The Journal of Ecology. Photon 108 (2014) 255-265
https://sites.google.com/site/photonfoundationorganization/home/the-journal-of-ecology
Case study. 6853-3275

Time Series Analysis of Forest and Tree Cover of West Bengal from 1988 to 2010, using RS/GIS, for Monitoring Afforestation Programmes

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The authors receive Thomas Edison Award-2014 in Ecology for Inspiration and Knowledge Distribution among young research scholars.

Article history:
Received: 16 December, 2013
Accepted: 24 December, 2013
Available online: 11 January, 2014

Keywords:
Forest Cover in West Bengal, ERDAS software, ARCINFO software, Forest Survey of India, GIS, Joint Forest Management, Monitoring afforestation, Forest cover mapping using Remote Sensing, Tree cover assessment

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Abstract
West Bengal is one of the most densely populated States of India, with a population density of 1029 persons per sq km (2011 census) as compared to the national average of 382 persons per sq km. The State is predominantly agriculture-based, with only 13.4% of the total land area being reserved as notified Forest. The Forest ecosystem however is extremely diversified. With the initiation of World Bank aided Social Forestry Project in the State in 190-81, large chunks of the barren lateritic tracts of the State were brought under green cover. Subsequently, another World Bank aided West Bengal Forestry Project was initiated during 1990s, for improvement of degraded forests through people's participation. The conventional methods of survey and enumeration of forest areas is extremely slow. The present paper shows the capability RS/ GIS technology in real-time assessment of forest/ tree cover, as part of monitoring of afforestation/ social forestry programme, on a large landscape level. A time series analysis of Forest cover will also act as a basis to monitor the forest carbon footprint, and facilitate formulation of REDD+ Projects in the State.

Citation:
Raha A.K., Mishra A.V., Das S., Zaman S., Ghatak S., Bhattacharjee S., Raha S., Mitra A., 2014. Time Series Analysis of Forest and Tree Cover of West Bengal from 1988 to 2010, using RS/GIS, for Monitoring Afforestation Programmes. The Journal of Ecology. Photon 108, 255-265.

1. Introduction

The State of West Bengal extends from the Himalayas in the North to the Bay of Bengal in the South. It lies between 21°34′N to 27°13′N latitude and 85°50′E to 89°52′E longitude covering a geographical area of 88,752 sq km., which is 2.7% of the total geographical

area of the country. Population density of the state was 767 per sq.km as compared to that of the country at 273 per sq km. (1991 Census). After the promulgation of Estates Acquisition Act of 1953, all the recorded forests of the state other than those under lease agreements with tea gardens had been brought under the management of Forest Department, West Bengal. Subsequently the Tea garden forests had been vested with Forest Department as "Resumed Forests". At present, all the recorded forests of the State are classified as Reserved Forests, Protected Forests and Unclassed State Forests, under the Indian Forest Act, 1927. The recorded forestland of the State (11879 sq km.) is 1.54% of the recorded forest land of India (770078 sq km.) (State Forest Report, West Bengal, 2010-11).

West Bengal has one of the oldest history of scientific management of its forests which dates back to mid-nineteenth century. Detail working plans were prepared by the British Foresters for management of this natural resource, which depended heavily on economic aspect of value addition, but did not totally overlook the aspect of Bio-diversity Conservation. In late nineteenth and early twentieth centuries, the art and science of artificial regeneration with fast growing spp. like teak (*Tectona grandis*), sal (*Shorea robusta*), champ (*Michelia champaca*), *etc*., after clear-felling of natural forest in Northern Bengal, was perfected.

However, in the districts of undivided Midnapore, Bankura and Purulia, the post-independence scenario was different. On the basis of Estate Acquisition Act of 1953, all the zamindari forests in these districts were taken over by the State and their management was vested with State Forest Department. These forests were notified as Protected Forests, under Indian Forest Act of 1927, without clearly defining or settling the rights of forest fringe people. These notified forests were in disjointed patches, varying between a few hectors to a few hundred hectors. The forests were surrounded by villages with large population and high population density. The poverty levels in these villages were also high due to near-absence of irrigation facilities and industries, as well as low agricultural productivity as the fields were monsoon-fed. The fringe population depended heavily on the sal coppice forests for their subsistence, fuel wood and fodder requirement. The heavy biotic pressure started denuding the forests and by the beginning of 1970s, most of the sal coppice forests in these districts had degenerated to bushy/scrub forests. The efforts of the Forest Department staff to control the process of degradation, by mere use of force or legal measures, led to total failure. The trend continued till mid seventies.

Meanwhile, in South Bengal, in the districts of Bankura, Midnapore, Purulia and elsewhere, large scale Eucalyptus and *Acacia auriculiformis* (Akashmoni) plantations were raised during sixties and seventies, as part of "degraded forest regeneration". Sal (*Shorea robusta*) plantations were also tried in degraded sal forest areas, however, with limited success due to heavy biotic pressure from fire and grazing in the young plantations. Beautiful patches of Eucalyptus and Akashmoni plantations provided ground cover to all those barren/degraded forest areas, which could not be otherwise regenerated with slow growing, miscellaneous species.

Simultaneously, another socio-economic experiment was initiated in Arabari village of Midnapore district by Forest Department in 1972-73, trying to regenerate nearly 1200 ha of degraded/ blank forest area with the help of around 615 families. The idea of sharing of usufructs with the villagers, from the resuscitated forest areas, was conceived in the Project. The success of the experimental project ultimately led to the generalized concept and adoption of Joint Forest Management (JFM) at the State and National level. The first Govt. Order on sharing of usufructs and constitution of JFM Committees was issued in 1988 and over the next few years, the voluntary movement of forest protection through people's participation spread like wild fire. Nearly 4000 Forest Protection Committees were formed to protect nearly 500,000 Ha of degraded forest areas of the State.

The movement received a material boost with the introduction of World Bank sponsored Social Forestry Project from the beginning of 1980s. The distribution of vested waste land to landless rural families, in the three districts of South West Bengal, in later part of the 1970s/ early '80s was also a giant step towards the future success of farm forestry in South West Bengal (Guhathakurata and Roy, 2000).

Early eighties also saw the global resurgence of Biodiversity conservation and renewed interest in the preservation of the endangered flora and fauna of the world. In keeping with the international and national trend, West

Bengal too shifted its priority in forest management towards conservation of natural flora and fauna in the forests and the wetlands. National forest policy of 1988 and the Forest Conservation Act, 1980 put severe restriction on the harvesting of the natural forests. The late eighties and early nineties saw increased activities in wildlife management in West Bengal. Large tracts of forest areas, having ecological importance and significance, had been declared as protected areas in the form of National Parks, Sanctuaries, Biosphere Reserves and Tiger Reserves. Policy decisions were taken to hand over administrative control of these protected areas (PA) to Wildlife Wing for more intensive management from wildlife conservation angle. Till date, nearly 34% of the total recorded forest areas of the State have been declared as P.A., as compared to 16.5% for the entire country.

2. Materials and Methods

2.1 Geographical location

The State of West Bengal extends from the Himalayas in the North to the Bay of Bengal in the South. It lies between 21034′N to 27013′N latitude and 85050′E to 89052′E longitude covering a geographical area of 88,752 sq km.

2.2 Objective of Research

The main objective of this case study is to develop a methodology, based on Remote Sensing technology, for rapid and near real-time monitoring of forest and tree cover for the entire state of West Bengal, in order to evaluate the success/failure of joint forest management and social forestry programme.

2.3 Identification of problems leading to the research

The Government forests in the State had been subjected to severe biotic pressure from the forest fringe population who depend on the forest for their livelihood and sustenance. At the same time, there were large chunks of Government owned waste land whose ownership were distributed to the land less/agricultural labourers as part of land reform measures. With the initiation of World Bank aided projects on social forestry and Joint Forest Management (JFM), for resuscitation of degraded forest land through people's participation, large scale afforestation programmes had been initiated in the State from the 1980's. The degraded forest also started recuperating through JFM. However, the conventional method of monitoring the afforestation programme as well as status of forest/tree cover is fraught with many loop holes. These are (i) time consuming, (ii) dependent on integrity of data collection at field level and (iii) sometimes outdated due to lag in data collection period and compilation of the same, as result the management at the policy level are unable to monitor and correct the course of deviation, if there is any, concurrently with the implementation of the project.

Forest Survey of India had started evaluating the forest cover of the country, based on LANDSAT imagery and through visual interpretation of the satellite data from 1987. Such rapid appraisal of forest cover, on national basis, led to discrepancies in results on vegetative cover in the States. In order to find the actual status of forest cover of the State, prior to launching of Social Forestry project and initiation of Joint Forest Management (JFM) with people's participation in the in the early 80's, and to monitor the changes over the years, West Bengal Forest Department took up collaborative project on Forest vegetation mapping, using satellite imagery, with RRSSC, Kharagpur, Department of Space, Govt. of India. Forest cover mapping was done with December, 1988 data from IRS-1A satellite, using supervised classification, and it showed that total forest and vegetation cover in the state had gone up to 14.32% from the recorded forest area of 13.4% as in 1988 (Sudhakar et al., 1992). Subsequent, periodic change detection studies have been carried out with November/December, 1991data from IRS-1A/ 1B, November/December, 1994 data from IRS-1B (Sudhakar et al., 1996) & 1997 Nov/Dec data from IRS-1C through the infrastructure of RRSSC, Kharagpur, Dept. of Space, Govt. of India. The Remote Sensing / GIS Cell of West Bengal Forest Dept., was launched in late 1999. January, 2000 data from IRS 1D and March, 2004 from IRS-P6 satellites were processed by the GIS Cell of the Forest Department. The time-series output had shown a considerable improvement in the forest cover of the state up to the year 2006 (Raha, 2007).

During 1995-96, works of wetland survey, using satellite imageries, in the state had been taken up and the same had been completed for eight Districts of the state which have large chunks of wetlands. These wetlands had been categorized and mapped into (i) wetlands having areas more than 10 ha each (ii) wetlands having areas less than 10 ha each (Raha et al., 1997).

At the initial stage of the Project, the district maps with latitude/longitude information were registered, Geo-referenced and digitized with Polyconic Projection, Datum Modified Everest. Other important features like Roads, Railways, Rivers *etc*., were digitized as separate layers. The central meridian and Projection origin were fixed at 88°E and 24°N. The radiometrically corrected Digital Data on CD-ROM, obtained from NRSC, Hyderabad, were imported into image format using ERDAS Imagine software. The imported scenes were then registered and geo-referenced with respect to the known features of the digitized coverage. Satellite Imageries were then extracted for each district, as thematic land use maps. Basic and available standard information like population, area, forest composition, FPC details of Forest Protection Committees (FPC) *etc*., were then attached to the digitized coverage as GIS data base.

Latest series of Indian Remote Sensing Satellite, IRS-P6 was launched in last part of the year 2003. The Mission's main objective was to provide continued satellite remote sensing data services for integrated land and water resources management, at micro level, with enhanced multi-spectral and spatial coverage.

The IRS-P6 satellite, weighing around 1250 kg had been launched from Sriharikota by the indigenously built Polar Satellite Launch Vehicle (PSLV), at an altitude of around 800 km. The Satellite is carrying three sensors, the LISS-III and LISS-IV multi-spectral sensors and the AWiFS. Resolution of LISS III in visible, NIR and SWIR bands is 23 m, that of LISS IV in visible and NIR bands is 5.8 m and AwiFS has a resolution of 56 m in visible, NIR and SWIR bands.

For the purpose of Forest and Tree cover monitoring in the State as in 2010, the GIS Cell of West Bengal Forest Directorate had requisitioned from NRSC, Hyderabad one Scene (Row 55, Path 107) of AwiFS data for December 2010 for change detection study. Since AwiFS data has a very large swath of 700 km, the entire geographical area of West Bengal was covered by the single scene. However, the AWiFS data was found very useful for rapid appraisal of Forest and Vegetation status of the State.

The Digital data were then registered with Geo-referenced vector coverage data, containing State and district boundaries of West Bengal, using ARC INFO GIS software.

The next step was to carry out unsupervised classification using ERDAS Imagine Image Processing software. The algorithm adopted was "Initializing the Means" along Diagonal Axis, Standard Deviation 2 and Convergence threshold of 0.980. Number of classes was fixed between 20 to 30, depending on the extent and diversity of forests in the districts. Attributes of the classified images were then grouped into different classes like Forest Cover, Vegetation / Tree cover / woodlot, water bodies and agriculture based on field knowledge, ground truth verification and earlier reference maps (Yichun et al., 2008).

While doing classification, subset images of the notified Forest areas were specially created for the forest-rich districts of South 24 Parganas, North 24 Parganas, West Midnapore, Bardhaman, Birbhum, and Jalpaiguri in order to segregate forest cover from the tree cover as correctly as possible (Figs. 5-6). However, in case of Bankura district, the recorded forest land is interspersed with vested and private wasteland, containing large scale *Eucalyptus/ Acacia auriculiformis*. Such group farm forestry plots have almost similar DN values as in case of plantations on Forest land, and for the purpose of rapid tree cover monitoring, it was not considered worthwhile to delineate small forest patches for segregation of forest cover from non-forest tree cover.

Moreover, since North and South Dinajpur, Malda, Nadia, Murshidabad, Coochbehar, Howrah and Hooghly districts contained very small percentage of recorded Forest land (Fig. 5) , which could not be delineated for the purpose of segregation, so the forest cover for these districts were assumed to be equal to the areas of recorded forest land. However, the FCCs for these districts were classified using the same algorithm, for generation of tree/vegetation cover. The entire exercise was completed in a period of six months and the data base was finally prepared in October 2012. In the present classification, the grassland of Jaldapara National Park and Buxa Tiger Reserve, which are notified Reserved Forest and are maintained as typical habitats of Rhino and Tiger, have not been categorized as Forest cover.

The permanent water bodies like rivers and creeks in Sundarban mangrove forest was included as Mangrove Forest cover while computing the Forest cover of the districts of South and North 24 Parganas. The rationale behind this is that historically, all such water

bodies enclosed within recorded Forest boundaries, were also recorded and quoted in the past as forest land. These wetlands are integral part of the mangrove ecosystem and should not be construed as degraded forest or water bodies, which can be planted up to increase the forest cover. This protocol has been adopted by West Bengal Forest Department to ensure a uniform platform for comparison of forest cover with the past records and to facilitate change detection. Forest Survey of India, Dehradun, in their study, had left out almost 50% of mangrove forest (water bodies) while computing the Forest cover of the State. However, the State Govt. had taken up the issue of different protocol followed by the two agencies. FSI, in its latest reports, have been separately covering mangrove ecosystem in order to clarify the discrepancies (India State Forest Report 2011).

Similarly, consolidated patches of Eucalyptus/Akashmoni (*Acacia auriculiformis*) and Casuarina (*Casuarina equisetifolia*) plantations, raised on private/vested wastelands under Social/Farm Forestry programmes, and having forest-like micro-ecosystem have been enumerated as Forest cover though these may be located outside recorded Govt. Forest and may be part of Group Farm Forestry. Such type of Forest cover is more prevalent in West Midnapore, Purulia, Birbhum, Bankura and Bardhaman districts.

Tree cover, calculated under this project includes the village grove, tree conglomerates around households, tea gardens, orchards and horticulture plantations (Table 1, Fig. 8). Though districts like North 24 Parganas, Nadia, Murshidabad, Howrah, Hooghly and North Dinajpur have hardly any recorded forest land, yet all these districts have appreciable tree/green cover mostly contributed by the village groves and trees around households in the rural areas (Fig. 6).

2.3 Research Justification

The methodology followed in this research paper is based on satellite data which incorporates transparency in the output of monitoring process and has much more reliability as compared to the conventional monitoring. The monitoring data generated is also are near real-time one which facilitates the project related decision making process at the highest level. The case study also proves that the technology is not too complicated and can be easily adopted by any Government Organization with reasonable amount of training of a few staff/officers.

3. Results and Discussion

The Forest cover, as calculated on the basis of December 2010 (Table 2, Fig. 7), AwiFS satellite data, comes to 15.10% of total geographical area of the State, as compared to the year 2006 figure of 15.68%. Forest Survey of India, in its India State Forest Report 1989 had arrived at the State's Forest Cover figure at 9.03%. India SFR 2005, published by FSI had calculated the percentage of Forest cover of the state at 13.99%, whereas the 2011 Report of FSI finally arrived at the State's Forest cover figure of 14.64% (India State of Forest Report, 1989, 2005, 2011). Even though the classification algorithm and protocol followed by the Central and State agency are different, yet both the assessments show that the State has around 15% of its geographical area under Forest cover. One very obvious discrepancy is the interpretation of Mangrove forest as Forest cover. As already have been explained in earlier paragraph, Sundarban has nearly 4200 sq km. of Reserved Forest, which comprises nearly 2000 sq km. of land mangrove vegetation and 1800 sq km. of water body which is an integral part of mangrove/ estuarine forest. Protocols followed in the classification by FSI and State Forest Department may be the basis of future reconciliation.

The marginal variation in Forest cover, as in the present study, may be due to difference of data quality, classification procedure, as well as the quantum of harvested forest (as per approved Working Plan). Also, in the present study, classification of forest cover and non-forest tree cover has been made after segregating the notified forest land from the non-forest land. This may have led to marginal decrease in Forest cover, as some of it may have been classified as non-forest tree cover. Another reason may be the slowing down of Joint Forest Management programme after the completion of externally aided West Bengal Forestry Project which ended in the beginning of this millennium.

However, the uniqueness of this project is that this is the first time a more detailed analysis of the satellite imageries (Figs. 1-4) could be done to calculate the total tree/ vegetation cover of the State, district-wise, which can form the basis of assessment of Forest/ Tree Carbon pool in the State, as well as

preparedness of the State towards implementation of REDD+ Projects under Climate Change scenario. The tree cover is estimated at 27.6% which shows that the only prospect of increasing the forest cover in the State, to reach a national target of 33%, lies in implementation of large scale Social Forestry programme, since in a densely populated state like West Bengal, there is no scope of increasing the quantum of recorded forest land any further.

Till 1999, the assessments made by Forest Survey of India on country-basis, was based on visual interpretation at 1:250,000 scale. However, the 2001 assessment was based on Digital Interpretation at 1;50,000 scale. Digital interpretation at 1:50,000 scale has several advantages over visual interpretation done at 1:250,000 scale. It minimizes subjectivity prevalent in visual interpretation. It also enables delineation of small areas, which cannot usually be delineated by visual methods due to cartographic limitations. As a result, all the areas down to 1 ha in extent and having forest cover have been included - irrespective of whether they are within or outside the recorded forest areas (India State Forest Report, 2001). Hence, the data on

Table 1: Forest/ Tree cover data of West Bengal as in 2010

District	Recorded geographical area	Geographical area (as per digitized data)	Forest cover	Wet-land	Total Forest Cover	Non-forest Tree Cover	Total Tree Cover	% Forest Cover 2010	% Tree Cover
24 Pgs. (S)	10159	10279	1958	1800	3758	868	4626	36.56	45.00
24 Pgs. (N)	3977	4087	26	13	39	1143	1182	0.95	28.92
W. Midnapore	14081	9360	2269	0	2269	1005	3274	24.24	34.98
E. Midnapore		4589	0	0	0	1119	1119	0	24.38
Purulia	6259	6343	876	0	876	349	1225	13.81	19.31
Bankura	6882	6888	2146	0	2146	0	2146	31.16	31.16
Burdwan	7024	7051	909	0	909	401	1310	12.89	18.58
Birbhum	4545	4571	355	0	355	510	865	7.77	18.92
Jalpaiguri	6227	6249	1852	0	1852	1016	2868	29.64	45.90
Darjeeling	3149	3160	1101	0	1101	533	1634	34.84	51.71
Cooch Behar	3387	3441	98	0	98	820	918	2.85	26.68
Howrah	1467	1499	0	0	0	444	444	0	29.62
Hooghly	3149	3166	3	0	3	502	505	0.09	15.95
N. Dinajpur	3140	3157	18	0	18	262	280	0.57	8.87
S. Dinajpur	2219	2141	0	0	0	80	80	0	3.74
Malda	3733	3663	20		20	780	800	0.55	21.84
Nadia	3927	3861	13	0	13	412	425	0.34	11.01
Murshidabad	5324	5497	8	0	8	897	905	0.15	16.46
Kolkata	104	185	0	0	0	0	0	0	0
TOTAL	88753	89187	11652	1813	13465	11641	24606	15.10	27.59

Table 2: Comparative statement of Forest Cover as monitored through GIS/RS is given below

Survey Period	% of Recorded Forest Land	% Forest cover
1988	13.4	14.32
1991	13.4	14.97
1994	13.4	15.06
1997	13.4	15.16
2000	13.4	15.30
2004	13.4	15.52
2006	13.4	15.68
2010	13.4	15.10

Table 3: Assessment of Forest cover by Forest Survey of India

State of Forest Report	Data period	Forest cover %
1989	1985-87	9.6
1991	1987-89	9.0
1997	1993	9.4
1999	1995-96	9.42
2001	2000	12.05
2003	2002	13.91
2005	2004	13.99
2009	2006	14.64

2011	2009	14.65

Figure 1: Standard FCC (left) and Classified Imagery of South 24 Parganas district, depicting Sundarban mangrove forest

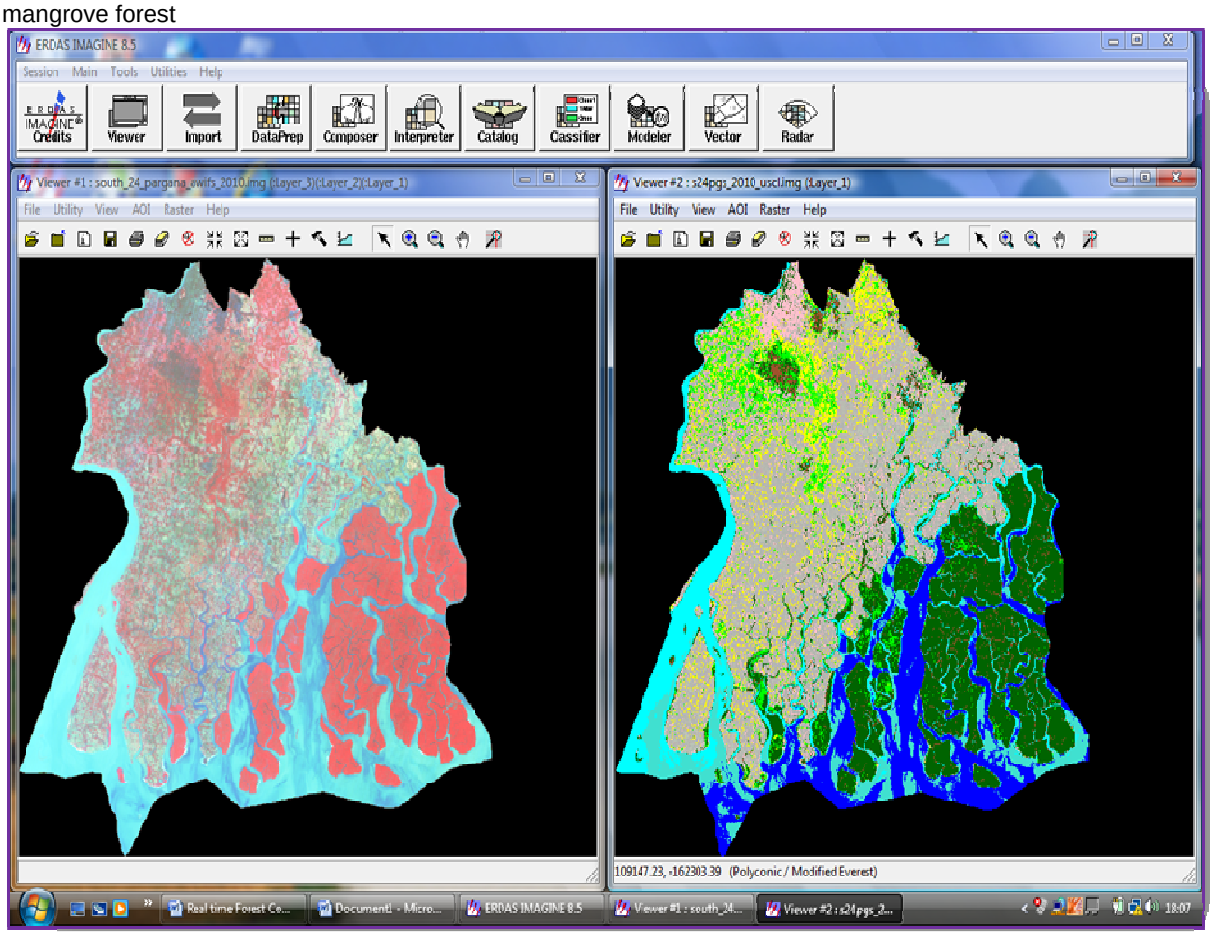


Figure 2: Standard FCC, Jalpaiguri district, Image period Dec 2010

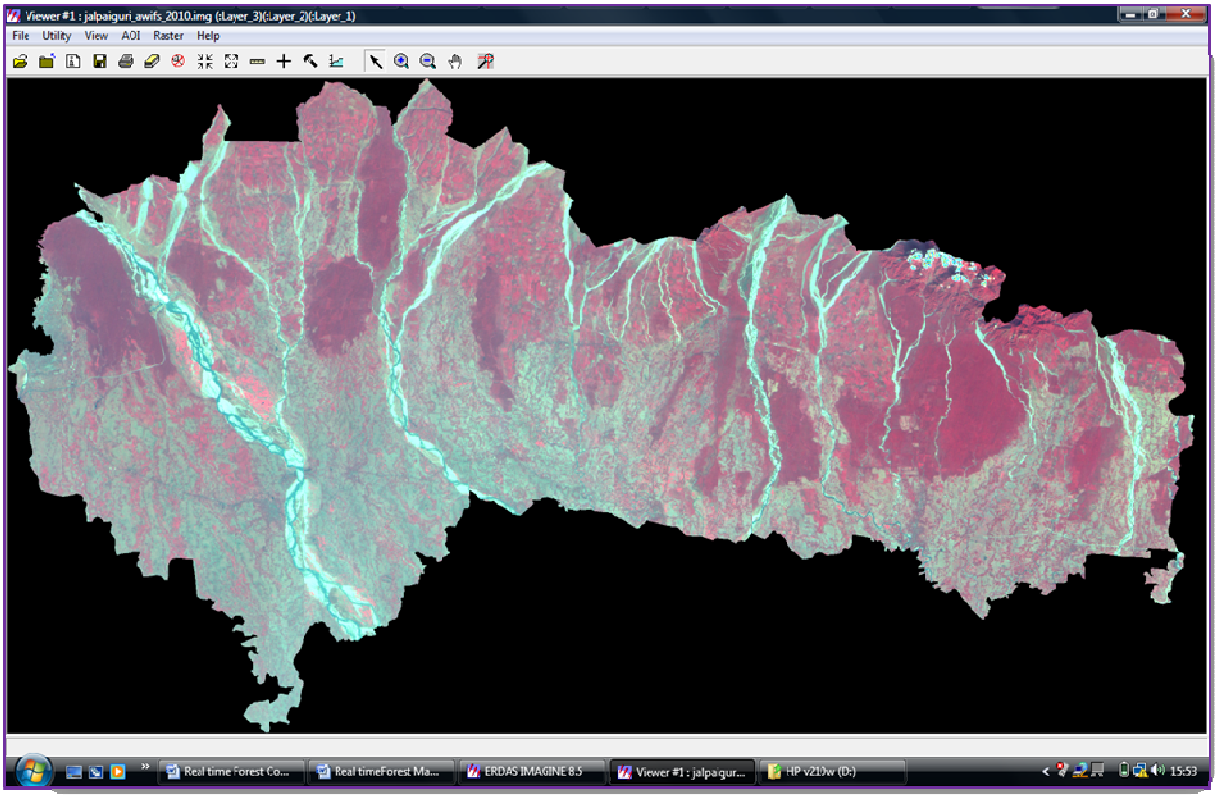


Figure 3: Classified Imagery of Jalpaiguri district showing forest and Tree covers

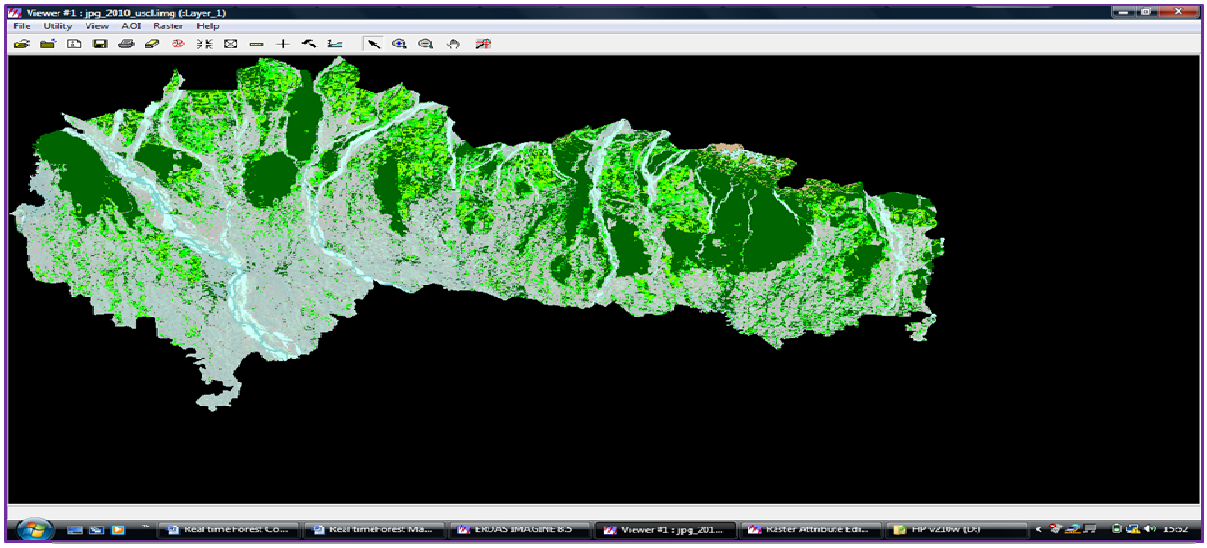


Figure 4: Classified Imagery (left) and Standard FCC of West Midnapore district

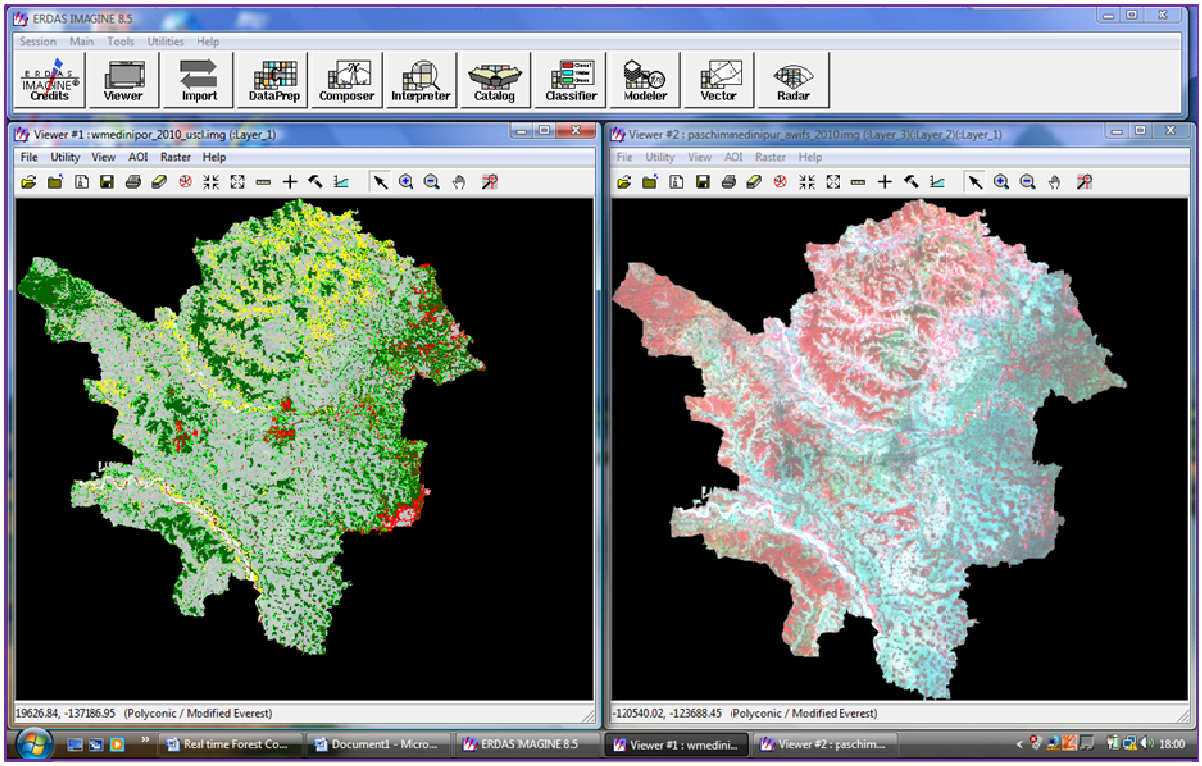


Figure 5: Zone wise % of Forest cover during 2010 in West Bengal

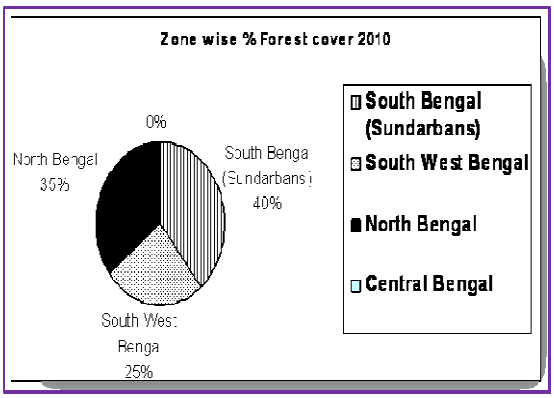


Figure 6: Zone wise % of Tree cover during 2010 in West Bengal

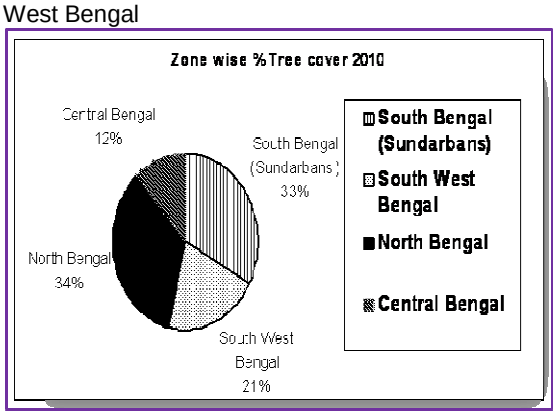


Figure 7: Relationship between forest cover and survey period (data source West Bengal Forest Department)

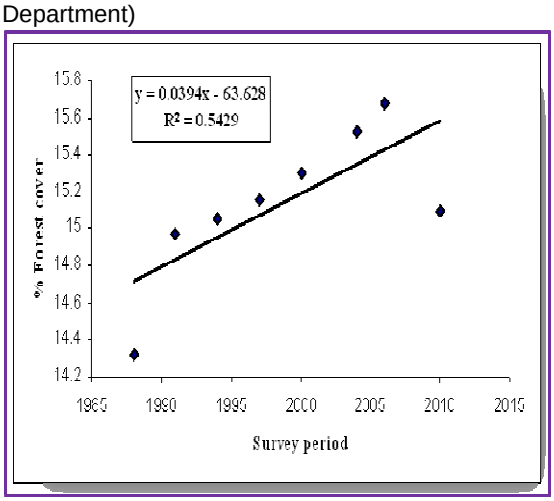
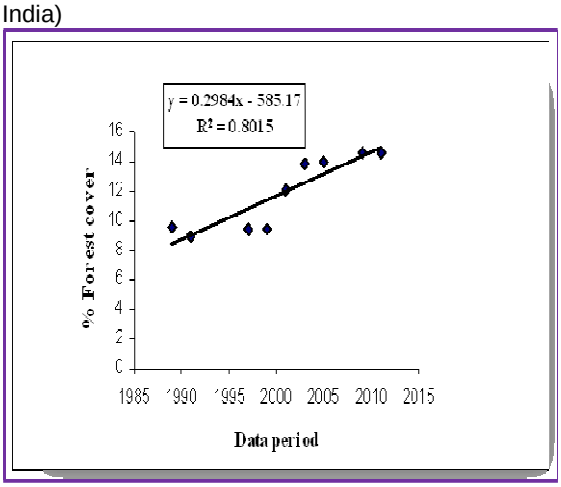


Figure 8: Interrelationship between forest cover and survey period (data source Forest Survey of India)



Forest cover of West Bengal, as assessed by FSI had shown an abrupt change in 2001 Report and has only confirmed the accuracy of assessment made by the State Forest Department, in collaboration with Regional Remote Sensing Service Centre Kharagpur, on a much detailed scale from 1988.

Conclusion

The World Bank aided Social Forestry Project, which was initiated in 1981, was co-terminus with the massive land reforms initiated in the State around the same time. Under the Land Reforms measure, vested, unutilized/waste land was distributed to the landless/ agricultural labourers as Patta (lease) on long term basis. Many of such patta land were unfit for agriculture and the patta land holders had put such unproductive land under tree plantations through Social Forestry programmes. However, with the massive success of group Farm Forestry in the South Bengal districts of East and west Medinipur, Bankura and Purulia, the characters of such apparent wasteland started changing into more productive land with better soil moisture; better soil organic content and these lands became less prone to drought. Status of Biodiversity conservation also improved substantially through the village farm forestry programmes. This changed scenario coupled with lesser attention on Government-sponsored programme of Social/Farm Forestry, during the last one decade or so, led to diversion of some of the tree plantation areas on private land into more attractive practice of agriculture/vegetable cultivation. Extension of forest cover outside forest land has thus suffered a setback during the last one decade.

Such setback in Social Forestry programme, along with intensive cultivation of agricultural crops and vegetables on land surrounded by disjointed Forest/Farm Forest patches, have given rise to increased man–wild elephant conflict in South West Bengal. During the period September to January every year from 1987 onwards, herds of wild elephants migrate to this part of the State from adjoining Dalma forest areas in the State of Jharkhand and the forests of Orissa. They cause damages to crops worth millions of Indian rupees. If the villagers can be encouraged to go for Farm Forestry with fast-growing and economically viable tree crops, such damages to agricultural crops by wild elephants can be brought down substantially. The forest fringe villagers will also be financially more secured and the greening of wasteland and reforestation may qualify the State to pose REDD+ Projects under Climate Change programme.

The present study shows the strength and effectiveness of the modern tool of Remote Sensing/GIS in rapid assessment and change detection of natural resources like Forest/ Tree

cover over very large landscapes, where the conventional methods of manual survey and assessment would have taken years together and would have defeated the very purpose of monitoring on real time basis (Ekwal 2011). In the present day scenario, where deforestation/ degradation of forest cover in the developing countries have assumed paramount interest in the context of climate change, frequent and periodic monitoring of greening / afforestation and forest conservation programmes at state/ country level through people's participation, can be made possible only through RS / GIS technology which is also the most reliable and cost- effective method.

Acknowledgement

The authors would like to thank West Bengal Forest Department and the forest officials of West Bengal Forest Directorate at various levels for providing all support to carry out the study.

Research Highlights

The case study highlights the capability of Remote Sensing Technology in a real-time monitoring of Forest and Tree Cover using Remote Sensing Technology

Periodic monitoring of Forest and Tree cover on a very large landscape level, facilitates drawing up of projects under REDD+ category

Monitoring Forest Cover using RS/GIS facilitates the affectivity of afforestation programme as well as success of Joint Forest Management involving people's participation.

Limitations

In order to carry out rapid data processing of a large landscape, satellite data with large ground coverage and low resolution was used. However, due to low resolution of the data there is a possibility of missing out on small, isolated patches of forest/tree cover leading to lower assessment. Moreover, the rapid monitoring process did not allow extensive ground truth verification and hence identification of species composition was not possible.

Recommendations

Forest/tree cover maps, with density classification of degraded oblique/open/closed forests, forest lands and species composition can be generated using high resolution data, which will take much longer time for analysis and may not be suitable for the objective as stated in this paper.

Funding and Policy Aspects

Conservation of forests and biodiversity has assumed an extremely important role in India, in the light of the national Forest Policy 1986 as well as the Green India Vision, launched by the ministry of environment and Forest. It is therefore of paramount interest that every State Government should set up an in-house RS/GIS cell within the State Forest Department to monitor their afforestation/conservation programmes. The officials of the Forest department can be trained up in the basics of the technology in order to ensure continuous monitoring of their greening programme.

Justification of Research

The methodology followed in this research paper is based on satellite data which incorporates transparency in the output of monitoring process and has much more reliability as compared to the conventional monitoring. The monitoring data generated is also are near real-time one which facilitates the project related decision making process at the highest level. The case study also proves that the technology is not too complicated and can be easily adopted by any Government Organization with reasonable amount of training of a few staff/officers.

Conclusion

The present study shows the strength and effectiveness of the modern tool of Remote Sensing/GIS in rapid assessment and change detection of natural resources like Forest/ Tree cover over very large landscapes, where the conventional methods of manual survey and assessment would have taken years together and would have defeated the very purpose of monitoring on real time basis (Ekwal 2011). In the present day scenario, where deforestation /degradation of forest cover in the developing countries have assumed paramount interest in the context of climate change, frequent and periodic monitoring of greening/afforestation and forest conservation programmes at state/ country level through people's participation, can be made possible only through RS/GIS technology which is also the most reliable and cost- effective method.

Author's Contribution and Competing Interests

Dr. A.K. Raha is the prime backbone of the manuscript. The other authors helped in collecting secondary data and information on West Bengal forests. The ground truth verification and classification of the satellite data in West Bengal forest has been equally contributed by all the authors. The authors do not have any conflict of interest.

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