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# REMOTE SENSING AND GIS APPROACH FOR WATERSHED MONITORING AND EVALUTION: A CASE STUDY IN ORISSA STATE, INDIA

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**ABSTRACT:** Dry land farming in India accounts for 63% of the cultivated land of 144 million hectares. The crop production on these lands is dependent entirely on the natural precipitation, which is highly erratic in terms of spatial and temporal distribution during the crop-growing season. To address these problems, Government of India has accorded high priority to watershed approach for development of rainfed areas through National Watershed Development Project for Rainfed Areas (NWDPRA). The project aims at in-situ moisture conservation primarily through vegetative measures to conserve rainwater control soil erosion and regenerate the green cover both on arable and non-arable lands. The present study is towards monitoring and assessment of changes in the watersheds spread over 3 districts of Orissa state using remote sensing technology. The Indian Remote Sensing Satellite (IRS), Linear Image Self Scanning Sensor (LISS II) data of 1988 and 1996, pertaining to the pre and post treatment periods of each watershed have been analyzed. Classified and Normalized Difference Vegetation Index (NDVI) outputs of two time periods were compared to derive information, on changes that occurred over a period of time in the watershed. The study revealed an increase in the area under cultivation, water bodies, plantation and tree cover as a result of watershed management. Improvement and progressive changes ranging from 4 to 27.4% have been observed within a span of 5 to 8 years. Further, saturation index was derived for some of the watersheds under study for the assessment of implementation of NWDPRA developmental activities.

## 1. INTRODUCTION

Dry land farming in India accounts for 63% of the cultivated land of 144 million hectares. These drylands are impoverished, deficient in plant nutrients, suffer from various forms of land degradation. The crop production on these lands is dependent entirely on the natural precipitation, which is highly erratic in terms of spatial and temporal distribution during the crop-growing season. Dryland farming is also affected by the socio-economic conditions of small holdings, expensive credit, low fertilizer use, and poor infrastructure. To address the problems of dryland farming, Government of India has accorded high priority to watershed approach for development of rainfed areas through National Watershed Development Project for Rainfed Areas (NWDPRA) and other externally aided watershed development projects. The emphasis is on increasing food production, reduce regional disparity between irrigated and rainfed areas and to ensure sustainable development of agriculture. Afforestation, cropping systems, soil and moisture conservation measures, agro–forestry and agro-horticulture are some of the developmental activities that are carried out in the watersheds under NWDPRA(NNRMS-TR-98,1998).

As the watershed development approach is an integrated one with the involvement and efforts of various departments and considerable budget, there is a need for a suitable indicator to assess the progress of implementation. It is necessary to holistically assess and evaluate the long-term effects and the impact of the activities through reliable methods. Conventional ground based sampling has proved costly and time consuming. The repetitive coverage of the satellite provides us an excellent opportunity to monitor the land resources and evaluate the land cover changes through a comparison of images acquired for the same area at different times. Changes like increased area under cultivation, conversion of annual cropland to horticulture, change in surface water bodies, afforestation, soil reclamation, etc., could be monitored through satellite remote sensing. Over the years, its utility to detect and determine the extent and nature of changes over a period of time has been successfully demonstrated. It is in this context of reducing the cost and time that we address the use of satellite remote sensing as a monitoring and evaluation tool with the following objectives.

(1) Evaluation of the impact of watershed programs implemented in the watersheds under study
(2) Assessment of implementation of NWDPRA developmental activities and their impact on arable and non-arable land.

## 2.0 METHODOLOGY

For the present study, nine watersheds treated under NWDPRA distributed in three districts of Koraput, Nawarangpur and Malkanagiri districts of Orissa State were considered. The Indian Remote Sensing Satellite (IRS), Linear Image Self Scanning Sensor (LISS II) data of 1988 and 1996, pertaining to the pre and post treatment periods of each watershed have been analysed at RRSSC/ISRO, Kharagpur, India. Classified and Normalized Difference Vegetation Index (NDVI) outputs of two time periods were compared to derive information, on changes that occurred over a period of time in the watershed. The location map of these treated watersheds was given as Figure 1.

**Figure 1**


### 2.1 Evaluation of the Impact of Watershed Program:

In the present study, change detection from satellite images was derived for monitoring and evaluation purpose. Remote sensing change detection is a process of determining and evaluating difference in a variety of surface phenomena over time. Changes can be determined by comparing spectral response differences at the same spatial location among a set of two or more multispectral data acquired at different times. There are many change detection algorithms using digital techniques like image differencing, image ratioing, normalized vegetation index differencing, principal component analysis and comparison of classified images (Jensen, 1986). In this study, NDVI image differencing and Supervised classification techniques are employed as tools for evaluation purpose. Comparison of two times classified outputs and Normalized Difference Vegetation Index (NDVI) images using change detection software was performed to study the land cover and vegetation vigour transformation (Singh, 1989;Fung, 1990). For change detection studies satellite data normalization is necessary and important for minimizing the changes in spectral responses due to atmospheric effects, sensor characteristics and sun illumination, etc. In the present study, since both data sets are from the Indian Remote Sensing satellites (IRS IA and 1B), having the same sensor characteristics, differences expected are minimal. However, scene to scene normalization was carried out whereby each spectral channel is made to appear as though imaged through the same atmospheric and illumination conditions. The scene statistics was used to normalize band by band for bringing the mean and standard deviation of two dates at par with each other.

**2.1.1 Comparison of Classified Outputs:** Supervised classification was performed using maximum likelihood algorithm for both period satellite data to cluster the pixels with similar spectral characteristics into homogeneous classes with respect to ground truth information. This algorithm assumes Gaussian distribution and each pixel is considered as a separate entity independent of neighbors. The classified images having different land use / land cover categories pertaining to pre and post treatment periods have been compared in order to evaluate the magnitude and direction of transformation which has taken place over a period of time.

**2.1.2 NDVI image Differencing:** NDVI has been used to describe vegetation dynamics and monitor the seasonal growing conditions for making primary productivity analysis (Singh,1989). The differencing of NDVI images generated for both the dates has been carried out to derive information on changes with reference to vigour/biomass. NDVI image differencing of two dates for forest vegetation is also done to derive progressive/retrogressive transformation details like open to closed, degraded to open categories, etc.

### 2.2 Assessment of Implementation of NWDPRA Developmental Activities:

In the present study, assessment of developmental activities was done empirically by deriving saturation index for each watershed. The saturation index is an indicative of extent of developmental activities taken up in the particular watershed, in which weightage is assigned to various activities keeping in view of their significance. Accordingly main activities have been identified for arable land, non-arable land, drainage line treatment, live stock development components and creation of basic infrastructure in the micro watershed. Rating of each activity against the assigning values was done on the basis of achievement against the targets set for that particular activity. For example, if marks assigned for an activity are 10 against the target of 100 units, then if the actual achievement is 50, then the actual marks for that activity would be 5. In this way, actual marks for each activity will be given against the assigned marks. The sum of assigned marks is 100. The sum total of actual marks will indicate the percentage saturation of a watershed in a given time frame. Likewise, if we are able to work out the saturation indices for 5%, sample watersheds of a given district or a state through suitable extrapolation and adjustments district/state wise position of extent of saturation/completion of dominant project activities may be indexed in quantification terms.

Under NWDPRA, there are nearly 40 identified project activities that broadly fall under the categories such as creation of infrastructure, conservation and production measures under arable and non arable lands, drainage line treatment, live stock development and people’s participation. For the purpose of calculating saturation index, only 18 quantifiable parameters have been taken into consideration. These activities are so chosen that they constitute a logical sequential order of the priorities in which assigned activities are to be performed and impacts in terms of their saturation over a period of time would be visible for the purpose of assessment and recording.

## 3.0 RESULTS AND DISCUSSION

The satellite images of watersheds acquired during pre and post treatment periods have offered a rich source of information about the land use /land cover changes in the watershed over a period of 5 to 8 years and shown as Figure 2. The impact of watershed development program depends on effectiveness of the technology in the background of needs, priorities, cultural practices, and community participation. The impact also depends on the political will of the government, acceptability of the people and coordination between officials and public. The benefits from the watershed development are many folds - direct and indirect. The land cover transformation details, watershed wise are indicated in Table1. The relative performance of the watersheds as per climatic zone was also presented in the table along with saturation index for five watersheds.

The concerted efforts has helped local people in meeting fuel and fodder needs, conserving soils, biomass increase and boosting crop yields. Land based treatment like soil and water conservation, introduction of rainfed farming technology, mixed cropping and demonstrations by authorities has improved the overall productivity of the area. Attempts are being made for reclamation of acid soils in the study area by adding paper mill sludge for neutralization of acidity. Installation of lift point for irrigation in some of the watersheds has brought lot of change in the cropping pattern. It was observed even in some places sugarcane is also grown. Most of the natural drainage lines in all watersheds are converted into paddy terraces. The overall improvement in the land and water resources development has been observed varying from 4.3 to 27.4% in the watersheds after the implementation of development programmes. The relative performance of all the watersheds in different climatic zones was also presented in the Table 1. The overall improvement in case of all existing watersheds varied from 13 to 27.4%. In

## Table 1 : Land use/Land cover transformation in treat ed watersheds under NWDPRA, Orissa

| Sl. No | **Watershed** Name | Total Geographical area (ha.) | Agro-climatic zone | Saturation Index (%) | Moist Fallow | Dry Fallow | Standing Agriculture | Waterbody | Plantation/Orchards | Wasteland/ barren | Dense Vegetation | Total performance( %) | Relative performance |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Goriajora Nalla | 2692 | 80 | 85 | -296 (-11%) | -385 (-14.3%) | 635 (23.6%) | 41 (1.5%) | 63 (2.3%) | -58 (-2.15%) | -67 (-2.5%) | 27.4 | 1 |
| 3 | Kukrogud Nalla | 3055 | 80 | 84 | -128 (-4.2%) | - | 625 (20.46%) | 66 (2.16%) | 69 (2.26%) | -20 (-0.65%) | -1 (-0.03%) | 24.88 | 2 |
| 4 | Sriranjala Nalla Extended | 3083 | 80 | --- | -88 (-2.8%) | - | 273 (8.86%) | 29 (0.94%) | 7 (0.23%) | -8 (-0.26%) | -37 (-1.2%) | 10.03 | 3 |
| 5 | Bariguma Nalla | 2911 | 81 | 92 | 52 (1.8%) | -372 (-12.8%) | 307 (10.54%) | 27 (0.93%) | 38 (1.3%) | -52 (-1.8%) | -83 (-2.85%) | 14.57 | 3 |
| 6 | Bariguma Nalla Extended | 2682 | 81 | --- | 142 (5.3%) | -169 (-6.3%) | 184 (6.9%) | 44 (1.64%) | -63 (-2.3%) | -38 (-1.4%) | 22 (0.8%) | 14.64 | 2 |
| 7 | Bhalupur Nalla | 2316 | 81 | 90 | 49 (2.1%) | -- | 224 (9.7%) | 8 (0.34%) | 20 (0.9%) | -301 (-13.1%) | -5 (-0.2%) | 13.04 | 4 |
| 8 | Bhalupur Nalla Extended | 3991 | 81 | --- | 82 (2.0%) | -- | 69 (1.7%) | 22 (0.6%) | -64 (-1.6%) | -109 (-2.7%) | -14 (-0.35%) | 4.3 | 6 |
| 9 | Chalangu da Nalla | 2452 | 81 | 85 | 70 (2.85%) | -69 (-2.81%) | 245 (10.0%) | 54 (2.2%) | -238 (-9.7%) | -62 (-2.52%) | 35 (1.42%) | 16.47 | 1 |
| 10 | Kaliapujar igarh Nalla Extended | 2682 | 81 | --- | 32 (1.19%) | -45 (-1.68%) | 54 (2.01%) | 24 (0.89%) | -43 (-1.61%) | -23 (-0.86%) | 12 (0.45%) | 4.55 | 5 |

case of extended watersheds overall improvement varied between 4.3 to 14.64%. It was also observed that the overall improvement was less in case of extended watersheds as compared to existing watersheds. This may be due to the fact all the existing watersheds were treated in the year 1991-92 and all the extended watersheds were treated in the year 1994-95. Hence much of improvement was not observed in the extended watersheds, as the processing of satellite data was carried out for the year 1996. Further it may be observed from the table, that the overall performance of the watersheds in the 80$^{th}$ climatic zone is better as compared to watersheds of 81st climatic zone of India. This may be due to the amount of rainfall and number of rainy days, which are higher in the former climatic zone

Personal discussion with the State government officials and people revealed that the socio-economic status of people living in the study area has been improved considerably. Besides these, it has been observed that during field visit that the number of tube wells and open wells in the watershed after treatment period has been increased as compared to pre- treatment period. In the upper reaches, check dam, brush wood check dam and boulder check dams were constructed. For middle reaches, loose boulder structures, earthen structures and runoff management structures were constructed. In case of lower reaches, water harvesting tanks and Gabian structures were constructed. Nalla congestion was removed at some places. Thus the experience indicated that the monitoring and status assessment through remote sensing is quite reliable and objective/resourceful for the planners and decision-makers.

## 4.0 FUTURE APPROACH TO WATERSHED MANAGEMENT

People's participation is the key to the success of any watershed development program. Awareness, commitment, participation and response are essential to achieve the objectives. The approach should emphasis the participatory management, involvement of the local community right from planning which helps in smooth and effective implementation of the program. The success of community participation depends upon group discussions, working together and united efforts. Motivation is another aspect in getting response and the response depends upon the modus operandi in establishing rapport, convincing the community, appropriateness of the technology and reaching the farmer in his own language. Demonstration and exhibition of results showing economical benefits and making arrangements for finances, implementation and marketing would ensure effective participation. It is in this context, non-governmental organizations (NGO) and voluntary agencies draw a better response, and are instrumental in building a better rapport and confidence and translate the organizational expertise required to manage the resources within their watershed. A new era should begin towards sustainable development by evolving a development plan with a high level of community participation utilizing scientific planning tools like satellite imagery and GIS to help the local people build a sustainable future with their own hands.

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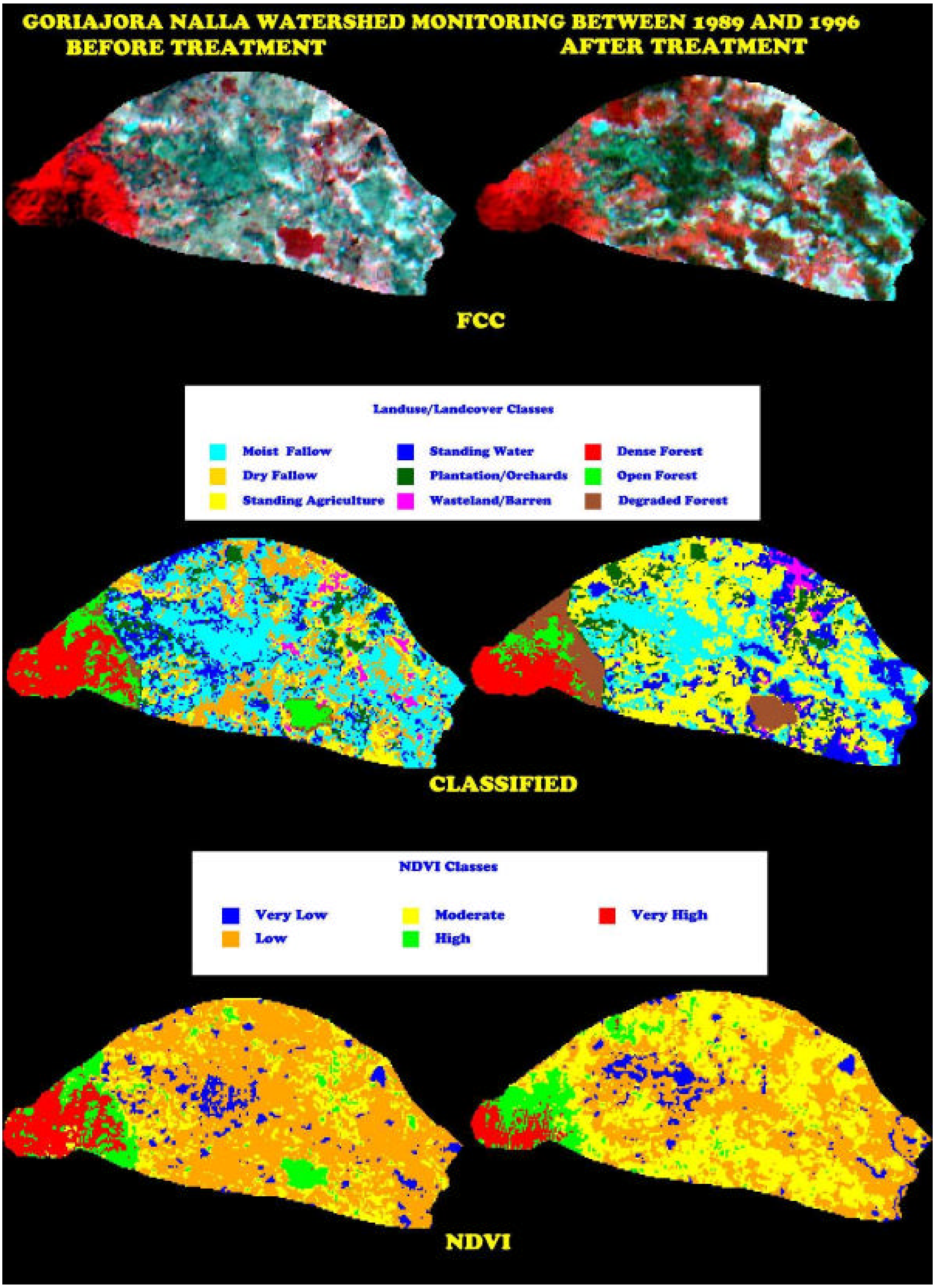
Figure 2


GORIAJORA NALLA WATERSHED MONITORING BETWEEN 1989 AND 1996
BEFORE TREATMENT
AFTER TREATMENT
FCC
Landuse/Landcover Classes
Moist Fallow
Standing Water
Dense Forest
Dry Fallow
Plantation/Orchards
Open Forest
Standing Agriculture
Wasteland/Barren
Degraded Forest
CLASSIFIED
NDVI Classes
Very Low
Moderate
Very High
Low
High
NDVI