A REPORT ON

MONITORING THE IMPACT OF CATCHMENT AREA TREATMENT USING REMOTE SENSING & GIS IN PARTS OF NARMADA CATCHMENT AREA

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Executive Summary

The Sardar Sarovar Project being constructed on Narmada River has become a boiling point between environmental organisations and administrators. The convict has caused loss of time and resources for completing the project. The recent Supreme Court of India Judgement might give a thrust in completing the project very soon.

Sardar Sarovar Project is a multi purpose project being constructed on the Narmada River. The project on completion would provide drinking water and irrigation facilities for Gujarat and Rajasthan states and the hydel power generated would be shared by Maharashtra, Madhya Pradesh and Gujarat. Government of India while according the approval of the project has stipulated various conditions to be followed by State Govts., and as per the condition II the three states, where submergence is going to take place namely Madhya Pradesh, Maharashtra and Gujarat, has to treat Catchment areas to arrest the siltation of the reservoir and hence to improve the life of the reservoir. Accordingly, the Maharashtra State Govt. has prepared action plans for treating the Catchment areas. The Catchment of Sardar Sarovar Project in Maharashtra State is covering an area of 1568.36 sq.km. and lies entirely on the left bank of Narmada river and is confined to parts of Akkalkuwa and Akrani Tehsils of Dhule district.

As per the guide lines issued by the Ministry of Water Resources, Govt. Of India, for the purpose of treatment of Catchment areas the sub-watershed will be considered as a unit. Out of the 80 sub-watersheds, 17 are considered as sensitive because they are directly draining in to the reservoir. The present study is confined to 6 sub-watersheds of Akkalkuwa tehsil. The CAT Plan implementation has started in the year 1993 and has completed in 1998. To study the impact of CAT plan implementation Remote Sensing and GIS techniques arc used. The satellite data corresponding to 1991 (Pre Plan Implementation), 1995 (During Plan Implementation) and 1998 (After Plan Implementation) are used to determine the vegetation status. The NDVI map corresponding to three temporal seasons are generated and statistics are calculated at sub-watershed level and compartment level. **The result shows that the *dense* forest has increased from 574 ha (1991) to 1079 ha (1995) and 2044 ha (1998), and the forest blanks has decreased from 6713 ha (1991) to 5099 ha (1995) and 4354 ha (1998).** *The RS and GIS techniques have helped in monitoring the CAT plan implementation impact. The study will be extended to other sub-watersheds based on the encouraging results from the present study.*

A. INTRODOCTION

Sardar Sarovar Project is a multipurpose project being constructed on the Narmada River. The Narmada River forms a common boundary between the States of Madhya Pradesh, Maharashtra and Gujarat. The project on completion would provide

- Irrigation to 1.8 million hectares (44.5 lakh acres) in Gujarat, 75,000 hectares (1.8 lakh acres) in Rajasthan.
- The hydel power generated (1450 MW) will be shared between Madhya Pradesh(56%) , Maharashtra (27%) and Gujarat (16%).
- Also it provides drinking water to 8215 villages and 136 towns in Gujarat and 131 villages in Rajasthan.

The total submergence area envisaged of Sardar Sarovar Project in Maharashtra is 7725 ha out of which 6488 ha area is under forest. Government of India while according approval to the project has stipulated various conditions as contained in their letter No. 8-372/85/FC dated 8.9.87. As per the condition-II State government will prepare a plan for treatment of catchment areas. The catchment of Sardar Sarovar Project in Maharashtra State is covering an area of 1568.36 sq.km. and lies entirely on the left bank of Narmada river and *is* confined to parts of Akkalkuwa and Akrani Tehsils of Dhule District.

As per guidelines issued by the Ministry of Water Resources, government of India, for the purpose of treatment of catchment area the sub-watershed will be considered as an unit and further the cost of treatment of directly draining sub watershed will be charged to the cost of the project, and that the general catchment areas treatment will be treated as a separate development activity. Taking this into consideration the total number of sub watersheds directly draining into the reservoir have been identified *from* the total 80 sub watersheds of Narmada catchment falling in Maharashtra. The total number of such directly draining sub watersheds in Maharashtra is 17 out of which 8 sub water sheds are of very high priority and 9 sub watersheds are of high priority and these sub watersheds form the area for which SSP CAT Plan was formulated.

B. STUDY AREA

The present study of monitoring the vegetation improvement in the catchment area since commencement of CAT Plan from 1993-94 is confined to Akkalkuwa Tehsil where six out of seventeen directly draining sub watershed in SSP viz; Na3a, Na 3b, Na 3c. Na 3d, Na 3f and Na 3w on the basis of satellite remote sensing data of the study area. All these six sub water sheds are of very high priority sub watersheds- of CAT Plan.

Study Area

The present study area of six directly draining sub watersheds into SSP reservoir are situated on left bank of Narmada river of Manibeli and Kathi ranges *of*

Mewasi Division in Maharashtra. It extends from 73^0 45' -74^0 0' N latitudes and 21^0 45' - $21^0$54' 45" E longitudes. The tract lies in Satpuda mountain ranges with deep valleys and slopes, nearly 50% is having steep slopes ranging from steep to very steep slopes with or without tree cover. The main geological formation of the tract is deccan trap basalt characterised by different lava flows of 10-20 meters thickness almost horizontally deposited.

Soils

The study area mainly consists of shallow soils, medium black soils and deep black soils. Deep black soils occur in narrow fringes in the valley portion. The soil is deep black in colour and Fertile which generally supports luxuriant tree growth. Medium black soil and black cotton soil mixed with organic matter is found in flat and slightly undulating areas. These soils vary in colour texture and depth and supports good tree growth. The coarse soil mixed with stone or murrum are seen on hilly and undulating terrain areas and having depth of 10 to 30 cms, supports poor and stunted vegetative growth.

Forests

The forests of this area as per Champion and Seth 1968 (revised classification) belongs to southern Tropical Deciduous type which further sub divided into (1) Dry Teak forests and (2) Dry deciduous mixed forests. Teak occurrence varies Irom 30 tc 60% in the dry teak forests and other species that occur in the area are Anogeissus latifotia, Garuga pinnata, Lannea grandis, Pterocarpus marsupium, Diospyros melanoxylon, Boswellia serrata. Acacia catechu Lagerstromia parviflora and occasionally Sterculia urenses. Bamboo clumps occur in valleys and moist sheltered pockets.

Climate

The climate of the area is typical sub-tropical climate created by its location between the tropic of cancer and the equator and the hill ranges are fed by South West monsoon. Therefore it rains during the period of June end to September end and the precipitation ranges from 600mm to 960mm. Maximum and Minimum temperatures; recorded in the area are 43^0 and 10^0 respectively. The rainfall data of Akkalkuwa Tehsil for the period 1992 to 1998 is given in the table below :

Year	
1992	953
1993	1137
1994	1387
1995	860
1996	740
1997	1082
1998	1258

Wildlife.

Large scale hunting and poaching by the local tribals and deterioration of forest crop and its density, the wild life has almost vanished. Tiger is occasionally seen while Panthers, wild cats. Barking deer, Sambhar, Hyena etc are found in small numbers.

Population:

17 villages of the Akkalkuwa Tehsil falls in the catchment of Sardar Sarovar Project. The population in this area over the decade increased at the rate of 18.12% based on 1981 and 1991 Census. The average per hectare population density in the catchment area as per 1991 census is 0.63.

Due to hilly and remote nature of terrain tribals in the tract are under developed. The tribals mainly depend on the cultivation for their livelihood. The landless are generally engaged on daily wages with cultivation *as* well as in government schemes under tribal sub plan. The villagers earn by collecting forest produce viz; bidi leaves, gum, honey, lac charoli etc. The main crops cultivated in this area are Jowar paddy hill millets, Udia, Mung, bauti etc. Due to unscientific practice of agriculture like shifting cultivation local tribals harvest very low yield of crops.

C. METHODOLOGY

CAT Plan:

The Catchment Area Treatment (CAT) Plan was prepared based on the existing condition of the forest (density, growth composition) biotic pressure and local requirements. The treatment is carried out under three afforestation schemes viz; i) Treatment Plan in Closed Forest (CAT: 1) 2) Treatment Plan in open/ degraded and forest blanks (CAT 2) and iii) Treatment in grass land and waste land Area (CAT:3).

Treatment Plan in Closed Forest (CAT -1);

Areas having forest crown density more than 40%.with better soil and minimum biotic interference are treated under CAT: I plan. The treatment is protecting the area from biotic interference, carrying out tending operations, afforestation of blanks and improving existing stocks by under planting. Nala bunding, check dams, bush wood dams. Rock fill *dams* are carried out to minimise run off and soil erosion. Trench cum mound stone wall construction and planting Sabar, agave species on these mounds was carried out to protect plantation works from Cattle-

Treatment Plan in open/degraded and Forest blanks (CAT 2):

Areas with forest crown density less than *40%,* badly adopted and very much vulnerable to moderate to severe erosion are treated under this plan. Intensive afforestation works like planting 2500 seedlings per hectare planted in 30 cm^3 pits

besides soil and moisture conservation works are done under this treatment plan. Broad leaved Miscellaneous species preferably indigenous nature are developed in nursery for one year in poly pots and used for planting purposes. Nala bunding, check dams. Gabion structure, bush wood dams, and other soil and moisture conservation works are carried out to minimise run off and soil erosion. Trench cum Mound, agave species on these mounds was done to protect the plantation works from biotic interference.

Treatment Plan in Grass lands and Waste land area (CAT;3);

Areas with severe erosion and having coarse soils and closure to the habitation are treated under this treatment plan. The treatment includes intensive soil and water conservation measures like community afforestation, soil pasture scheme and formation of engineering structure like Check dam, Gabian structure, nala bunding is done. Introducing improved grasses such as Cenchrus, Ber, Sheda, Pavanya, marvel, stylosanthus etc, is done. Fifty trenches of 2m x 0.6 m x 0.3m *size* and 100 grass beds of size 8 m x 1.75m x 1.15m are prepared per hectare. 200 *gms* of improved grass seed is sown in each grass bed. Soil and moisture conservation works like nala bunding, bush wood, gabion structure are done in these areas. Trench cum mound, stone wall construction and planting of sabai, agave species on these mounds was done to protect the plantation works from biotic interference.

The following materials are used for carrying out the project.

- **Remote sensing data**

Three period satellite data was used for monitoring the impact of developmental activities which are described above. The data used are

IRS IA LISS II	DOP : 22-12-1991
IRS 1 B LISS II	DOP : 13-12-1995
IRS IC.LISS III	DOP: 4-12-1998

- Survey Of India topographical maps on 1:50,000 scale
- Working plan maps of North Dhule Division
- Spatial and attribute information regarding the developmental activities – cost involved, zone of area where activities are carried out and time details specifying when the activities are carried out

The methodology adopted for the project is described in the flow chart. The sequence of steps that are carried out given below.

- Loading of-satellite data
- Registration of satellite data
- NDVI generation
- Digitisation of cultural features
- Generation of sub watershed, compartment mask
- Overlay of compartment and sub watershed boundaries

- Ground validation of output
- After ground validation, final Forest Density Map generation
- Statistics and Output generation

The satellite data was registered with map information using map-to-image transformation model and image-to-image transformation model. The Normalised Difference Vegetation Index (NDVI) is generated and segregated into 5 major categories based on the ground truth provided by the user department. The classes identified are dense forest, open forest, degraded forest, forest blank and water bodies. The watershed boundaries and compartment boundaries are digitised and are overlaid on the satellite data and classified map. The output is validated in the field. After ground validation, the final forest density map is generated.

The area statistics are generated for the three years 1991, 1995 and 1998 at compartment and sub watershed level. The hard copy output is generated on 1:50,000 scale depicting the three FCC and NDVI maps. Final output is generated on 1:50,000 scale and statistics are generated watershed wise and compartment wise. The results are enclosed in the table.

Remote Sensing

Remote Sensing is defined as a means of observing the earth's surface and environment from air or space by means of electromagnetic waves of the optical or microwave range. The restriction to electromagnetic waves is due to the fact that the observation from a spacecraft excludes other possibilities such as sonic waves, which require a medium like air, water or solid earth for propagation. Other means of indirect observation by, for example, stationary magnetic or electric fields are not sensitive enough for high geometric resolution measurements.

Remote sensing is characterized by the fact that it measures qualitatively and quantitatively features of the earth or its atmosphere without any material contact. The instruments applied are called sensors. If they consist of both a transmitter and a. receiver, then we are talking about "active sensors". In the case of external signal sources it is possible to use just receivers' i.e. "passive sensors."

The Target's features can be measured indirectly through the interaction with electromagnetic waves. Various methods are applicable. Figures I and 2 show the proper arrangement for passive and active sensors, respectively. In the passive case one determines either

- the amount o *f* electromagnetic emission of the target itself, or
- the reflectivity of optical signal power of the sun at the target, or
- The amount of scattered power, if the "target" is, for example, an aerosol of the atmosphere, or
- Absorption of solar radiation power in the media to be measured..

ELECTROMAGNETIC INTERACTION

Electromagnetic interaction is a function of the physical parameters of the target. It is especially a function of the dielectric properties (permissivity) of the target's material. The material's behavior against microwaves can be classified into three categories.:

- If the material behaves like a metal, then the waves cannot penetrate this matter. Electromagnetic waves irradiating such a metallic surface are almost completely reflected. The type of reflection (specular or diffuse) depends on the roughness of the surface.
- If the material is water, then the incident waves are reflected at the water surface to a large extent. Only some small fractions of the incident energy can enter and penetrate the target and will be attenuated to almost zero power after a short way, say a few wavelengths or fractions thereof.
- "Dry"', non-metallic materials change the wavelength of the incoming signals because the refractive index is larger than in vacuum or air, and the signals split, in accordance with Snell's law, into a transmitted and a reflected component (see Figure 5). With increasing water content of the target the similarity of the material's properties with that of metallic matter under electromagnetic interaction increases.

Generally, interaction of the waves with matter and its characteristic features can be described to a large degree by the following factors;

- reflectivity/scatter, backscatter;
- absorptivity, and to some degree, by
- the transmissivity.

Reflection, Absorption and Backscatter.

They define the percentage of signal power reflected, absorbed and scattered by the target. The values of these quantities are functions of the microstructure, the chemical nature and the biological state of the target. As an example: the leaves of plants consist basically of a. sponge-like structure, with many randomly distributed holes and droplets of water and other holes filled with some pigments. They can be modeled simply by a lossy layer of a certain permissivity, where the loss is frequency-dependent. Dispersive multi-reflection, therefore, occurs in the leaves. The chlorophyll elements absorb radiation energy of the blue and red sections of the light spectrum. The reflected signal lacks these absorbed parts of the solar spectrum, and therefore, looks green. In the infrared parts almost all the signal energy is reflected, if the structure is in proper conditions. If, however, the structure is collapsed because of stress conditions, then the reflectivity is affected.

If photosynthesis no longer occurs, then the plant color changes to yellow, which shows that almost all spectral radiation components of the visible light are reflected. The typical spectral characteristics of healthy leaves is given in Figure 7. It is , of course, also a function of the season, i.e. of the phenological state of the vegetation.

Spectral Signatures.

The spectral bands generally used in Remote Sensing

1) 0.45 -0.52 *:m* : Water penetration, differentiation, soil/vegetation and deciduous/coniferous flora.

2) 0.52 - 0.60 *:m* : Peak of "green" reflectance; assessment of vegetation-vigor.

3) 0.63 - 0.69 *:m* : Vegetation discrimination: chlorophyll absorption.

4) 0.76 - 0.90 *:m* : Biomass determination.

5) 1.55 – 1.75 *:m* : Moisture Content; soil moisture, snow/clouds discrimination.

6) 10.40-12.50 *:m* : Thermal mapping, vegetation stress analysis, soil moisture discrimination.

7) 2.08 - 2.35 *:m* : Hydrothermal mapping, rock type discrimination.

***Vegetation* Indicies**

Vegetation indices are particular combinations of spectral responses in different wavelength bands, which emphasize a particular feature of the vegetation. The development and use of vegetation indices is guided by three general objectives:

- To enhance, through an appropriate combination of spectral bands, the relevant vegetation features. Ideally, the indices should have a better-defined relationship with physiological properties of the crop and forest vegetation than individual spectral measurements.

- To standardize the representation of crop forest species spectral response (useful in region to region or year to year comparisons).

- To reduce the dimensions of the data sets (i.e. an index reduces to one data set then sets which contribute to its calculation),

It is also worth noting that ratio indices have the added advantage of being dimensionless; this renders the calibration of the radiance values to reference standards unnecessary (calibration of the index with respect to ground features remains, of course necessary),

The Normalized Difference Vegetation index (NDVI) and the Perpendicular Vegetation Index (PVI) are widely used in forestry studies.

THE NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

The NDVI is defined as the ratio of the difference between the near infrared and red reflectance to their sum or

NDVI = (near infrared - red) / (near infrared + red)

The index is called normalized because it is divided by the sum of radiance's and thus normalizes somewhat for differences in solar spectral irradiance's. The NDVI is dimensionless and can take values from -I to +1. Negative values are found when the red reflectance is higher than the near infra red as for certain types of dry soils. The value of the NDVI is mainly determined by the difference between the near infrared response which increases with increasing vegetation in the scene, and the red response which decreases with decreasing vegetation.

Field measurements have established that there is a relationship between green biomass and the NDVI up to a certain value of the cover biomass above which the NDVI remains constant (saturation level).

A relationship of the type

$$LAI - a^{b.NDVI} + c$$ where LAI = Leaf Area Index, m^2 / m^2

The reflectance data in the spectral band forming the NDVI provide indications on biophysical parameters (rates) such as primary productivity (via the local density of the chlorophyll and the photosynthetic capacity of the canopy) and evapotranspiration (via a variable stomatal resistance to gas and water vapour transfer).

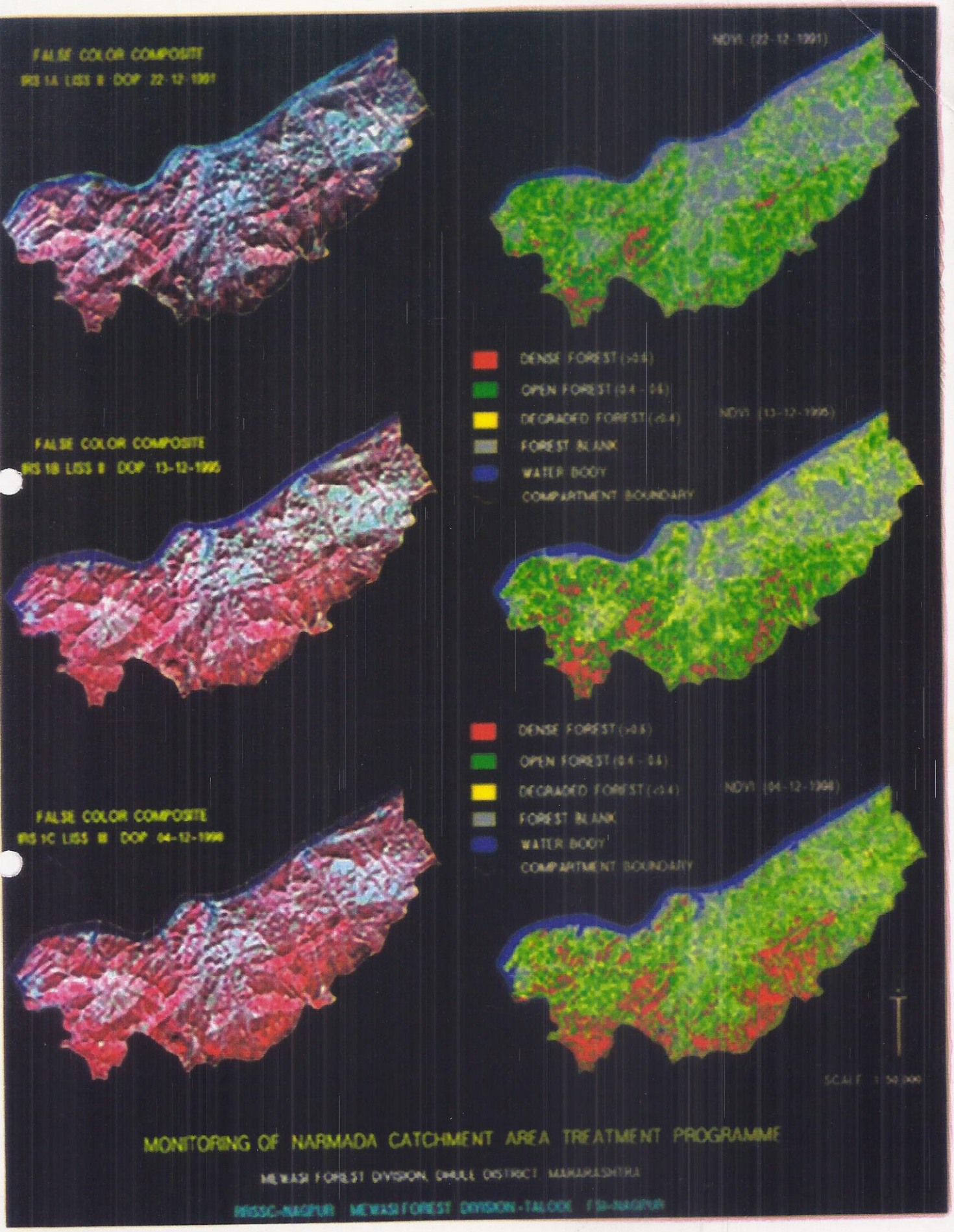
D. RESULTS AND DISCUSSIONS

- This work has been carried out jointly by the Maharashtra State Forest Department Dhule, Regional Remote Sensing Service Centre, Nagpur and Forest Survey of India, Nagpur. This joint venture has resulted *in* to the monitoring of Catchment Area Treatment (CAT) plan of Sardar Sarovar Project using Remote Sensing and GIS in 6 sub-watersheds falling in Mewasi Forest Division of Dhule circle. The present work has shown potentiality of *RS* and GIS in monitoring the impact of CAT plan implementation- The total area treated is around 7,900 ha out of total area 13,932 ha in a span of 5 years during 1993 to 1998.
- The dense forest has increased from 574 ha (1993) to 1079 ha (1995) and 2044 ha (1998). This has resulted an increase of dense forest by nearly two times between 1991 and 1995 and again in between 1995 and 1998. The treatment has positive impact in improving the vegetation status in the Catchment.

- The forest blanks has decreased from 6713 ha (1993) to 5099 ha (1995) and 4354 ha (1998). This has resulted mainly because of afforestation in new areas and preventing forest degradation according to CAT programs.
- The decrease in forest blanks is by 40% from 1993 to 1998. The forest blanks have been converted mainly into open forest.
- There is a phenomenal change in the vegetation intensity. During the treatment period, the blanks are changed from degraded forest to open forests to dense forests. The 3 season satellite data has helped in monitoring the changes periodically.
- The changes in forest density are ratified by ground validation by forest department and RS derived outputs.
- Due to the increase in height of the dam and the subsequent impounding of water in the reservoir, the area under water bodies has increased from 485 ha (1993) to 811 ha (1995) and 1114 ha in 1998. This increase is mainly in the river bed, along the river.

E. CONCLUSION

- The forest density/type map and statistics generation required an input in the preparation of Forest Management Plan preparation would typically take 6-9 months for a forest division having an area more than 3000 sq. km. This is much faster than the time required by conventional approaches which required around 2-3 years.
- Reliability of the maps generated by using RS & GIS would be high as subjectivity while mapping is least.
- Eliminating Subjectivity and scope for human errors.
- Accurate location of sample plots which aid in making more comprehensive and realistic plans.
- Quantification of land use/misuse and its precise location.
- Satellite data serves as reliable record and very useful in Detection of encroachments.
- Typical cost for this approach would be Rs. 1.75/Ha as compared to over Rs. 7/ha for conventional approach.
- The updating of information and hence change monitoring will be much faster as the earlier data is compatible for digital analysis.
- The monitoring of changes in Forest can be studied enabling almost near real-time as RS satellite data has repetitive coverage.
- Forest fire mapping and damage assessment for taking timely appropriate measures.
- The RS & GIS database for the state once established would facilitate analysis of various alternatives before arriving at the operational management model.
- The GIS would enable exploring various possibilities for improving the parameters such as Site quality which depend on various factors such as slope, groundwater, meteorological parameters etc.



MONITORING OF NARMADA CATCHMENT AREA TREATMENT PROGRAMME

NEWASA FOREST DIVISION, DHULE DISTRICT MAHARASHTRA

RSSSC-NAGPUR NEWASA FOREST DIVISION-TALODE FSI-NAGPUR

S.No.	Water-shed No.	Water bodies			Forest blanks			Degraded forest			Open forest			Dense forest			Total		
		1991	1995	1998	1991	1995	1998	1991	1995	1998	1991	1995	1998	1991	1995	1998			
1.	Na 3a	269	437	562	1019	732	853	565	508	544	994	1063	686	138	245	341	2985	2985	2986
2.	Na 3 b	1	0	1	355	253	164	219	248	289	597	537	492	219	353	445	1391	1391	1391
3.	Na 3 c	3	15	32	1756	1160	1145	771	867	832	1166	1430	1030	130	356	788	3827	3827	3827
4.	Na 3 d	98	182	203	948	669	507	243	339	315	253	320	357	38	70	198	1580	1580	1580
5.	N a 3 f	3	6	17	1721	1535	1074	485	612	754	461	508	632	45	54	238	2715	2715	2715
6.	N a 3 h	111	171	199	913	750	611	247	366	342	156	144	246	4	1	34	1432	1432	1432
Total		485	811	1014	6712	5099	4354	2530	2940	3076	3627	4002	3443	574	1079	2044	13931	13931	13931

Sl. No.	Water Shed No.	1993	1994	1995	1996	1997	1998	Total	CAT – 1	CAT – 2	CAT – 3	Total
1.	Na 3a	***	***	480	***	***	***	480	171	309	0	480
2.	Na 3b	***	318.5	500	12	***	***	830.5	388	397.5	45	830.5
3.	Na 3c	560	1678	433	***	30	***	2701	568	1773	360	2701
4.	Na 3d	***	480	295	220	***	***	995	295	638	62	995
5.	Na 3f	***	1211	475	85	***	150	1921	301	1458	162	1921
6.	Na 3h	***	472	***	400	***	100	972	264	670	38	972
Total		560	4159.5	2183	717	30	250	7899.5	1987	5245.5	667	7899.5