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EFFECT OF FOREST COVER CHANGES ON SEDIMENT YIELD OF UPPER INDRAVATI RESERVOIR CATCHMENT ORISSA

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PREFACE

Construction of reservoirs entails a huge expenditure and they affect river regime and environment substantially. Hence every effort needs to be made to preserve reservoir storage capacity and minimize the adverse effects of dams on river regime and environment.

Assessment of Reservoir catchment regions at regular intervals would enhance the understanding of geodynamic process and help in identifying effective control measures. Topographic and remotely sensed data gives quicker and more accurate information about Land Use/Land Cover of catchment and reservoir spread. This could be used in assessing the effect of changes in Land use on Sediment Yield from a catchment.

In this report titled " Effect of Forest Cover Changes on Sediment Yield of Upper Indravati Reservoir Catchment, Orissa", using the Remotely sensed data, the Land Use Classification has been classified and the Annual Sediment Yield from the catchment has been estimated for the year 2000, using the Statistical Methods applicable for Indian Catchments.

The study has been carried out by Sh Shaik Mohammed Saheb, P.R.A. and Sh V Sreenivasulu, Scientist B of Deltaic Regional Center, Kakinada, under the guidance of Sh K S Ramasastri, Director, NIH.

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ABSTRACT

The natural process like erosion in the catchment area, movement of sediment and its deposition in various parts of reservoir require careful consideration in the planning of major reservoir projects. In recent years, denudation of catchment through human activity by way of agriculture, deforestation, extensive grazing etc. has been progressively accelerating soil erosion and disturbing solid-liquid equilibrium in the river catchments. The silt, which gets deposited at different levels, reduces the storage capacity of reservoir. Reduction in the storage capacity beyond a limit prevents the reservoir from fulfillment of the purpose for which it is desired.

Periodic sediment yield provides vital information on the rate of soil erosion and changing land use pattern in the catchment and therefore forms the basics of planning, designing and maintaining water resources projects in a river basin as well as for preservation of the catchment echo system.

Upper Indravati reservoir, on the Indravati River in Orissa, India, is a multi-purpose reservoir. Land use and Land cover pattern in the catchment demarcated for the year 2000 using multi-temporal Remote sensed data. It is observed that Scrublands, total forest area, Arable Land constitutes 59, 11 and 21 percentage of total catchment area respectively. There is a 3.61 % decrease in the area of Scrublands from year 1996 to year 2000 and 0.9 % increase in Arable land. The Others Land Use Category has also has shown an increase of 3.77 %.

Sediment Yield from the catchment is estimated in the range of 2.750 to 4.282 m3/ha/year, using different statistical methods. The maximum of estimated rate is within the design limit of the reservoir.

1.0 Introduction

Uncontrolled deforestation, forest fires, overgrazing and excessive agricultural practices accelerate soil erosion resulting in a large increase sediment flow in streams which cause serious problems in engineering projects for flood control, soil conservation, irrigation, navigation and water-power development. Costly maintenance, loss of efficiency and, in some cases, damage of important engineering works have been experienced due to deposition of sediments in reservoirs, navigation and irrigation channels.

The storage capacity of reservoirs is reduced owing to siltation, aggravated by the change in the land use/land cover practices in the catchment area. It is reported that 175 million hectares is subjected to various degrees of environmental degradation. In India, about 534 million tons (16.4 tons/ha) of soil are removed annually; 1,577 million tons (29 per cent) are carried away by rivers to sea and 480 million tons (9 per cent) are deposited in reservoirs, resulting in loss of 1 to 2 percent storage capacity (Narayana and Ram Babu, 1983).

It is estimated that 200 to 2500 tonnes/km^2/year soil is eroded from major Indian Catchments. Percent Loss of capacity per year for some of the Indian reservoirs is given in the table no. 1.

Table No. 1. Percent Loss of Capacity per year for some of the Indian Reservoirs

Name of the Reservoir	River	Period of Observation Years	% Loss of Capacity
Gobindsagar	Sutlej	17	0.35
Panchet Hill	Damodar	18	0.65
Matatila	Betwa	13	0.78
Maithon	Barakar	16	0.50
Hirakud	Mahanadi	11	0.36
Mayurakshi	Mayurakshi	19	0.49
Gandhisagar	Chambal	5	0.05
Lower Bhavani	Bhavani	12	0.20
Tungabhadra	Tungabhadra	10	0.97

An extreme case In India is that of Ichari diversion dam on Tons River where the reservoir created by 53 m high dam got silted up to crest in just two years. On the average the in India (12 reservoirs) the percent loss of capacity per year is 0.50.

The sedimentation rate in reservoirs region wise are given in Table No 2.

Table No. 2: Sedimentation Rates for Different Regions in India

Sl No	Region	Sedimentation Rate Ha. M/100 sq km /year
1	Himalayan region (Indus, Ganga ,Brahmaputra basin)	Varies from 5.658 to 27.85
2	Indo-Gangetic plains	varies from 0.3 to 16.03
3	East flowing rivers excluding Gnaga upto Godavari	6.08 in case of Hirakund reservoir
4	Deccan peninsular east flowing rivers including Godavari	Varies from 0.15 to 12.16
5	Narmada Tapti basin	Varies from 3.64 to 7.16
6	West flowing rivers	Varies from 0.96 to 25.4

Source: CWC, New Delhi, India (1991)

1. 1 Impact of LAND USE/LAND COVER on Sediment Yield

Land soil and vegetation relationships related to the properties of soil, land use changes, and vegetation management effect the movement, retention and use of water. Such relationship can definitely give a clue to impact of vegetation management on soil erosion and water yield.

The major role of forest is to interception of the raindrops so that their kinetic energy is dissipated by the plants rather than imparted to the soil. Generally forests are the most effective in reducing erosion because of their canopy, For adequate erosion protection at least 70% of the ground surface must be covered. The effectiveness of a forest cover in reducing erosion depends upon the height and continuity of the canopy, the density of the ground cover and the root density.

On a world scale investigation of the relationship between soil loss and land use pattern show that erosion reaches maximum up to 75 $kg/m^2/yr$ in the bare land while it approaches maximum up to 0.30 $kg/m^2/yr$ only under the natural conditions.

1.2 Reservoir Sedimentation Prediction

Large multipurpose reservoirs have been constructed across rivers for irrigation and generating hydroelectric power. In practice, reservoirs are designed to have adequate storage capacity and a reasonably long span of effective life, with provision to take care of the assumed rate of sedimentation. However, many of the these multipurpose reservoirs built at great cost have been silting up at a much faster rate than expected because of extensive erosion in the catchemtn areas. A comparision of the assumed rate of siltation and actual rate of siltation of some river valley projects in India on which huge national investments have been made, is given as Table No. 3 . These figures speak of the alarming rate of silatation.

Table no. 3 Rate of Siltation in some river Valley Projects

Project	Assumed Rate (Ha-M/100 Sq. m/Year)	Actual Rate (Ha-M/100 Sq. M/Year)
Ramaganga	4.29	17.30
Maithan	1.62	12.15
Panchat	2.47	9.92
Bhakra	4.29	6.22
Mahi	1.29	8.99
Beas	4.29	6.11
Chambal	3.61	5.29
Nizamsagar	0.29	6.34
Tungabhadra	4.29	6.11

Source : Methodology for Priority Delineation Survey, AILUS, Ministry of Agriculture, Government of India, 1991.

The process of erosion and subsequent sedimentation in reservoirs brings in focus reservoir sedimentation. Various uses/advantage of predicting sedimentation could be:

- To estimate the expected life of a reservoir which is most important criteria in the justification from the economic view point. The prediction would require an estimate of the average amount of sediment which would enter the reservoir and part the part which would be trapped in the reservoir.

- As the cost of a planned water resources project would largely be influenced by the conservation methods to be employed at a later stage, it becomes imperative to include the expected sedimentation and its remedial cost in the economic analysis of the project

Various objectives of predicting reservoir sedimentation could be at various stages like in planning stage, in design stage and in operation stage.

The some of the various factors affecting silting in reservoirs, these could be:

- Catchment area
- Monthly and annual rainfall
- Slope of the catchment
- Vegetation cover and land use pattern
- Type and shape of reservoir

2.0Review

The depletion of forest has imposed a serious problem of accelerated erosion globally. Removal of vegetation cover upsets the natural rate of erosion and the ecosystem with a short temporal span, On a land covered by grass, even a deep layer of overland flow causes little erosion because the energy of moving water is dissipated in friction with grass stems, which are tough and elastic. On a heavily forested land, countless check dams made by leaves, twigs, roots and fallen tree trunks take up the force of overland flow. Without such vegetation cover the eroding force is applied directly to the bare soil surface, easily dislodging the grains and sweeping them down slope.

The studies on the forest influence on different hydrological parameters are in progress in different parts of the world.

Some of the efforts in this direction in India are Ranganathan (1949) , Bhattaharya (1956), Dabral et. al . (1963) and Dabral (1965) are the pioneer workers who initiated the work on the protective functions of forest and on the effects of forest on hydrological parameters such as effect of deforest on the intensity and frequency of rainfall and floods, rainfall interception by leaf litter, soil moisture in chir, pine, teak and Sal forests etc. Vegetation characteristics and their effects on heir runoff and peak rates (mathur and Sajwan, 1978), effect of rainfall distribution (Biswas, 1980), consequences of deforestation and overgrazing on the hydrological regime (Gupta, 1980), overland flow, sediment output and nutrient loss from forest sites (Pathak , et. al. 1984) , forest influences on hydrological parameters (Lohani , 1985), sediment from different landuses (Bhatia 1986), hydrological impact of deforestation (Haigh, et. al., 1988), Hydrological responces of Landuses (Chandra, 1989).

Manavalan et. Al (1993) and Jain and Goel(1993)derived an empirical relationship between water spread, water level at dam site and storage capacity of the reservoir using temporal remotely sensed data. Charkraborthi (1993) used Indian Remote Sensing (IRS-1A) satellite data in estimating the gross erosion of Salauli watershed, a tributaroy of Zuari River in Goa, India. Lagwankar et al (1993) estimated the siltaion rate of reservoirs located in Maharastra to be 3.4-8.34 Ha/100 km^2 /year .

R Nagarajan and R Vinod Kumar (1998) has analyzed Radhanagiri Reservoir, on the Bhoganali River in Maharastra. Changes in the Land Use/land Cover in the years 1950 and 1992 were analysed using multi-temporal remotely sensed and thematic map. These results are used in the Sediment Yield Estimation from the catchment using statistical regression models.

A mathematical model for the studies of siltation in the Indravati reservoir has been developed at CWPRS. A river reach of 26 km starting from about 6 km upstream of Mohulpatna to the Indravathi dam site has been considered for the model. Studies carried out for without mining case indicate the reservoir life to be 89 years (CWPRS, Technical report no 3248, 1995).

2.1 Estimation of Sediment yield

The existing sediment yield models vary greatly in complexity, from simple regression relationship, linking spatial variation of annual sediment yield to climate and physiographic variables, to simulation models. The regression equations that relate the sediment yield to the catchment and hydrometerological parameters are mostly used for priction of sediment yield from ungauged catchments. Review of literature shows that there are a number of regression equations available that were applied to various Indian catchments. For the estimation of sediment yield, mostly three parameters, viz., land use, topographical/morphological parameters and rainfall/discharge data have been considered.

Some of the sediment yield equations developed using data from Indian catchment are discussed below.

Sediment yield from the catchment can be calculated using the Central Board of Irrigation and Power (1977) method and the statistical regression model. Catchment area and precipitation are used in the method as input. The following equation has been applied in calculating the annual silt:

$$S= 0.118 A^{0.815} \qquad \text{..... (1)}$$

Where S = Annual slit deposition rate
A = Area of the catchment in km^2

On the basis of data from reservoirs that were then available, Khosla obtained the equation

$$Vs = 0.0032 A^{0.72} \qquad \text{.... (2)}$$

In which Vs is annual sediment yield in Mm^3 and A is catchment area in km^2.
Dhruv Narain and Ram Babu used from 17 major reservoirs in India and obtained the relation for annual sedimentation rate as

$$T1 = 5.5 + 11.1 Q \qquad \text{...... (3)}$$

In which Q is the annual runoff in M ha m and T is the erosion rate m tons per year. This equation was further refined as

$$T1 = 5.3 + 12.7 Q W \qquad \text{......(4)}$$

Here W is defined as W =T1/A, A being catchment area in M ha. Average of W was found to be 1.25 Mt Tons/ M ha Also using data from 18 river basins, the following relationships were obtained.

$$T = 0.014\ A^{0.84}\ P^{1.37} \quad ..... (5)$$
$$T = 14.25\ Q^{0.84} \quad ..... (6)$$
$$T = (0.342 \times 10^{-6})\ A^{0.84}\ (EI_{30})^{1.65} \quad ..... (7)$$

In which P is average annual rainfall in cm, A is catchment area in M ha, and EI_{30} is the product of average value of the sum of maximum 30 minute rainfall intensity in cm/hr and kinetic energy value E given by

$$E = 210 + 89 \log_{10} I_{30} \quad ..... (8)$$

Where E is in tons per ha. M. Ram Babu et al prepared Iso-erosion map of India in which EI_{30} contours were plotted. Since T is proportional to EI_{30}, these contours are know as iso-erosion contours.

The statistical regression model developed by Kumar (1985 takes into consideration most of the watershed characteristics and dynamic parameters such as annual precipitation. This model was validated and tested using data input from more than 30 small and medium - scale irrigation schemes in peninsular India and in Doon Valley (Chakraborthi, 1991).

$$V_s = 1.186 \times 10^{-6}\ P^{1.384}\ A^{1.292} D_d^{0.397}\ S^{0.129}\ F_e^{2.51} \quad ......(9)$$

Where

V_s = Sediment yield in m^3/ha/year
P = Annual precipitation in cm
A = Watershed in km^2
D_d = Drainage density in km /km^2
S = Watershed average slope
F_e = Vegetation cover factor
F_e = $(0.2F_1 + 0.21\ F_2 + 0.6\ F_3 + 0.8F_4 + F_5) / \Sigma_1^5 F_i$ ...(10)

Where

F_1 = Reserved and protected forest land (dense)
F_2 = Unclassified forest land (moderate)
F_3 = Arable land (low /sparse)
F_4 = Shrub and grassland (open area)
F_5 = Watershed (rock outcrop).

Garde et. al. analysed the data from 31 small and large reservoirs in India. Taking into account the trap efficiency, the deposited material was expressed as V_{SAB} the absolute volume of sediment yield in M m^3 per year and was related to other pertinent variables by the equation.

$$V_{SAB} = (1.06 \times 10^{-06})\ A^{1.29}\ P^{1.38}\ S^{0.13}\ D_d^{0.40}\ F_c^{2.51} \quad .....(11)$$

In which S is the land slope, D_d is the drainage density in km^{-1}, P is the mean annual rainfall in cm and V_{SAB} is the absolute volume of eroded sediment in M M3, Here F_c is the erosion factor which is related to land use as.

$$F_c = 1/A_i\ (0.20\ A_F + 0.40\ A_{UF} + 0.60\ A_A + 0.80\ A_g + A_w) \qquad ....(12)$$

Where

A_F = Protected forest area in km^2
A_{UF} = Unclassified forest area in km^2
A_A = Arable area in km^2
A_g = Scrub and Grass area in km^2
A_W = Waste area in km^2

The coefficients of A_i are arbitrarily chosen. This equation gave less than ± 30 per cent for 90 per cent of data. It may be mentioned that this equation does not take into account lithology of area explicitly; however it is indirectly taken into account by inclusion of rainfall and vegetation.

Garde and Kothyari have carried out a more rigorous analysis of sediment yield from India catchments. Using data from 50 small and large catchment in India they have developed the following relationship for sediment yield erosion rate in cm.

$$Y = 0.02\ P^{0.60}\ Fe^{1.70}\ S^{0.25}\ D_d^{0.10}\ (P_{max}/P)^{0.19} \qquad .....(13)$$

Where P_{max} is the average maximum monthly rainfall in cm, S is the average catchment slope defined and Fe is the erosion factor defined as

$$S = A_i\ S_i/A \qquad ....\ (14)$$

And

$$F_c = 1/A_i\ (\ 0.3\ A_F + 0.80\ A_A + 0.60\ A_g + 0.1A_w\ ) \qquad .....(15)$$

3.0 Problem Definition & Objectives

3.1 Problem Definition

Soil erosion is one of the main reasons for poor crop yield in the study area. Erosion depletes not only moisture status of the soil which becomes a constraint for the crop growth due to erratic and occasional failure of monsoons, but also makes the field mechanically unfit for agriculture due to exposure of boulders and stones on hill slopes. Majority of land under crop in the area has slopes, which are not intercepted by any terracing and /or bunding.

The present field boundaries of the uplands are only property boundary indications and serve little purpose for conservation of soil or moisture. The tribal people depend mainly on the primitive agricultural practice known as " Podu", which involves deforestation and cultivation in the valleys. After three years of cultivation, when the fertility of the ground decreases, they migrate to new virgin valleys. Shifting cultivation on the hill slopes adds to the hazard and the total landscape gives a ghastly look, without any vegetation except a tree here and there.

The intensity of erosion in the catchment areas has been sever mainly due to rugged topography and long steep hill slopes under shifting cultivation. The problem has been further aggravated by high intensity rainfall.

It may be noted there three major rivers flowing into the Upper Indravati Reservoir, which are carrying significant sediment load into the reservoir. The shape of the reservoir also a playing a major role in trapping the sediment into the reservoir which may be effecting the storage capacity of the reservoir.

3.2 Objectives

The main objectives of the present study are to

(a) To demarcate changes in Upper Indravati catchment area using temporal remotely sensed and Thematic data.

(b) To use this information to estimate the Sediment yield from the catchment.

4.0 Study Area

4.1 Upper Indravati Hydroelectric Project (UIHEP)

The Upper Indravati Hydroelectric Project (UIHEP) is a large Multipurpose river Valley project in the state of Orissa. The study area consists of a portion of the Indravati catchment spreads over 2630.00 Sq Km.. It is situated in the southern portion of the Orissa state i.e. Koraput and Kalahandi districts, within the North latitude of 18^{o} 45' and 19^{o} 40' and East longitude of 82^{o} 43' and 83^{o} 10'. The area is covered by nine number of Survey of India totposheets in 1:50,000 scale i.e. 65 M/2,3,4, 65 I/14,15,165, 65 J/9,13 and 65 N/1. The Index map of the Upper Indravati Catchment (Combined) is shown as Fig. 1. UIHEP has a reservoir with a water spread of 110 sq. km at FRL of 642.00 m (RL). The Index map of Reservoir is shown as Fig. 2.

The primary objectives of the project are

I) To generate 600 MW of electricity

II) To provide Irrigation for 1.28 lakhs hectares of land in Khalahandi District

The project comprises of four dams, eight dykes and two link channels (within the reservoir). In the power side there is an Intake structure, one headrace tunnel, surge shaft, two pressure tunnels, valve house. Four Penstocks, power House and tailrace channel, barrage on the Hati river with headworks, and three main canals, with a distribution network. The reservoir level (FRL) of RL 642.00 m will have a water spread of 110 sq. km. with 1500 Mm3 live storage and 800 Mm3 dead storage. The reservoir will have a maximum depth of 71 m and an average depth of 21 m. The reservoir is approximately 43 km long in the NNE-SSW direction, and 9 km wide at its widest point. Salient features the primary structures of the Upper Indravati Project

4.11 DRAINAGE

A well-developed and dense drainage pattern is the remarkable feature of the area. The major rivers flowing in the project area are river Indravati and its tributary Tej, which flow from north to south. San, Golagar, Ammulgar and Paraga rivers flowing from west to east from a part of the catchment of the project area. Ghagada and Murani nalas join together to form Larkagrarh river which again falls in Muran river. Muran river flowing in southwest to northeast direction will directly discharge to the reservoir. Chhabeli nala flowing in south-north direction will also directly discharge to the proposed reservoir.

Drainage of the catchment area seems to be somewhat controlled by geology and structure. Most of these rivers are perennial, effluent and have high

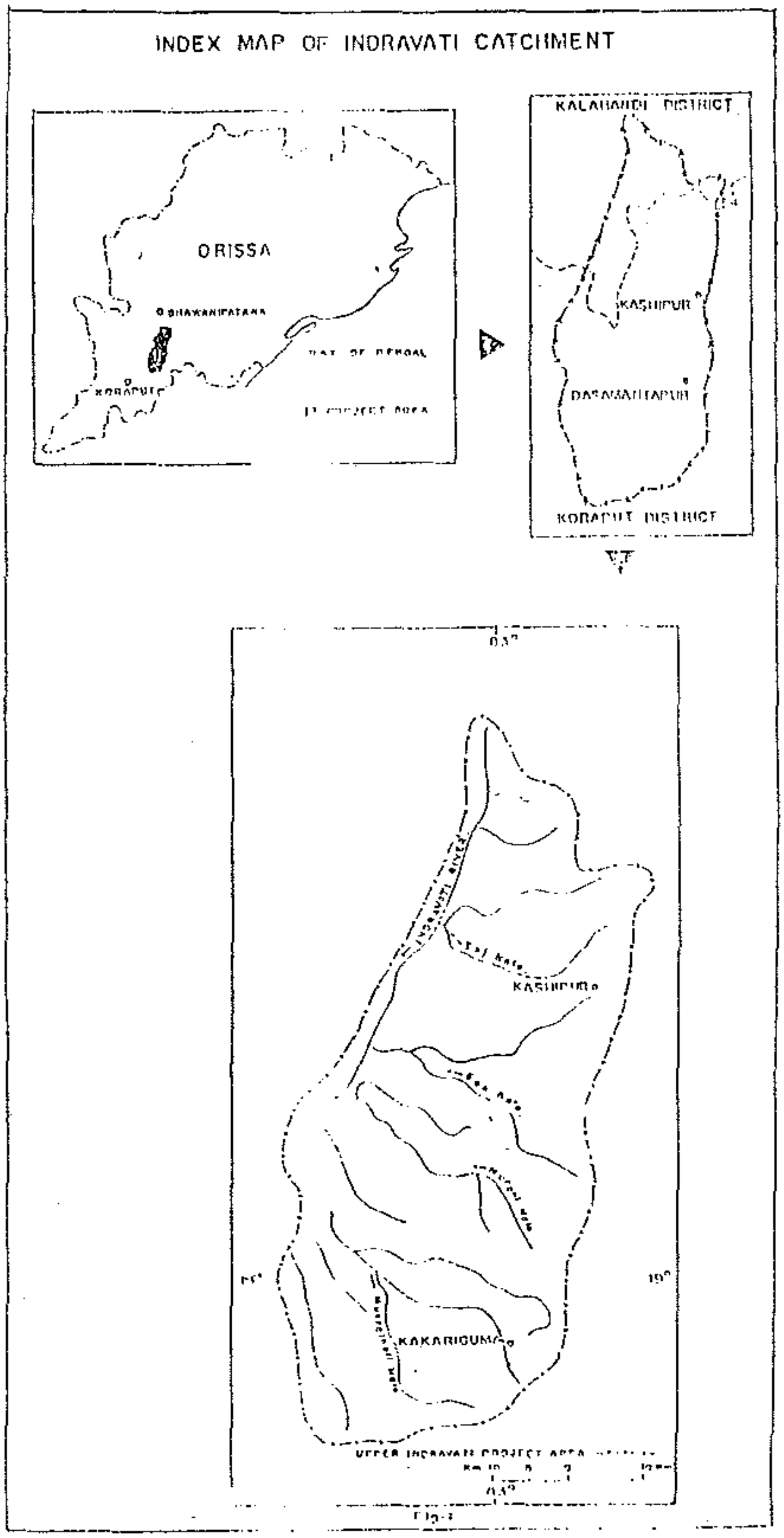

Fig. No. 1 Index Map of Upper Indravati Reservoir Catchment

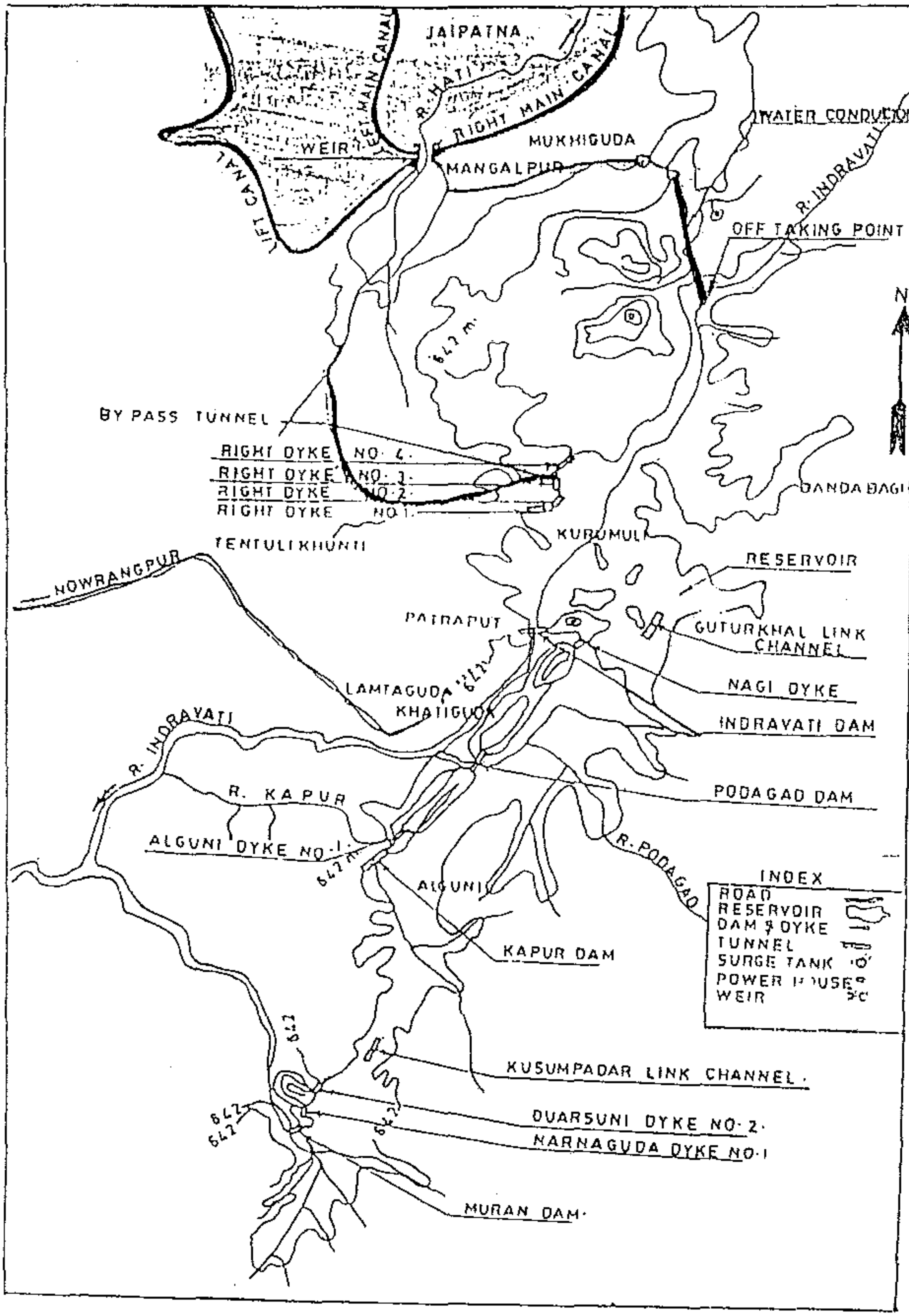

Fig. No. 2 Index Map of Upper Indravati Project

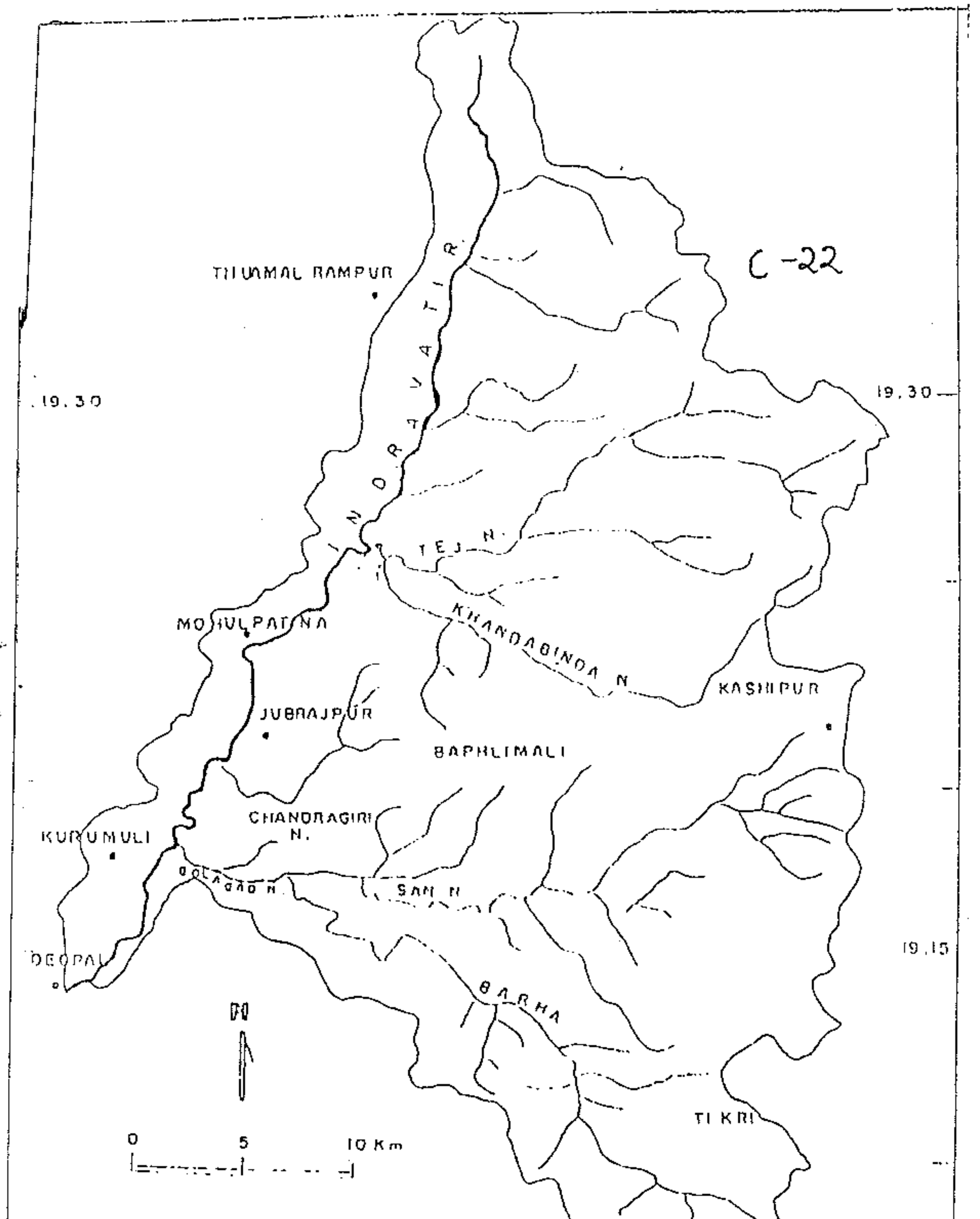

Fig. No. 3 Catchment Map of River Indravati discharge in the monsoon months of June and September. Occasional flash floods are not uncommon in these rivers.

4.12 River Indravati

River Indravati Originates in Thuamul Rampur Platue in Kalahandi District at an altitude of more than 915 m. on the Western slope of Eastern Ghats and traverses in southwesterly direction, through the hill ranges of Kasipur Taluk. The catchment map of the river Indravati is shown as Fig. 3. The Indravati basin in this reach has got a series of hills of varying altitude even more than 915 m. In this region the river joined with a number of small tributaries namely Kandabindha, the Chandragiri, the Gologad and the Podagad, which substantially contributes to the parent river. After flowing through a number of rapids, the river emerges into the plains near village Lamtaguda of Nowrangpur sub-division of Koraput District. The river is joined with Kapur and the Muran. Taking then, more or less westerly direction, the river flows through Nowrangpur Sub-Division and enters the Bastar District of Madhyapradesh near Jagdalpur. Beyond this, the river turns towards the south at an elevation of 82 m. and having a total run of 530 km from its origin the river ultimately falls into the river Godavari. The catchment area of river Indravati at Deopalli gauging site is 1153 Sq. km.

It may be noted that the Indravati river has a number of tributaries, small rivers and nallahs on its course of flow from its confluence with Tej river upto Deopali at Khatiguda. Out of them Khandabinda, Chadragiri and Golagar rivers merging into the Indravati river may be considered to carry significant amount of flow and sediment load into Indravathi river. The quantums of discharges and silt carried by these or any other rivers in the aforesaid reach are not available.

4.13 River Muran

River Muran is originated from Kakrigumma in Koraput District of Orissa. After its origination, some tributaries and small streams joined to it and just at the upstream of Muran Dam, river Chabili has joined with river Muran. The catchment area of river Muran is 1028 sq. km.

4.14 River Podagada

The catchment area of river Podagada is 389 sq. km.

4.2 Physiograph and Relief

Physiographically the area consists of the Easternghat hill ranges and the valleys between the mountain ranges. Most of the intermontane valleys are structure controlled. The hill range showing definite strucutal trands (NE-SW to N-S) and deformed by structural features are demarcated as structural hills.

The highest peak of 1391 meters is at Hatimali Parbhat. The general slope direction of the catchment area is towards west. Major portion of the project area has more than 15 percent slope. The alluvial plains along rivers Indravati and Chhabeli have 0 to 1 per cent slope, although smaller in extent.

4.3 Meteorological Characteristics

4.31 Climate:

The climate of the catchment may be distinctly divided into three seasons, namely, (a) the winter, (b) the summer and (c) the rainy season.

4.32 Rainfall : The rainfall in the catchment is 1432 mm. The monthly normal rainfall in the Upper Indravati catchment is given in Table 4. On an average there are 65 rainy days in a year.

Table No:4 Monthly normal rainfall in Upper Indravati catchment

Month	Rainfall in Kalahandi portion (in mm)	Rainfall in Koraput Portion (in mm)
January	11.5	6.7
February	15.4	11.3
March	13.6	16.2
April	23.7	53.4
May	33.7	75.0
June	228.3	205.8
July	343.5	351.1
August	348.6	380.3
September	220.9	262.1
October	81.4	116.5
November	17.5	35.8
December	3.2	7.6
Total	1341.3	1521.8

4.33 Temperature: The host season commences by about the beginning of March when temperature begins to rise. May is the hottest month when the mean daily maximum temperature is about 23°C. With the onset of the South-West monsoon by about the second week of June, temperature drops appreciably and throughout the S-W monsoon season the weather is generally cool. December is usually the coldest month with the mean daily maximum at 28° C and the men daily minimum at about 8°C.

4.34 Relative Humidity: The relative humidity is high during the S-W monsoon and post-monsoon months. The air becomes gradually drier thereafter. The summer is the driest part of the year with the relative humidity particularly in the afternoons going below 30 percent.

4.35 Winds: The winds are generally light to moderate with some increase in force during summer and monsoon seasons. The winds are mostly from the directions between Southwest and North–West in the monsoon season. In the post-monsoon and cold seasons they blow from the direction between west and northwest. In summer months the winds are variable in direction.

4.4 Geology

The project area is a part of the Eastern Ghat group of rocks. Broadly, they are grouped into the Khaondalite suite of rocks, charnockitic suite and granite gneisses with intrusives like porphyritic granite, granite gneiss and augen gneisses.

4.5 Vegetation

The Vegetation types occurring in the Catchment area are given in table no. 5.

Table No 5: Types of Vegetation in the Upper Indravati Catchment

Local Name	Taxonomic name
Sal	Shorea Robusta
Asan	Terminalia tomentosa
Dhaura	Anogeissus latifolia
Jamun	Syzigium cumini
Kendu	Diospyros melanxylon
Bahara	Terminalia balerica
Harida	Terminalia Chebula
Kusum	Schleichera trijuga
Mahul	Madhuca latifolia
Sissoo	Dalbergia latifolia
Piasal	Pterocarpus arsupium
Chandera	Santalum album
Bamboo	Dendrocalamus strictus

4.6 Socia-Economic conditions:

Schedule tribes and Scheduled castes form the main populations of the area. Cultivation is their main occupation. However, in general agricultural practice is very primitive and at present they are mainly dependent on rainfall. Groundwater is not widely used for the purpose, except from a few dug wells. The tribal people depend mainly on the primitive agricultural practice known as " Podu", which involves deforestation and cultivation in the valleys. After three years of cultivation, when the fertility of the ground decreases, they migrate to new virgin valleys. Artificial fertilizers are not being used. Beside this pottery, basket-making and weaving are the cottage industries of these tribes. The level of literacy among the tribal people is very low.

5. 0 Methodology

A number of empirical and conceptual sediment yield models are being used To Sediment yield analysis. Generally, such models utilize parameters like land use/land cover, soil, slope and drainage as inputs in spatial mode.

Depending upon the methodologies adopted for Estimating the sediment yield from a basin, a large number of models are available. These models vary greatly in complexity, from a simple regression relationship linking spatial variation in annual sediment yield to climate and physiographic variables, to complex simulation models. The simulation models provide a physically based representation of the process occurring in small segments of the catchment and route the response of these segments to the catchment outlet. The regression equations, that relate sediment yield of a basin to its hydro-meteorological conditions, are mostly used for prediction of sediment yield.

5.1 Sediment Yield Estimation Methods Adopted

Looking into the data availability status and the available models the following methods of estimating Sediment yield have been adopted in the present study.

5.11 Method – I CBIP Method

Sediment yield from the catchment was calculated using the Central Board of Irrigation and Power (1977) method and the statistical regression model. Catchment area, surface cover derived from satellite data, and precipitation were used here. The method considers the catchments area of the reservoir. The following equation has been applied in calculating the annual silt:

$$S = 0.118\, A^{0.815} \qquad \text{..... (1)}$$

Where S = Annual slit deposition rate
A = Area of the catchment in km^2

5.12 Method – II Khosla's Equation

On the basis of data from reservoirs that were then available, Khosla obtained the equation

$$Vs = 0.0032\, A^{0.72} \qquad \text{..... (2)}$$

In which Vs ia annual sediment yield in Mm3 and A is catchment area in km2

5.13 Method – III Statistical regression model developed by Kumar et al.

The statistical regression model developed by Kumar (1985 takes into consideration most of the watershed characteristics and dynamic parameters such as annual precipitation. This model was validated and tested using data input from more than 30 small and medium – scale irrigation schemes in peninsular India and in Doon Valley (Chakraborthi, 1991).

$$V_s = 1.186 \times 10^{-6} P^{1.384} A^{1.292} D_d^{0.397} S^{0.129} F_e^{2.51} \quad ......(8)$$

Where

V_s = Sediment yield in m^3/ha/year
P = Annual precipitation in cm
A = Watershed in km^2
D_d = Drainage density in km /km^2
S = Watershed average slope
F_e = Vegetation cover factor
$F_e = (0.2F_1 + 0.21 F_2 + 0.6 F_3 + 0.8F_4 + F_5)/ \Sigma_1^5 F_i$ ...(9)

Where

F_1 = Reserved and protected forest land (dense)
F_2 = Unclassified forest land (moderate)
F_3 = Arable land (low /sparse)
F_4 = Shrub and grassland (open area)
F_5 = Watershed (rock outcrop).

5.14 Method – IV Garde et al Method

Garde et. al. analysed the data from 31 small and large reservoirs in India. Taking into account the trap efficiency, the deposited material was expressed as V_{SAB} the absolute volume of sediment yield in M m^3 per year and was related to other pertinent variables by the equation.

$$V_{SAB} = (1.06 \times 10^{-06}) A^{1.29} P^{1.38} S^{0.13} D_d^{0.40} F_c^{2.51} \quad .....(10)$$

In which S is the land slope, D_d is the drainage density in km^{-1}, P is the mean annual rainfall in cm and V_{SAB} is the absolute volume of eroded sediment in M M3, Here F_c is the erosion factor which is related to land use as.

$$F_c = 1/A_i (0.20 A_F + 0.40 A_{UF} + 0.60 A_A + 0.80 A_g + A_w) \quad ....(11)$$

Where

A_F = Protected forest area in km^2
A_{UF} = Unclassified forest area in km^2
A_A = Arable area in km^2

A_g = Scrub and Grass area in km^2
A_W = Waste area in km^2

5.2 Meteorological & Catchment Characteristics

5.21 Rainfall

The Mean Annual precipitation, over the Catchment area is 1423 mm.

5.22 Drainage analysis

Surface drainage lines and elevation contours of the catchment were traced from Survey of India topographic sheet No. 65 I/11,12,14,15,16, J/9,13, M/2,3,4, N/1 at 1:50,000 scales. Horton's law of stream order of stream branch method was followed in designating the individual streams. Based on the measurement drainage density (Dd) and Catchment slope were calculated.

5.3 Land use/ land cover mapping

5.31 Methodology

Digital analysis was carried out using Earth Resources Data Analysis System (ERDAS), an image processing software. Multi-spectral cloud free digital data of IRS – 1D, LISS-III of path 104 and Row 59 acquired on 23th November 98 was imported into ERDAS. Contrast and Spatial enhancement techniques were applied on raw data in ordered to make the raw image more interpretable. A standard FCC (RGB:123 band combination) was prepared and this image was registered with the help of SOI toposheet Nos 65 M/2,3,4, 65 I/14,15,165, 65 J/9,13 and 65 N/1. Registration was done with high accuracy.

The base map is prepared from the toposheet and was digitized. The resampled image was masked with this base map. Based on the ground truth observation, training sets were identified on masked image for different landuse/ladcover. Finally the masked image was classified using the Supervised Classification, and the thematic map of land use/lane cover for the year 2000 has been prepared. Histogram for this map was calculated to know the area of each class.

5.32 Land Use /Land Cover Classification

As per the required input for the above models, the Land Use/Land Cover categories of Upper Indravati Project Area classified into total 7 categories, which are discussed below.

1. Dense and Protected forest land
2. Open Forest land
3. Arable land
4. Scrub land
5. Water Bodies
6. Waste Land
7. Others

6.0 Results & Discussion

6.1 Rainfall & Catchment Characteristics

The Annual Mean Rainfall and Catchment Characteristics are calculated as discussed in Methodology and presented in Table No . 6.

Table No . 6: Rainfall and Catchment Characteristics of Upper Indravati Catchment

Parameter	Value
Mean Annual Rainfall (P)	1423 (mm)
Drainage Density (D_d)	3.564 (m/km^2)
Catchment Slope (S)	0.003

6.2 Land Use/Land Cover Classification

In the present study the classification during the year 2000 has been done and for the year 1996 the values are taken from the report titled "Preparation of Watershed Management Plan for Catchment Treatment of Indravati & Podagada Catchment pertaining to Upper Indravati reservoir of Upper Indravati Hydro Electric Project (UIHEP)" by ORG Center for Social Research , Bhubaneswar.

The Classified Land use /Land Cover data during 1996 and 2000 summarised in Table no 7.

Table no. 7 Land Use/Land Cover Classification (1996 and 2000) in Upper Indravati Catchment

	1996		2000		Change
LAND USE/LAND COVER CATEGORY	Area (Sq. Km.)	%	Area (Sq. Km.)	%	%
Dense Forest	233.8	8.89	220.4	8.38	-0.51
Open Forest	84.7	3.22	80.4	3.06	-0.17
Arable Land	514.4	19.56	538.1	20.46	0.90
Scrub Land	1619.1	61.57	1524.1	57.95	-3.61
Waste Land	43.0	1.64	44.1	1.68	0.04
Water Bodies	125.7	4.78	114.6	4.36	-0.42
Others	8.9	0.34	108.0	4.11	3.77
Total	2630.0	100.00	2630.0	100.00	

Source for 1996: Executive Engineer, Indravati Development Division – II, Khatiguda, Orissa.

6.21 Classification for the year 1996

The major Land use in the catchment area is Scrub Lands which constitutes an area of 1619.1 Sq. Km, which is 61.57 percent of the total catchment area. The Dense and Open Forest together constitutes an area of 318.5 Sq. Km., which is 12.01 percentage of the total area. The total Arable Land in the catchment is 514.4 Sq. Km., which is 19.56 percentage. The wasteland, water bodies and others constitute an area of 177.6 Sq. Km., which is 6.7 percentage of the total area.

6.22 Classification for the year 2000

Out of the total project area of 2630 Sq. km., Agricultural lands which are primarily used for farming and for production of food, fiber and other horticultural crops in the project area occupy 538.1 Sq. km., which is 20.46 percentage of the total area. Which includes plain land agricultural and cultivation on hill slopes and uplands.

All the forestlands inside the catchment have been delineated as Reserved / Protected forestland (Dense) and Unclassified forestland (Moderate). In total, the forestlands occupy 300.8 Sq. km. in the project area, which constitutes to 11.03 percentage. The area under dense forest cover consists of mainly Sal.

Forest, having canopy cover within 10 to 40 per cent i.e. open forest consisting of mainly Sal is scattered throughout the project area including the reserved forests. The associates i.e Dendrocalamus strictus, Diospyros melanxylon, terminalia alata, Pterocarpus marsupium , Sanatalum album etc. are found mixed in these open forests. This particular category of forest occupies 80.41 sq. km. i.e. 3 percent of the total area.

Scrublands in the project area are estimated to be 1524.45 Sq. km. i.e. 57.95 percentage of the project area. This type of land is found scattered and covers more than half of the project area. This particular category of land needs special soil and water treatment once the irrigation status in the area and can be converted into cultivable lands to some extent. The FCC Map and Classified Land Use/Land Cover Map of Upper Indravati catchment are presented as Fig. No. 4 and 5 respectively.

6.3 Sediment Yield Estimation

Upper Indravati Project, Sedimentation index has been assumed at 1 ac-ft/year/sq. Mile of catchment while preparing the Project report taking the Silt Observations recorded in the adjacent Machkund River basin. The observed silt data of River Indravati near gauging station at Deopalli (1981 to 1989) observed during monsoon period only are presented in the table no. 7.

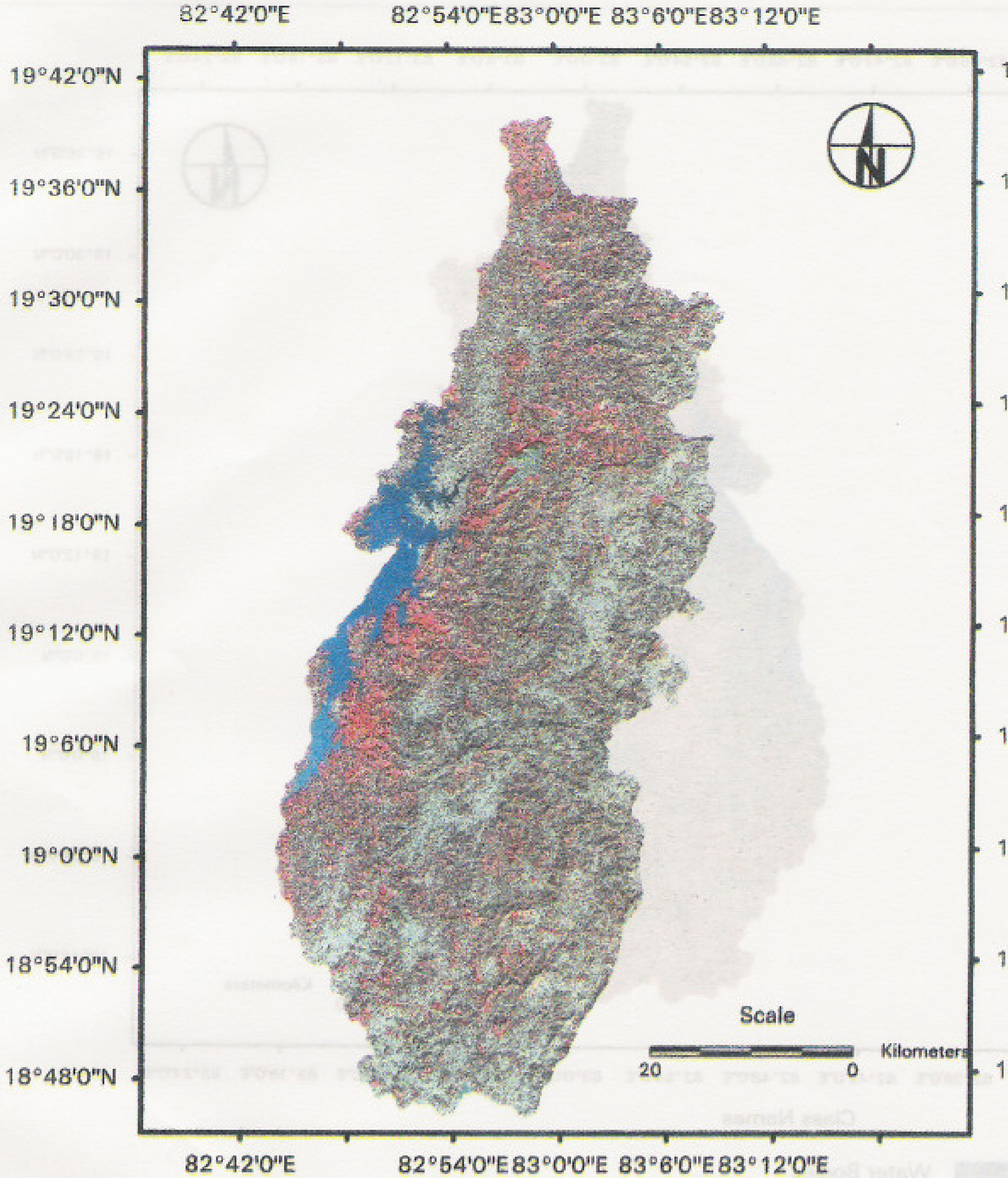

Fig. No. 4. FCC Map of the Study Area (IRS ID, LISS III, Nov 2000)

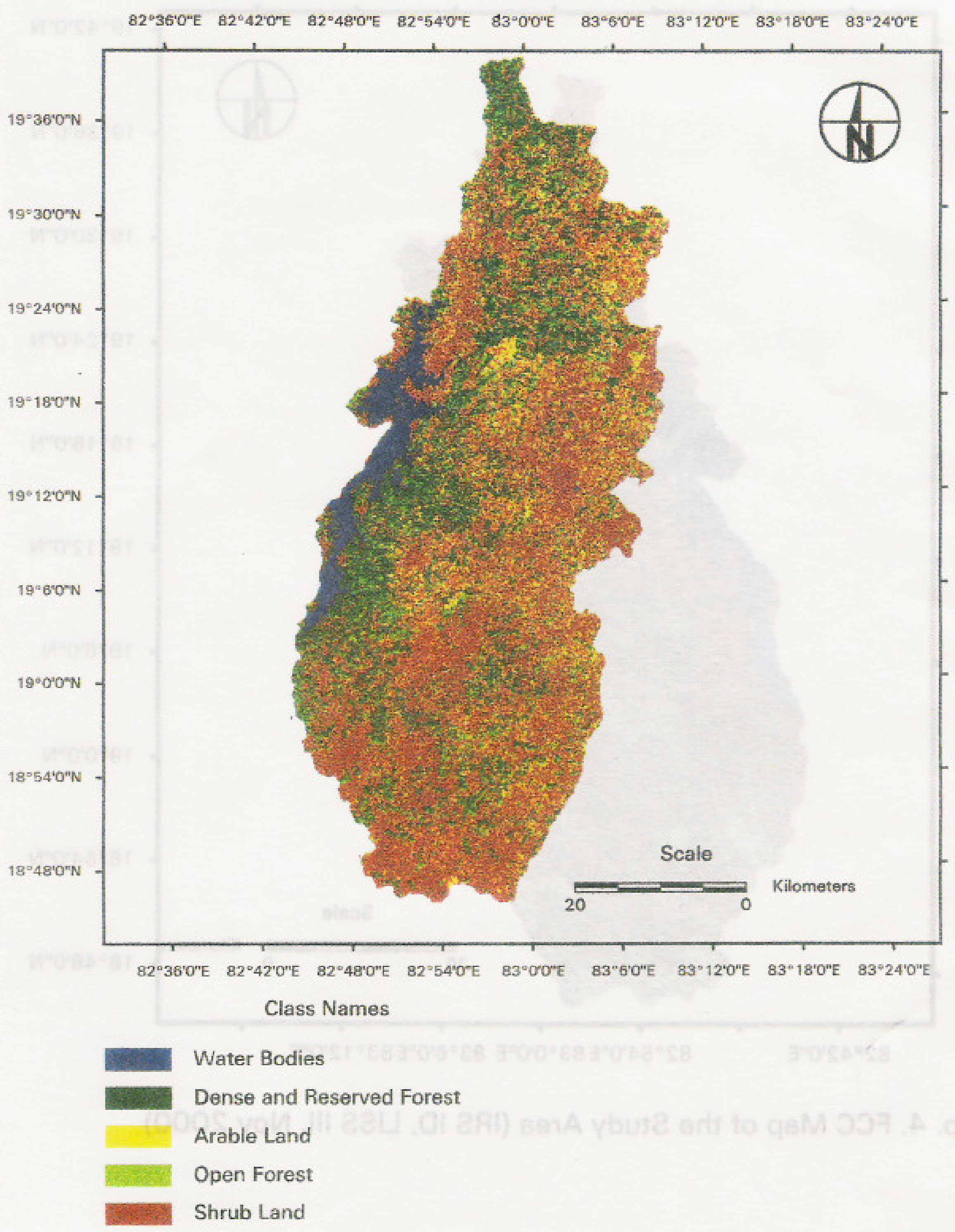

Fig. No.: 5 Classified Land use / Land cover Map of Upper Indravathi Reservoir Catchment

Table No. 8: Observed Silt Data of river Indravati near gauging station at Deopalli (1981 to 1989)

Year	Sediment In M^3/Ha/Year
1981	4.482
1982	3.033
1983	3.056
1984	4.775
1985	3.997
1986	2.283
1987	3.433
1988	4.278
Average	3.667

The annual slit rate for this reservoir using four methods discussed in the Methodology are summarised in the Table No.: 9

Table No 9: Estimated Annual Sediment Yields from the Upper Indravati Catchment using the different methods.

Method	Annual Sediment Yield in m^3/Ha/Year
Method – I	2.750
Method – II	3.528
Method – III	4.282
Method – IV	3.880

6.4 Discussions

The methodologies discussed have been applied to Demarcate the Land Use/Land Cover and to estimate the Sediment yield from the Upper Indravati Catchment area.

The major land use in the catchment is scrublands, which constitutes for about 59 percent of the total area and also which is responsible for more sediment erosion. It is observed from the results that there is a 3.61 % decrease in the area of Scrublands from 1996 to 2000 and 0.9 % increase in Arable land. The Others Land Use Category has also has shown an increase of 3.77 %.

According to the Method – I and Method – II, the annual sediment Yield is 2.7550 and 3.528 m^3/Ha/Year respectively. These methods take only Area and Annual rainfall into consideration. The Method – III estimates annual sediment Yield at 4.282 m^3/Ha/Year, which considers the land use, rainfall and catchment characteristics. The Method – IV estimates annual sediment

Yield at 3.880 m^3/Ha/Year, which also considers the land use, rainfall and catchment characteristics.

The orientation of the reservoir shows that the reservoir is narrow and elongated (breadth 1 to 9 km, length 43 km). It is oriented from north-east to south-west. The four dams on the river Indravati, Podagada, Kapur and Muran are all situated along the western periphery of the reservoir. The main river and its tributaries are thus flushing the reservoir from the eastern and north-eastern periphery.

The siltation rate of 4.76 ha-m/100 km^2/year was assumed by the Central Water Commission to work out the life of the reservoir and it was fixed as 100 years. The upper limit of rate of sedimentation, generally in Orissa is 3.6 ha-m/100 km2 /year. It is also observed from the historical observed data that the average sediment yield from the catchment is 3.667 m^3/Ha/Year. The results from the study indicate that the Annual sediment yield from the catchment is with in limits of the design life of the reservoir. These results are in agreement with the results from the similar kind of studies in the region.

Even though there are not much noticeable land use changes during 1996 to 2000, it is felt that the land use which is more responsible for the soil erosion that is scrub lands which is the major land use in the catchment needs some protection.

7.0 Conclusions

This study has clearly brought out the importance of land-cover features, rainfall and Catchment characteristics in assessing the sediment yield from the catchment of high rainfall areas.

The following are the summary of results in the present study.

In the year 2000 the total forest cover in the Catchment is 300.89 Sq. Km., which is of 11.44 percentage of total area. Out of the total forest cover, 220.47 Sq. Km (8.38 percent) is dense and reserved forest and 80.41 Sq. Km (3.06 percent) is Open Forests. The Shrubs constitutes the major land use in the Catchment, which is 1524.15 Sq. Km., which is 57.95 percentage of the total area. The arable Land is 538.17, which is 20.46 percentage of the total catchment area.

There is a 3.61 % decrease in the area of Scrublands and 0.9 % increase in Arable land from the year 1996 to 2000. The Others Land Use Category has also has shown an increase of 3.77 % during the same period.

The Annual Sediment yield during year 2000 for Upper Indravati Catchment is in the range of 2.750 to 4.282 m3/Ha, which is within the reservoir capacity design limit. The average observed annual sediment yield is 3.667 m3/Ha.

8.0 Scope for further study

The results in the present report are based on the sparse data. An up to date information on land use/land cover in the form of map is very vital for spatial planning management and utilisation of land for agriculture, forestry, pasture, environment studies, economic production and especially for preparing a suitable catchment management plan. Realising the importance, the annual sediment yield during the year 2000 for the Upper Indravati reservoirs has been estimated in the present study.

Similar kind of study at regular intervals may be useful for the continuous monitoring of the effect of land use on the sediment yield. Sediment load observations may also be carried out on seasonal basis during the monsoon period to check the sediment deposits into the reservoir.

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Salient features the primary structures of the Upper Indravati Project

Location	Long	E 82° 45′	to	E 82° 55′
	Lat.	N 19° 05′	to	N 19° 25′

Hydrology:

Catchment Area	:	2630 Sq. Km.
Maximum annual rain fall	:	2345 mm
Minimum annual Rainfall	:	1138 mm
Mean Annual Rain Fall	:	1792 mm
Probable Maximum flood	:	23030 cum/sec
Reservoir:		
Full reservoir Level (FRL)	:	642.000 m
Maximum water level	:	643.000m
Maximum Draw Down Level (MDDL)	:	625.000 m
Gross storage at FRL	:	2300 M. Cum
Live Storage	:	1485.50 m. Cum
Dead Storage	:	814.50 M. Cum.
Water spread area at FRl	:	110 Sq. Km.
P.M.F Inflow	:	27070 cum.

Dams

A. INDRAVATI DAM – Masonry, Gravity Type

This is a masonry gravity dam on the Indravati River. The dam has a maximum height of 45 m length of 539 m. it is provided with seven spillway gates (total capacity 11,430 M^3/s) and four low-level depletion sluices (total capacity 555 M^3/s).

Length overall	: 539 m.
Non-overflow sections	: 410 m.
Spillway	: 129 m.
Dam top level	: 645 m.
Width	: 7.5 m.
Maximum height of Dam	: 45 m
Spillway crest level	: 629.5 m
Radial gate no/Width X Height	: 7 / 15.00 X 12.5 m.
Capacity MWL EL 643	: 11,430 cum/s
Depletion sluice No. /width X height	: 4 / 2.00 X 3 m
Discharge El 643	: 555 cum/s

B. PODAGADA DAM -- Homogeneous Earth Fill

This is a homogeneous earth fill dam with a maximum height of 77.5 m and length of 462 meters. It impounds the Podagada River a major tributary.

Podagada Dam is provided with a Diversion cum depletion sluice of 650 M^3/sec capacity but no spillway.

Length	: 462 m.
Dam top level	: 647.50 m.
Top Width	: 9.0 m
Parapet height	: 1.0 m
Maximum height	: 77.50 m
Protection	
Upstream	: 0.6 m. Riprap over 0.3m, Filter
Down stream	: Grass Turfing

Capacity MWL EL 643	
Depletion Tunnel No. /Diameter	: 1/ 6.2 m.
Sill Level	: 590.0 m.
Flow MRI 643	: 650 cum/s

C. KAPUR DAM Homogeneous Earth Fill

Kapur is a homogenous earth fill dam of maximum height of 64 m and 537 m in crest length, It closed the Kapur river. It has no spillway or sluice.

Length	: 537 m.
Dam top level	: 646.00 m.
Top Width	: 9.0 m
Parapet height	: 1.0 m
Maximum height	: 64.00 m
Protection	
Upstream	: 0.6 m. Riprap over 0.3m, Filter
Down stream	: Grass Turfing

D. MURAN DAM – Masonry, Gravity Type

Located on the Muran river, a major left- bank tributary of river Indravati, this dam is a masonry gravity structure with a maximum height of 65 m and a crest length of 494 m. It is provided with five spillways with a combined capacity of 8060 cumecs. It has four depletion sluices with a total capacity of 588 m^3/s.

Length overall	: 494 m.
Non-overflow sections	: 403 m.
Spillway	: 91 m.
Dam top level	: 645 m.
Width	: 7.5 m
Maximum height of Dam	: 65 m.
Spillway crest level	: 629.5 m.
Radial gate no/Width X Height	: 5/15.0/12.5 m.
Capacity	: 8,060 cum/s

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