological Economics, 28, 41-53.

Chen, X. W., (2002) Using remote sensing and GIS to analyse land cover change and its impacts on regional sustainable development. International Journal of Remote Sensing, 23, 107-124.

Dhakal S., (2002) "Report on Indicator related research for Kitakyushu Initiative", Ministry of Environment, Japan

Foody, G,M.(2003) 'Remote sensing of tropical forest environment : towards the monitoring of environment resources for sustainable development', International Journal of Remote Sensing, 24, 4035-4046.

Hall,J.P., (2001), Criteria and indicators of sustainable forest management. Environmental Monitoring and Assessment, 67, 109-119.

Hart, M. (1999) 'Guide to Sustainable Indicators' 2nd Ed, Hart Environmental Data, North Andover MA, USA.

Houghton, R.A., Skole, D. L., Nobre, C. A., Hackler, J.L, Lawrence, K.T., and Chomentowski, W. H., (2000), Annual fluxes or carbon from deforestation and regrowth in the Brazilian Amazon.Nature, 403, 301-304.

Rao D.P (2000) Role of remote sensing and geographic information system in sustainable development, International Archives of Photogrammetry and Remote Sensing. Vol. XXXIII, Part B7. Amsterdam 2000.

Rao, D.P., (2001) A remote sensing-based integrated approach for sustainable development of land water resources. IEEE Transactions on Systems Man and Cybernetics, 31, 207-215.

Rao,K.S., and Pant, R., (2001), Land use dynamics and landscape change pattern in a typical micro-watershed in the mid elevation zone of central Himalaya, India. Agriculture Ecosystems and Environment, 86, 113-123.

Schultink, G., (1992), Integrated remote-sensing, spatial information system, and applied models in resource assessment, economic development, and policy analysis. Photogrammetric Engineering and Remote Sensing, 58, 1229-1237.

UNCSD, (1996) "Indicators of Sustainable Development Framework and Methodologies", Division for Sustainable Development, United Nations, New York.

Walz, R., (2000). Development of environmental indicator systems: experiences from Germany, Environmental Management, 25, 613-623.