Completion report on

"Remote sensing data based soil conservation studies to control sedimentation in Sriramsagar reservoir".

Submitted by

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Final Physical Progress Report on the R&D Project titled "Remote Sensing Data Based Soil Conservation Studies to Control Sedimentation in Sriramsagar Reservoir"

1.0 INTRODUCTION

The Sriramsagar reservoir is a major irrigation project built across the river Godavari, in Nizamabad district, Andhra Pradesh (Fig.1). The reservoir catchment area is covered in three states namely Maharashtra, Andhra Pradesh and Karnataka. The break up of the catchment is as follows.

Table.1: State Wise Catchment Area of the Sriramsagar Reservoir

State	Area in Km^2	Percentage of total area
Maharashtra	71,760	78
Andhra Pradesh	15,675	17
Karnataka	4,405	5
Total	91,750	100

Several major projects were constructed on the upstream of Sriramsagar project on the river Godavari and its tributaries. These projects intercept about 70% of the total catchment. Most of the silt from the catchment area is trapped by these dams. The balance 30% is the free catchment which is immediately above the foreshore of the Sriramsagar project. The free catchment area is covered by the two states of Maharashtra and Andhra Pradesh. The rate of siltation for the design of Sriramsagar project was taken as 571.49 m^3/km^2/year. This figure is arrived for the free catchment area below Jaikwadi on Godavari, below Siddeswara on Purna and below Nizamsgar on Manjira. The catchment considered is 10, 428 sq.miles of free catchment and 7% of intercepted catchment which works out to be 12,178 sq.miles. The annual load that comes to Sriramsagar reservoir is 18.20 Mm^3/year (0.6365 TMC/year). The loss of capacity is estimated as 256.5 Mm^3/year (9.00 TMC).

2.0 STATEMENT OF THE PROBLEM

Sriramsagar Reservoir is one of the major silt affected reservoir (APERL, 1984).The total loss of storage capacity of Sriramsagar is 36.77% (Shangle, 1991). Earlier reconnaissance studies carried out by Andhra Pradesh State Remote Sensing Applications Center (APSRAC, 1993) in this area indicates that the rate of sediment yield in the catchment is very acute.

The Centre for Water Resources of JNT University has also conducted with the assistance of AICTE in the model watershed namely Suddavagu watershed. The studies indicated that the soil erosion is around 1186.33 m^3/km^2/year. But the actual design value of Sriramsagar project is 571.49 m^3/km^2/year. In the AICTE project, the calculated sediment values are not verified through actual observation of sediment load in the stream. Now in the present project it is proposed to verify the calculated sediment yield with the observed sediment yield from the three selected watersheds in the catchment. These selected watersheds are Jukal, Haldi and Poulang watershed as shown in Fig.1.

3.0 OBJECTIVES OF THE PROJECT

- To prepare various thematic maps namely land use/land cover map, slope map and drainage map by using remote sensing and Survey of India toposheets in the selected watersheds in the catchment of Sriramsagar Reservoir.
- To calculate sediment yield from the selected watershed by using various empirical equations.
- To validate the sediment yield so calculated by actually observing the sediment load at the outlet of the watersheds.
- To suggest appropriate soil conservation measures in the watersheds.

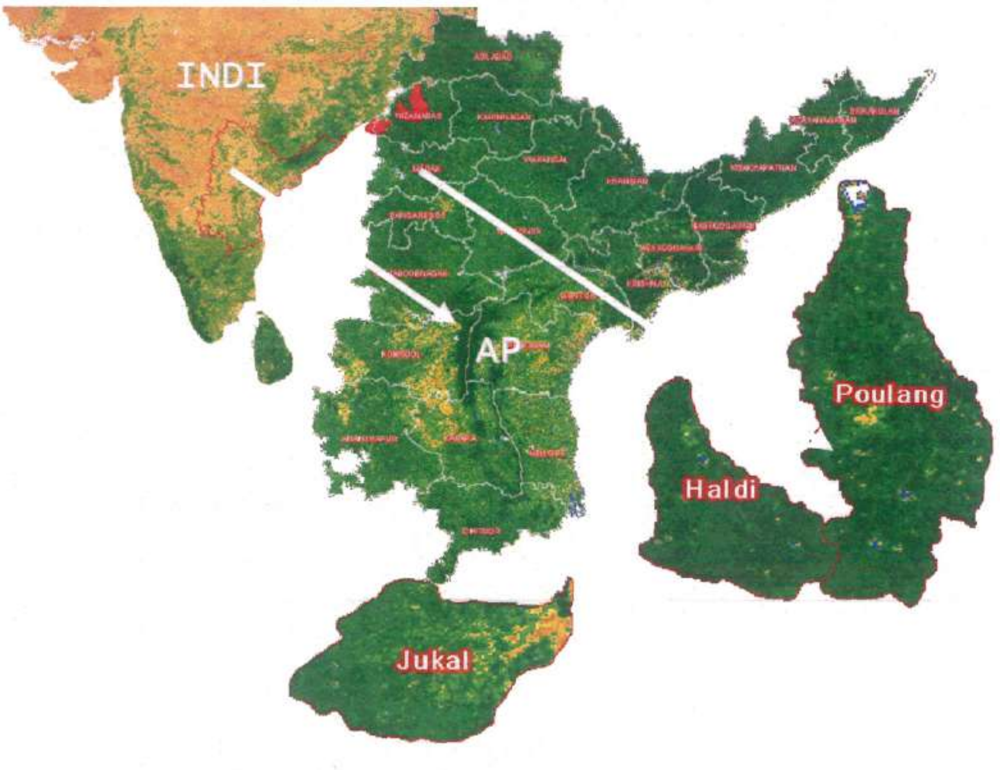


Fig.1: Study Area Location Map

4.0 METHODOLOGY

The theoretical calculation of the sediment yield is accomplished by estimating various watershed parameters such as area, runoff, temperature and vegetative cover factor from the satellite data and toposheets. These parameters are substituted in the various empirical formulae namely Garde equation, Universal Soil Loss Equation, Khosla Equation and Dhruvanarayana Equation. Practically the sediment is also calculated from the actual discharge observed from the mouths of the watersheds and the analysis of the water samples collected and analyzed for the sediment concentration. The schematic diagram of the methodology is as shown in the Fig.2.

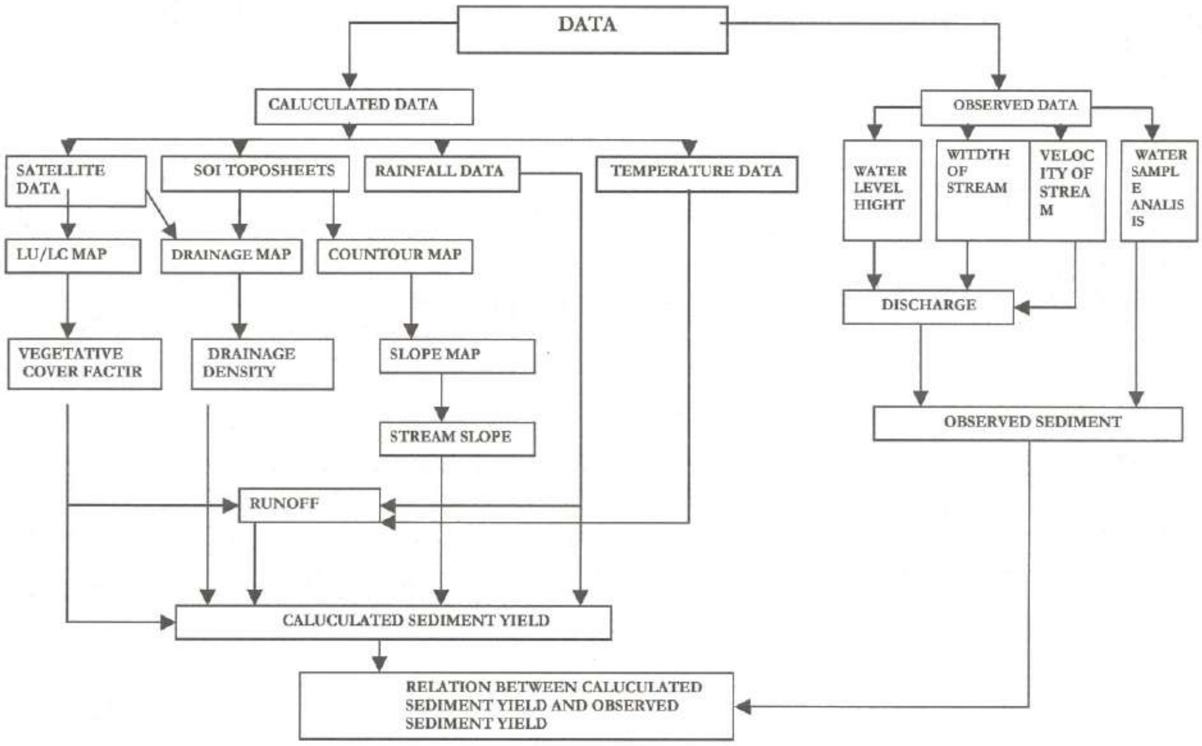


Fig.2: Flow Chart of the Methodology Map

5.0 DATA COLLECTION

With respect to the above methodology the following data has been collected from various organizations.

- Rainfall data for the years 2006, 2007 and 2008 is collected from the Bureau of Economics and Statistics, Hyderabad.

- Temperature data for the years 2006, 2007 and 2008 is collected from Indian Meteorological Department, Hyderabad.

- Satellite remote sensing data of IRS-LISS-III is collected from NRSA, Hyderabad and date of passing is: 18 th November, 2006, 13 th November, 2007 and 07 th November, 2008.

6.0 PREPARATION OF THE THEMATIC MAPS

The thematic maps are prepared in this project are drainage map, slope map and land use / land cover map. These maps are essential to provide input to various parameters in the sediment estimation formula

6.1 Drainage map

To achieve the first objective toposheets have been collected from Survey of India (SOI) for the selected three watersheds namely Jukal, Haldi and Poulang watersheds. The drainage maps have been prepared using SRTM satellites data and toposheets as shown in Fig.3, 4&5 by using GIS software. The drainage maps are prepared to find out the drainage densities of the watersheds.

6.2 Slope map

Contour maps were prepared in all the three watersheds from SOI toposheets and then slope maps have been derived. While doing the above exercise SRTM satellite data was also used to have clear cut drainage and contours. The slope maps are as shown in Fig.6, 7&8.

6.3 Land Use/ Land Cover map

The Remote Sensing satellite Data from the NRSA has been collected to prepare Land Use/ Land Cover maps for the watersheds by using ERDAS 8.1 software to determine the vegetative cover factor. The Land Use/ Land Cover maps for the Jukal, Haldi and Poulang watersheds for the years 2006, 2007 and 2008 are shown in the Fig.9 to 17 respectively.

6.4 Calculation of Vegetative Cover Factor

This factor is an input to the Garde's equation for sediment calculation. The equation is

$$F_c = \frac{0.2F1+0.2F2+0.6F3+0.8F4+F5}{F1+F2+F3+F4+F5}$$

Fc=Vegetative cover factor
F_1= Area under reserved and protected forest in km^2
F_2= Unclassified forest area in km^2
F_3= Cultivated area in km^2
F_4= Grass and pasture land in km^2
F_5= Waste land in km^2

The above values are obtained from the land use and land cover maps prepared from satellite imagery. Fc value is calculated and is shown in the following Table-2.

Table-2: Calculated Vegetative cover factor for the Catchments

Year	Jukal Fc	Haldi Fc	Poulang Fc
2006	0.668	0.568	0.601
2007	0.677	0.586	0.579
2008	0.645	0.614	0.613

6.5 Calculation of Annual Runoff

The annual runoff is an input to the sediment calculation formula of Garde and Druvanarayana.

The equation (Garde et al., 1985) is

$$R_m = \frac{Fc^{0.49}(Pm-0.5Tm)^{0.59}(Pm-0.5Tm)}{26.5}$$

R_m = Mean annual Runoff in cm

P_m = Mean annual Rainfall in cm

T_m = Mean annual Temperature in Celsius

F_c = Vegetative cover Factor

The values for the above parameters are calculated from the rainfall data obtained from the Bureau of Economics and Statistics, Temperature data is obtained from the Indian Meteorological Department. The runoff values are calculated as shown in the following Table-3.

Table-3: Calculated annual runoff from the Catchments Using Runoff Equation for the Years -2006, 2007 and 2008

Year	Jukal Runoff in Mm^3	Haldi Runoff in Mm^3	Poulang Runoff in Mm^3
2006	157.27	130.177	286.125
2007	101.24	80.270	176.250
2008	82.716	88.297	219.744

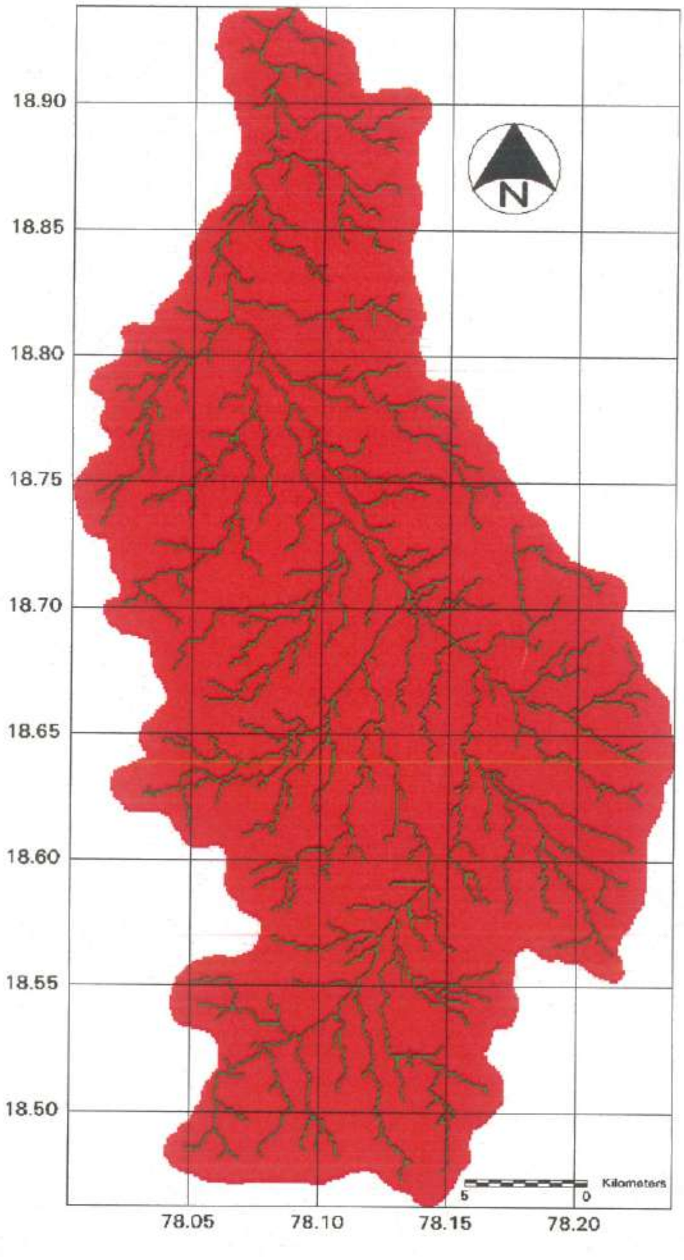


Fig.3: Drainage map of Poulang Watershed

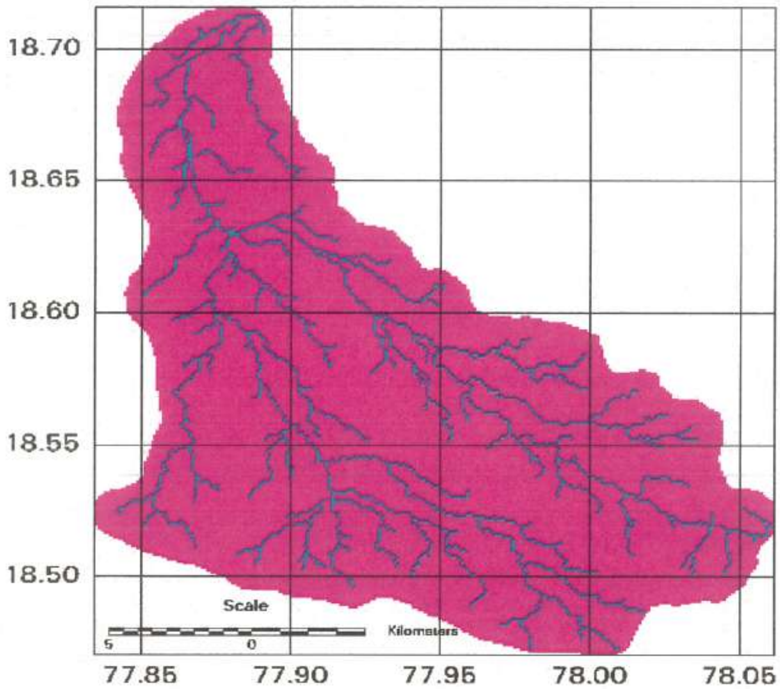


Fig. 4: Drainage map of Haldi Watershed

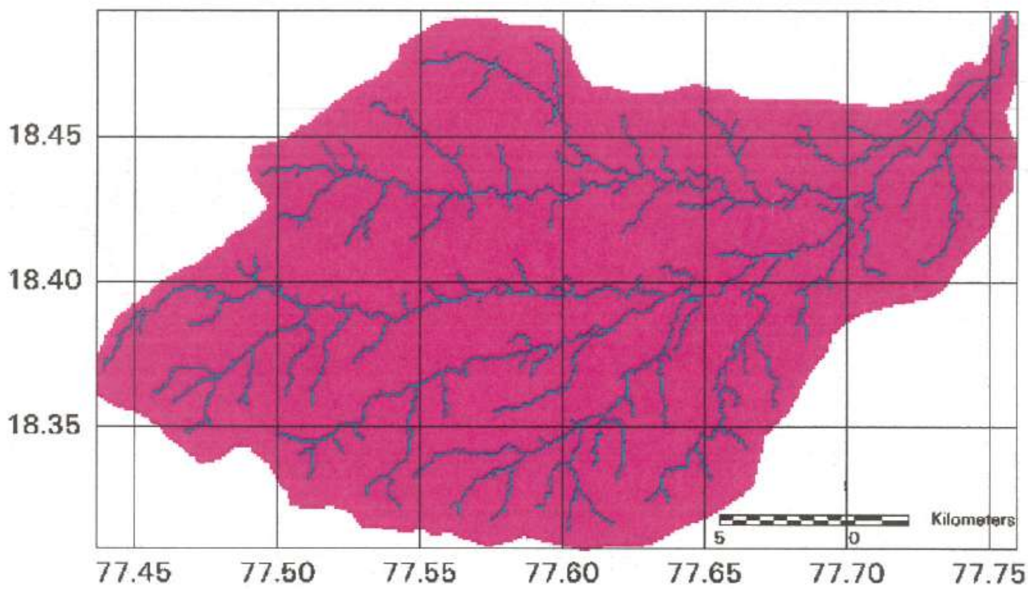


Fig.5: Drainage map of Jukal Watershed

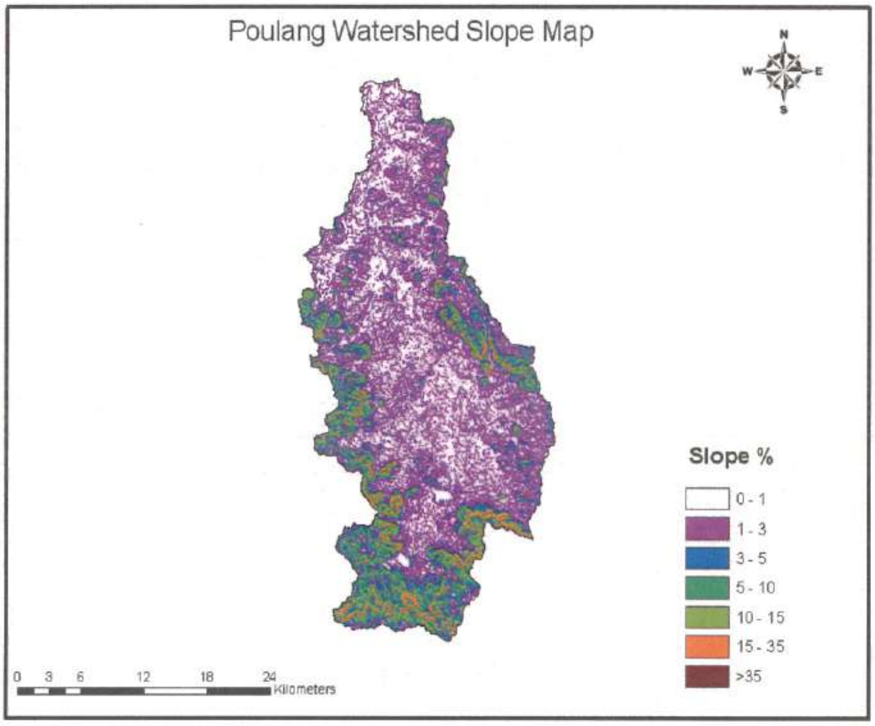


Fig.6: Slope Map of the Poulang Watershed

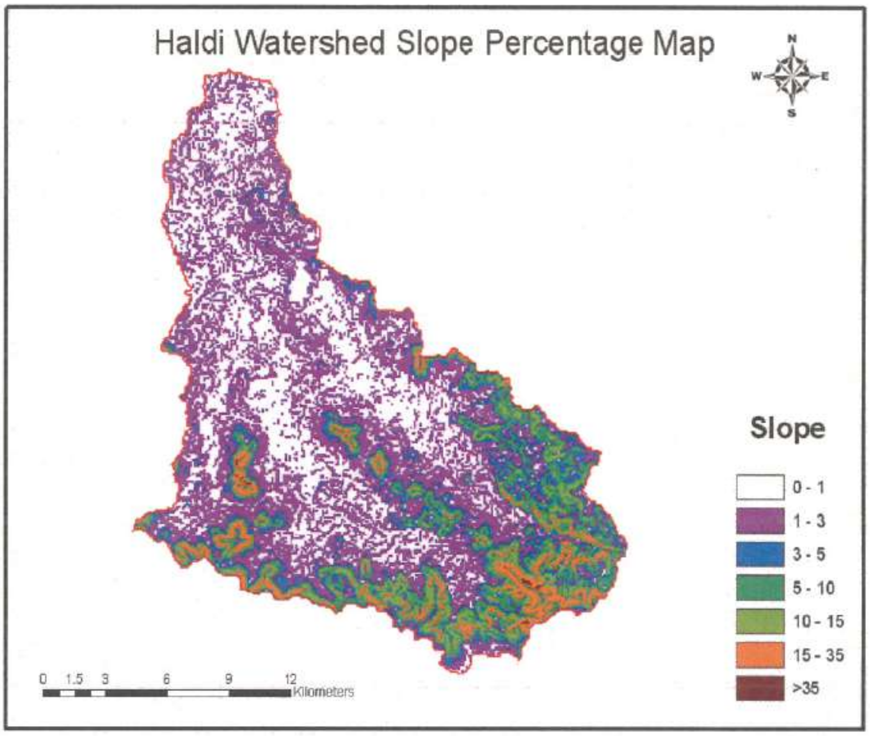


Fig.7: Slope Map of the Haldi Watershed

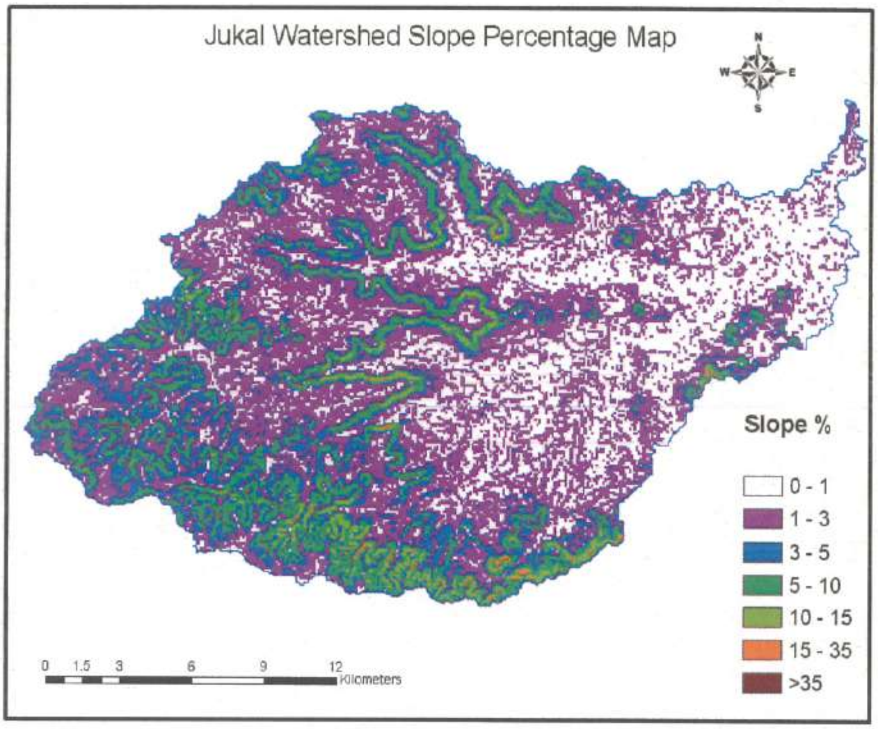


Fig.8: Slope Map of the Jukal Watershed

6.6 Calculation of Sediment Yield

6.6.1 Khosla's Equation

The equation used to calculate annual sediment yield (Khosla, 1953) is

$$V_s = 3.23 * 10^{-3} * A^{0.72}$$

Where,

Vs = Annual sediment yield in Mm^3

A = Catchment area in km^2

Table-4: Sediment Yield Calculation from the Catchments Using Khosla's Equation for the Years -2006, 2007 and 2008

Name of the watershed	Catchment area in km^2	Annual sediment yield in m^3/year	Annual sediment yield in m^3/km^2/year
Jukal	452	263000	582
Haldi	349	218000	625
Poulang	763	384000	503

6.6.2 Universal Soil Loss Equation

The equation used to calculate the average annual soil loss (Wischmeier et al., 1978) is

A=R K L S C P

Where,

A = Average annual soil loss in tons /acre /year
R = Rainfall factor
K = Soil erodibility factor
L S = Slope length & gradient factor
C = Crop management factor
P = Supporting conservation factor

Table-5: Sediment Yield Calculation from the Catchments Using Universal Soil Loss equation in theYears-2006, 2007and 2008

Name of Watershed	Catchment Area in km^2	Rainfall Factor in cm	Soil Erodibility Factor	LS Factor	Crop Management Factor	Supporting Conservation Factor	Soil loss in tons /acre/year	Soil loss in $m^3/km^2/year$
Jukal	452.00	100	0.22	0.0997	0.5	0.60	0.658	460.00
Haldi	349.00	100	0.22	0.1189	0.5	0.60	0.785	549.00
Poulang	763.00	100	0.26	0.1102	0.5	0.60	0.860	602.00

6.6.3 Dhruvanarayana's Equation

The equation used to calculate (Dhruvanarayana et al., 1983) is

T_1=5.5+ 11.1 Q

T_2=5.3+12.7Q.W

Where is

W=T_1/A

T_1 and T_2= Annual sedimentation rate in M tons/year

Q = Annual runoff in M.ha-m

A = Catchment area in M.ha

Table-6: Sediment Yield Calculation from the Catchments Using Dhruvanarayana's Equation in the Year -2006,

Name of the watershed	Catchment area in M.ha	Annual Runoff in M.ha -m	Annual Sediment rate M tons /year	Annual Sediment rate In m^3/year	Annual Sediment rate In m^3/km^2/year
JUKAL	0.0452	0.015	T1=5.674 T2=29.213	T1=16066340.00 T2=82719616.00	T1=35545.00 T2=183008.00
HALDI	0.0349	0.013	T1=5.644 T2=31.999	T1=15981408.00 T2=90608427.00	T1=45792.00 T2=259623.00
POULANG	0.0763	0.028	T1=5.817 T2=32.413	T1=16471644.00 T2=91780507.00	T1=21588.00 T2=120289.00

Table-7: Sediment Yield Calculation from the Catchments Using Dhruvanarayana's Equation in the Year -2007

Name of the watershed	Catchment area in M.ha	Annual Runoff in M.ha -m	Annual Sediment rate M tons /year	Annual Sediment rate In m^3/year	Annual Sediment rate In m^3/km^2/year
JUKAL	0.0452	0.010	T1=5.612 T2=21.227	T1=15890964.00 T2=60106508.00	T1=35157.00 T2=132979.00
HALDI	0.0349	0.008	T1=5.589 T2=27.570	T1=15825754.00 T2=78067112.00	T1=45346.00 T2=223688.00
POULANG	0.0763	0.017	T1=5.688 T2=21.394	T1=16106167.00 T2=60579148.00	T1=21109.00 T2=79396.00

Table-8: Sediment Yield Calculation from the Catchments Using Dhruvanarayana's Equation in the Year-2008

Name of the watershed	Catchment area in M.ha	Annual Runoff in M.ha -m	Annual Sediment rate M tons /year	Annual Sediment rate In m^3/year	Annual Sediment rate In m^3/km^2/year
JUKAL	0.0452	0.008	T1=5.591 T2=18.189	T1=1583100.00 T2=51504044.00	T1=35025.00 T2=113947.00
HALDI	0.0349	0.008	T1=5.588 T2=21.567	T1=15822962.00 T2=61069067.00	T1=45338.00 T2=174983.00
POULANG	0.0763	0.021	T1=5.743 T2=25.373	T1=16261819.00 T2=71846369.00	T1=21313.00 T2=94163.00

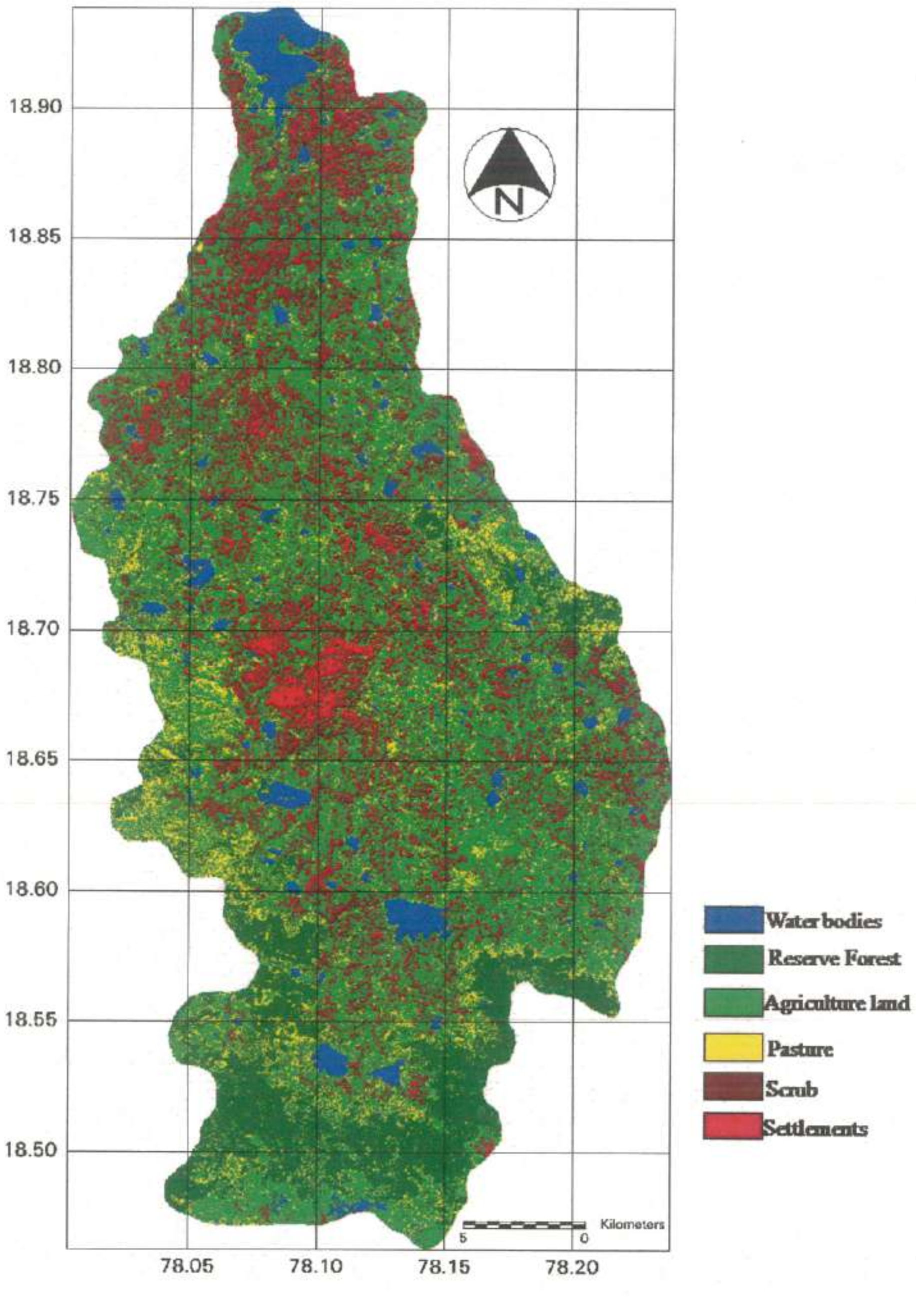


Fig.9: LU/LC Map of Poulang Watershed-2006

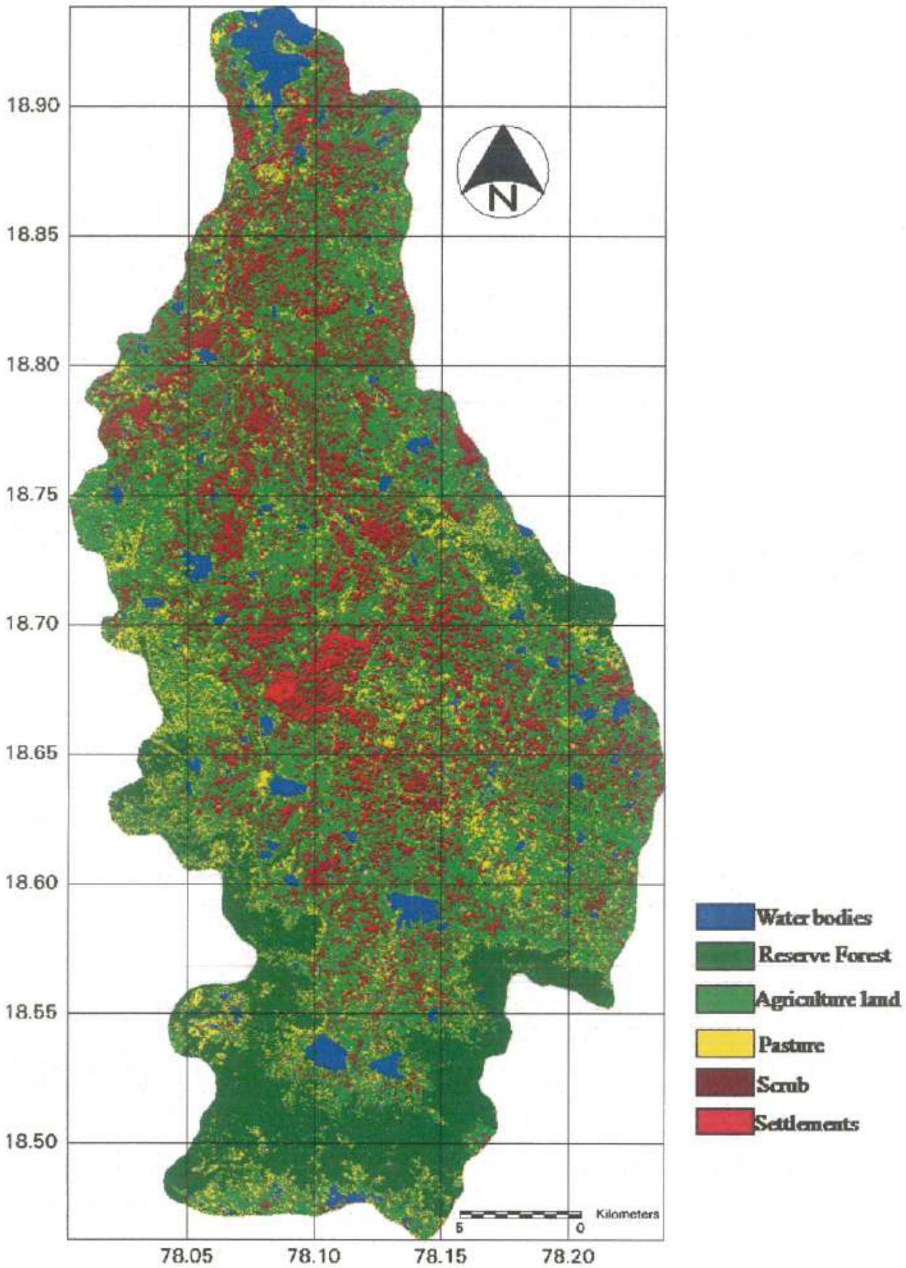


Fig. 10: LU/LC map of Poulang watershed-2007

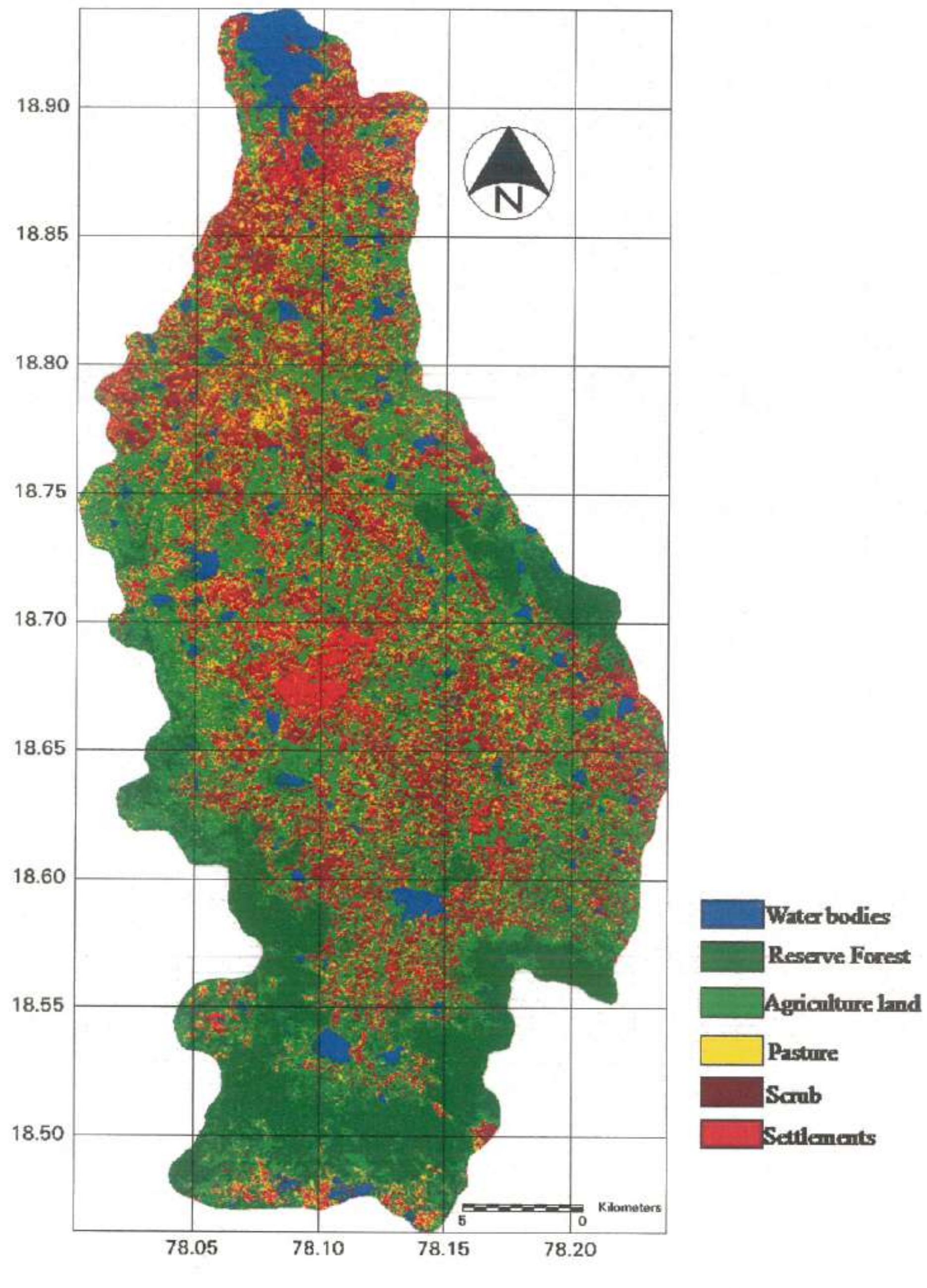


Fig.11: LU /LC Map of Poulang Watershed-2008

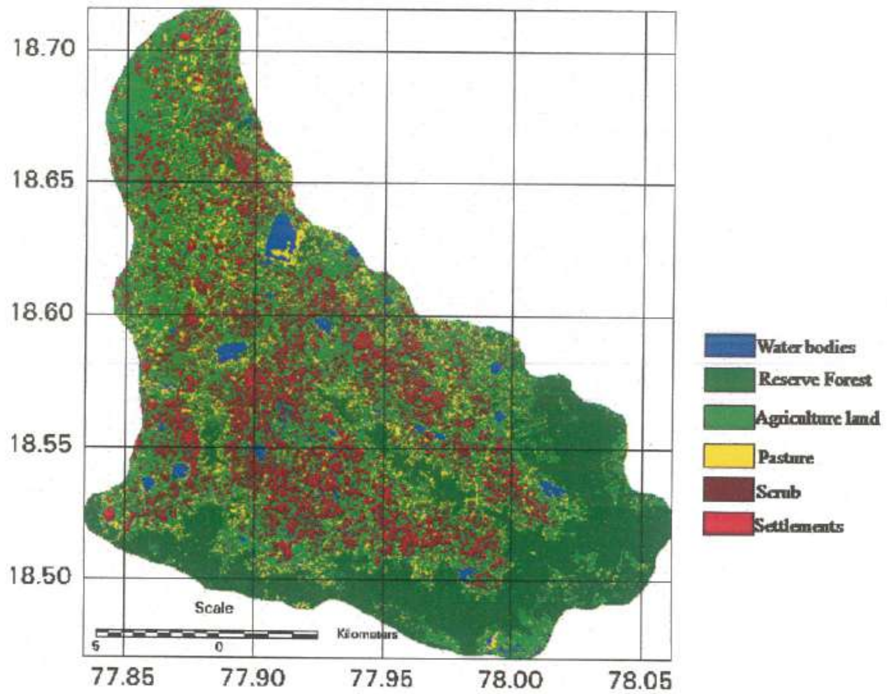


Fig.12: LU/LC map of Haldi watershed-2006

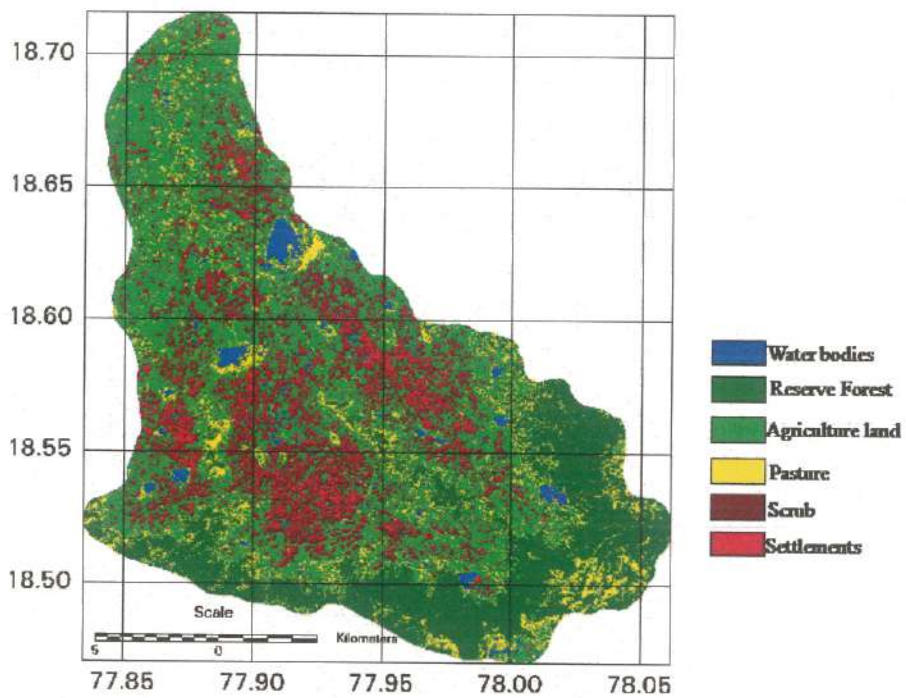


Fig.13: LU/LC Map of Haldi Watershed-2007

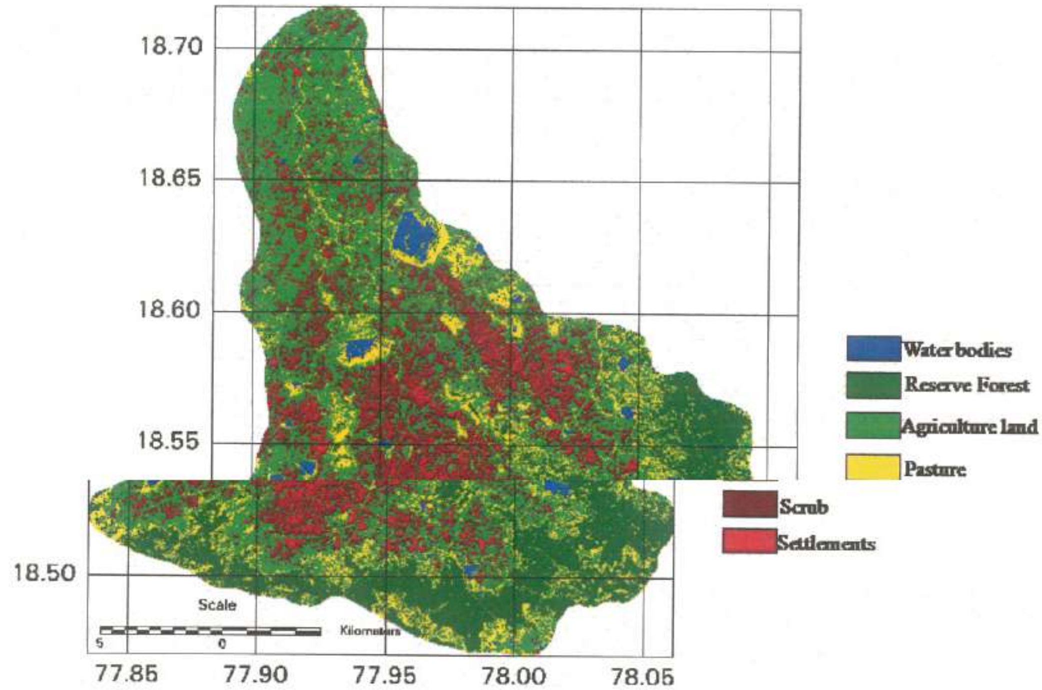


Fig.14: LU/LC map of Haldi watershed-2008

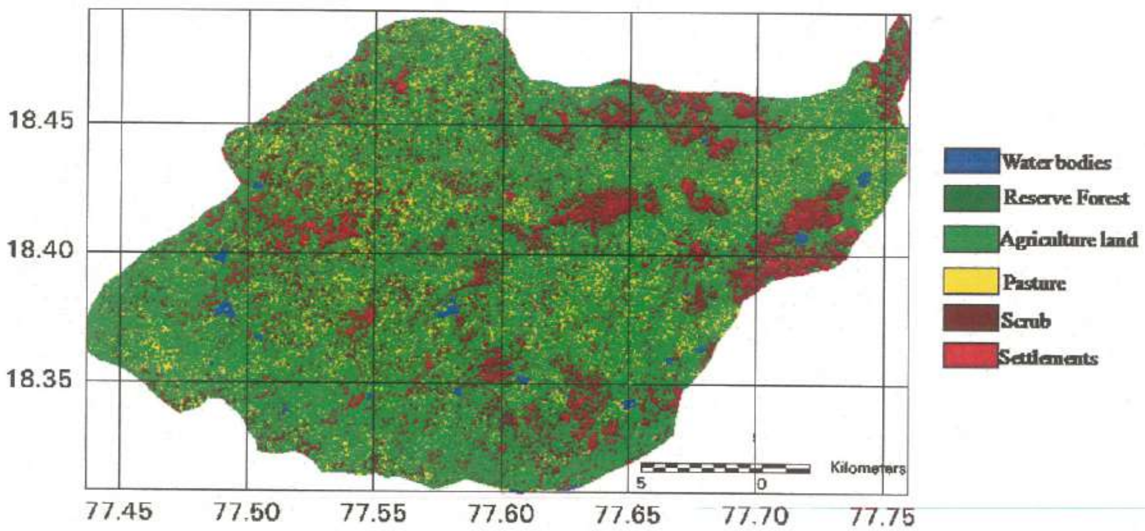


Fig.15: LU/LC map of Jukal watershed-2006

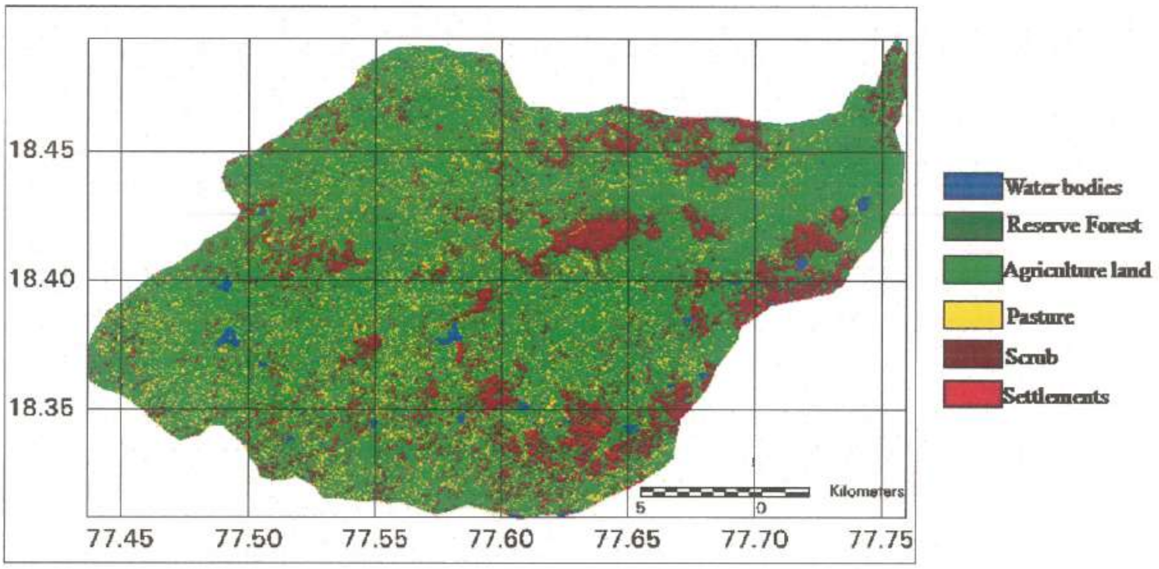


Fig.16: LU/LC map of Jukal watershed-2007

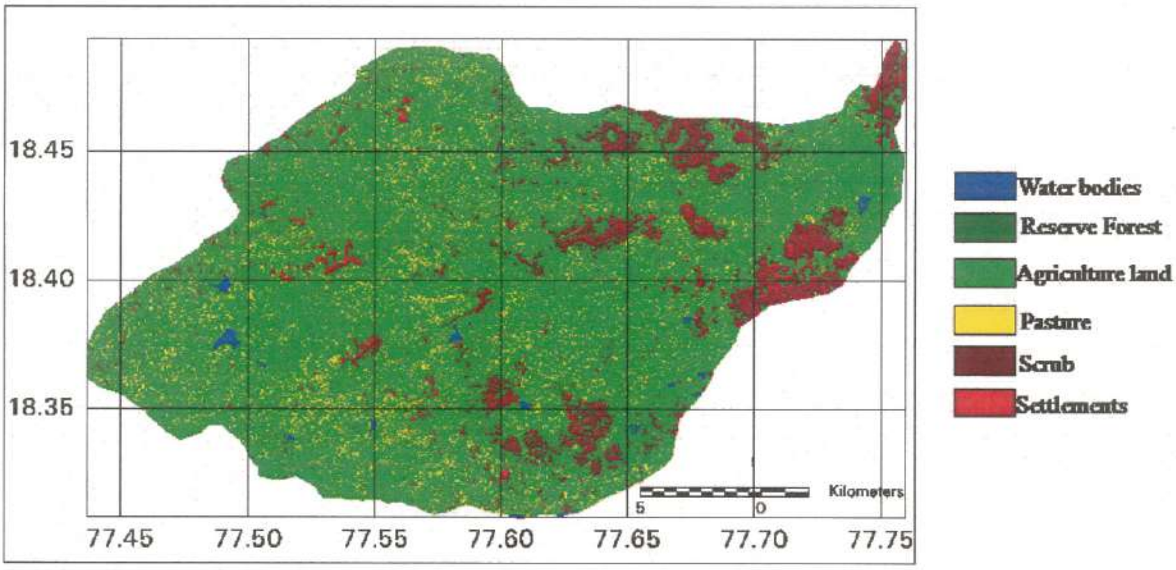


Fig.17: LU/LC map of Jukal watershed-2008

6.6.4 Garde's Equation

The equation used to calculate absolute volume of eroded material (Garde et al., 1983) is

$V_{SAB} = 1.182 * 10^{-6} * A^{1.03} * P^{1.29} * Q^{0.29} * S^{0.08} * D_d^{0.4} * F_c^{251}$

Where,

V_{SAB}= Absolute Volume of eroded material, Mm^3/year

A= Catchment area, km^2

P= Annual rainfall, cm

Q= Annual runoff, Mm^3

S = Stream Slope

Dd= Drainage density, Km^{-1}

Fc= Vegetal cover factor

Table-9: Sediment Yield Calculation for the Catchments Using Garde's Equation for the Year-2006

Name of Watershed	Area in Km^2	Vegetative Cover Factor (Fc)	Annual Rainfall in cm	Annual Runoff In M m^3	Stream Slope	Drainage Density in Km^{-1}	Sediment Yield per year in M m^3	Sediment Yield per year m^3/km^2/year
Jukal	452.00	0.668	97.100	157.296	0.43	1.429	0.393	869.00
Haldi	349.00	0.568	105.156	130.177	0.80	1.598	0.234	670.00
Poulang	763.00	0.601	103.930	286.125	0.50	1.612	0.733	961.00

Table-10: Sediment Yield Calculation for the Catchments Using Garde's Equation for the Year-2007

Name of Watershed	Area in Km^2	Vegetative Cover Factor	Annual Rainfall in cm	Annual Runoff In M m^3	Stream Slope	Drainage Density in Km^{-1}	Sediment Yield per Year in M m^3	Sediment Yield per Year m^3/km^2/year
Jukal	452.00	0.677	76.78	101.24	0.43	1.429	0.412	912.00
Haldi	349.00	0.586	80.74	80.27	0.80	1.598	0.156	447.00
Poulang	763.00	0.579	81.08	176.25	0.50	1.612	0.637	835.00

Table-11: Sediment Yield Calculation for the Catchments Using Garde's Equation for the Year-2008

Name of Watershed	Area in Km^2	Vegetative Cover Factor	Annual Rainfall in cm	Annual Runoff In M m^3	Stream Slope	Drainage Density in Km^{-1}	Sediment Yield per Year in M m^3	Sediment Yield per Year $m^3/km^2/year$
Jukal	452.00	0.645	70.156	82.716	0.43	1.429	0.306	677.00
Haldi	349.00	0.614	83.747	88.297	0.80	1.598	0.292	837.00
Poulang	763.00	0.613	89.767	219.744	0.50	1.612	0.894	1172.00

7.0 PRACTICAL ESTIMATION OF SEDIMENT YIELD IN THE FIELD

In the present project three watersheds namely Poulang, Jukal and Haldi are selected in such a way that they contribute silt directly to the reservoir. Automatic water level recorders have been installed on the bridges (Fig.18), build at mouths of the watersheds to estimate the discharge. Unfortunately the instrument with float mechanism (Fig.19) was struck due to heavy floods and data could not be obtained for the year 2006. For next season this instrument is modified by introducing pressure sensor instead of float mechanism and has been rebuilted the entire apparatus to take the readings from the 2007 monsoon onwards.

Fig.18: Installation of Automatic Water Level Recorder on Streams

7.1 Pressure Sensor

A pressure sensor is kept at the bottom / datum level in water. The pressure on the sensor is proportional to the water column above the sensor and is converted into electrical signals. These electrical signals are calibrated in terms of height.

The pressure sensor is anchored firmly to the pillar of the bridge (Fig.20) with protective metal cover and it is connected to the data logger through a cable supported by wire rope. The data logger is securely kept in a box near side walls of the bridge (Fig.21). It is powered by solar panel for uninterrupted power supply (Fig.22) Fig.23 shows the photograph of the microprocessor based data logger, along with the pressure sensor.

7.2 Measurement of Water Flow

A fish type unit with rotating cups is used for water flow measurements (Fig.24). When the unit is immersed in the flowing water the cups rotate in proportion to the velocity of water flow. The revolutions are converted into electrical pulses and are measured by an electronic counter. The fish always directs itself in the direction of the flow and the revolutions of cups are calibrated in terms of velocity and are measured with electrical pulse counts.

The stream velocity measurements are made at the time of the flood. Velocity measurements are carried out along the cross section of the river at different places and at representative depths. The fish is lowered into the flowing water up to the required depths with the help of wire rope and measurements are made with the help of electronic pulse counter.

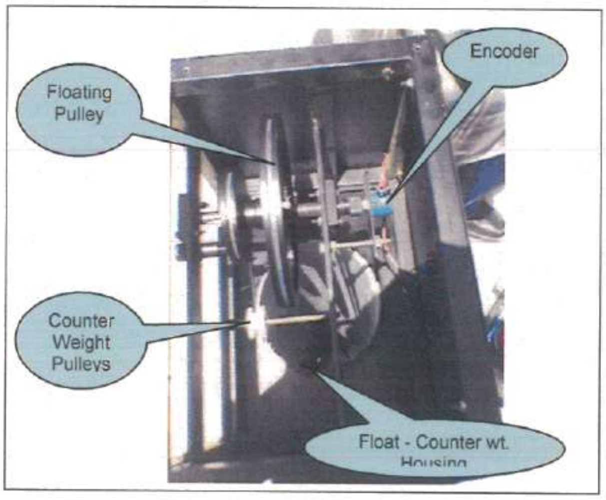


Fig.19: Float Mechanism Instrument

Fig.20: The Pressure Sensor is Anchored Firmly to the Pillar of the Bridge

Fig.21: The Data Logger is Securely Kept in a Box Near Side Walls of The Bridge

Fig.22: Powered by Solar Panel for un interrupted power supply

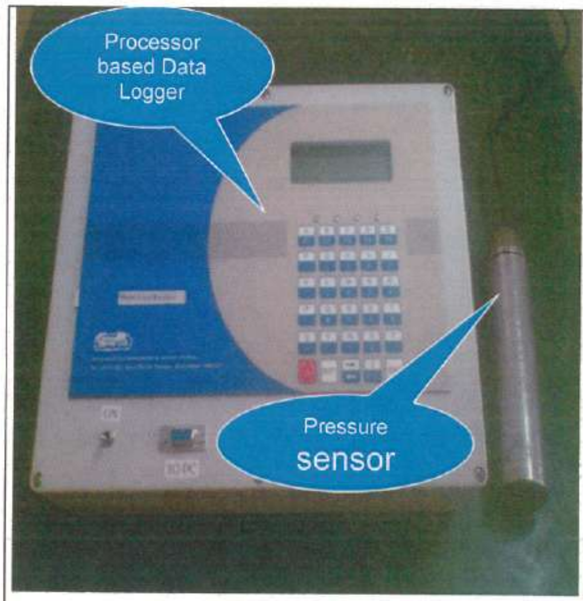


Fig.23: Micro Processor Based Data Logger with Pressure Sensor for Automatic Water Level Measurements

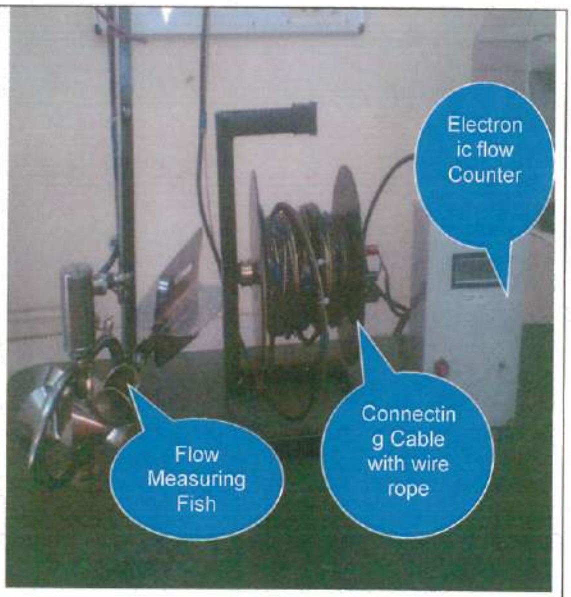
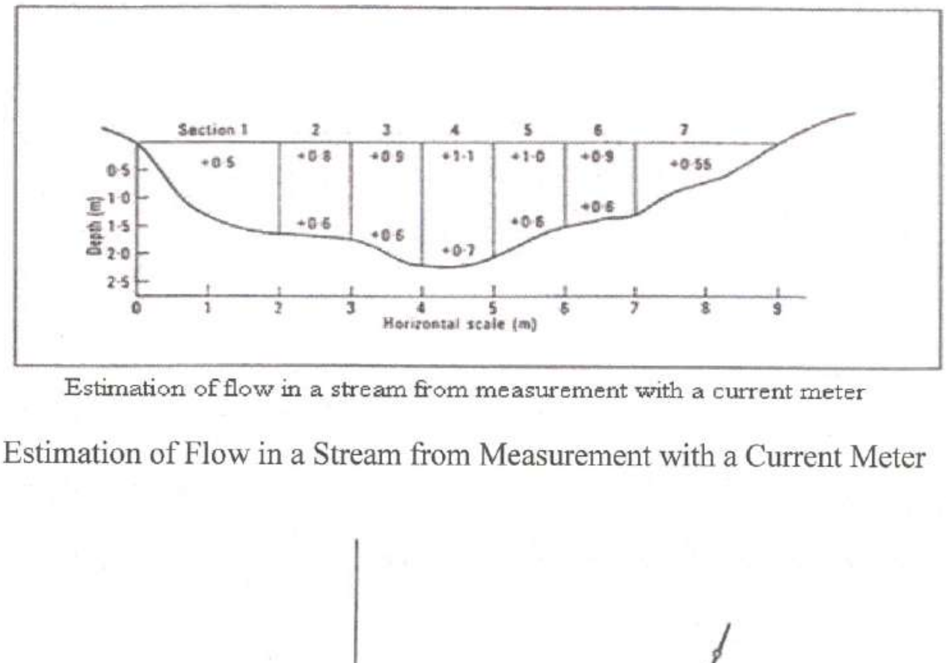


Fig.24: Fish for flow Velocity Measurements

7.3 Discharge Calculation

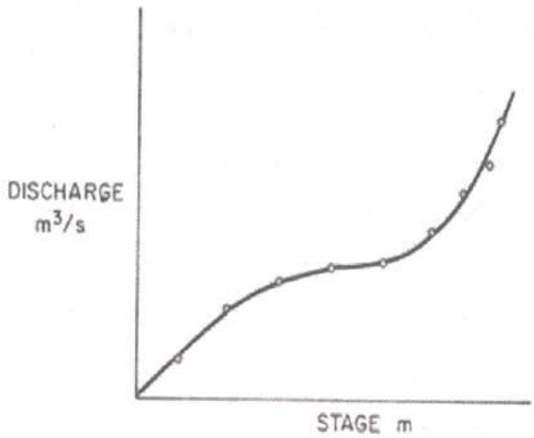
The velocity of the stream flow is usually measured with the current meter at three places along the river cross section and at three depths at regular intervals during the flood period (Fig. 25). At the same time an automatic water level recorder records the water level in the stream by using pressure sensors. The water column height is multiplied with the width of the stream strip to arrive at the cross sectional area available for the flow in that strip. Several such strips are added to get total cross-section area available for flow in the river / stream. The discharges are obtained by multiplying cross sectional area with average velocity of a particular strip and total discharge in the river/stream is obtained by adding all the discharges in the individual strips. A rating curve (Fig.26) can be constructed by plotting height of water in the stream verses discharge.

However in the present project the observations are made at a bridge and the shape of the cross sections of the streams is almost like rectangle. Hence following procedure is adopted as shown in Table-12.



Estimation of flow in a stream from measurement with a current meter

Fig.25: Estimation of Flow in a Stream from Measurement with a Current Meter



Rating Curve for a stream

Fig.26: Rating Curve for a Stream

Table-12: Calculation of Discharge from Observed Values of the Stream

Date	Time	Stream flow water depth in m	Stream width in m	Cross sectional Area= Depth*Width in m^2	Average Velocity in m/sec	Discharge =Area*Velocity in m^3/sec	Discharge in m^3/10 minutes
05/06/07	3:43:3	0.01	90	0.9	0.98	0.882	529.2
05/06/07	3:53:3	0.01	90	0.9	0.98	0.882	529.2
05/06/07	4:03:3	0.01	90	0.9	0.98	0.882	529.2
05/06/07	4:13:3	0.01	90	0.9	0.98	0.882	529.2
05/06/08	4:23:3	0.00	00	0.0	0.00	0.000	000.0
05/06/07	4:33:3	0.01	90	0.9	0.98	0.882	529.2
05/06/07	4:43:3	0.01	90	0.9	0.98	0.882	529.2
05/06/07	4:53:3	0.01	90	0.9	0.98	0.882	529.2

7.4 Sediment Sampling

Single sample is taken at half the depth of flow to estimate the average sediment concentration. The point-integrating sampler (Fig.27) is used to collect sediment sample from a fixed point on the stream.

Fig.27: The Sediment Sampler

7.5 Sediment Yield Estimation from the Water Sample

The sediment yield is estimated from the water sample by following laboratory procedure detailed below and the estimated sediment is shown in Table-13&14.

- 4 grams of Alum ($Al_2 (SO4)_3.16H_2O$) is added to100 ml of water.
- 5ml of the above solution is added for one liter of the sample.
- Then sample is properly stirred and allowed overnight for settlement of the sediment.
- Next day, the sample is filtered for sediment by using pre-weighted filter paper.
- After filtration, the silt along with filter paper allowed to dry.
- After drying, filter paper along with sediment is weighed.
- Finally silt weight is = final weight (filter paper +silt)-filter paper weight (Fig.28).

Fig.28: Laboratory Estimation of Sediment Yield from the Water Samples

Table-13: Sediment Yield Estimation from Collected Water Samples for the Year - 2007

Name of Watershed	Discharge m^3/year	Sediment in Kgs/ m^3	Kgs /Year	Tons /Year	m^3/Year	m^3/km^2/year
Jukal	54017366	3.15	170154703	170154	481810	1066
Haldi	200563091	0.74	148416687	148417	420258	1204
Poulang	55494558	0.85	47170374	47170	133567	175

Table-14: Sediment Yield Estimation from Collected Water Samples for the Year- 2008

Name of Watershed	Discharge m^3/year	Sediment in Kgs/ m^3	Kgs /Year	Tons /Year	m^3/Year	m^3/km^2/year
Jukal	111886116	1.87	209227036	209227	592447	1311
Haldi	92874319	1.47	136525249	136525	386585	1108
Poulang	238891464	1.28	305781073	305781	865850	1135

8.0 RESULTS AND DISCUSSION ON CALCULATED AND OBSERVED SEDIMENT YIELD

It can be observed from the Tables-15&16 that the sediment yield calculated by Garde's equation alone matching approximately with the observed sediment yield from the watersheds. However many serious differences between these two values (calculated and observed sediment) is also exist as much as up to some 50 percent. Therefore it is tried to obtain relation between calculated sediment yield and observed sediment yield; similarly also tried to obtained relation between calculated runoff and observed runoff. The data is fitted by a regression equations, using power fitting, polynomial fitting, linear fitting and logarithmic fitting. It may be noted here that while fitting the following equations all the data obtained from three watersheds are used in view of the same morphometry for all the three watersheds.

Table-15: Comparison of Calculated and Observed Sediment Yield and Runoff for the Year – 2007

Name of Watershed	Dhruvanarayana Equation Sediment yield m^3/km^2/year	Khosla Equation Sediment yield m^3/km^2/year	USL Equation Sediment yield m^3/km^2/year	Garde's Equation		Observed in the Field	
				Runoff In Mm^3	Sediment yield m^3/km^2/year	Runoff In Mm^3	sediment yield m^3/km^2/year
Jukal	T_1=35157.00 T_2=132979.00	582.00	460.00	101.24	912.00	54	1066.00
Haldi	T_1=45346.00 T_2=223688.00	625.00	549.00	80.27	447.00	200	1204.00
Poulang	T_1=21109.00 T_2=79396.00	503.00	602.00	176.25	835.00	55	175.00

Table-16: Comparison of Calculated and Observed Sediment Yield and Runoff for the Year – 2008

Name of Watershed	Dhruvanarayana Equation Sediment yield $m^3/km^2/year$	Khosla Equation Sediment yield $m^3/km^2/year$	USL Equation Sediment yield $m^3/km^2/year$	Garde's Equation		Observed in the Field	
				Runoff In Mm^3	Sediment yield $m^3/km^2/year$	Runoff In Mm^3	sediment yield $m^3/km^2/year$
Jukal	T1=35025.00 T2=113947.00	582.00	460.00	82.716	677.00	112	1311.00
Haldi	T1=45338.00 T2=174983.00	625.00	549.00	88.297	837.00	127	1108.00
Poulang	T1=21313.00 T2=94163.00	503.00	602.00	219.744	1172.00	238	1135.00

From the following Tables-17&18 and Fig.29&30 it can be observed that only polynomial fitting is yielding high R^2 values both for the runoff and sediment.

Table-17: Calculated Verses Observed Runoff Regression Equations

Type of Regression	Equation	Coefficient of determination (R^2)
Linear	$y = 1.1237x$	0.0133
Log	$y = 160052\text{Ln}(x) - 2E+06$	0.0183
Power	$y = 22.401x^0.7426$	0.0229
Polynomial	$y = 1E\text{-}18x^5 - 1E\text{-}12x^4 + 5E\text{-}07x^3 - 0.0784x^2 + 4542.1x$	0.1228

Table-18: Calculated Verses Observed Sediment Regression Equations

Type of Regression	Equation	Coefficient of determination (R^2)
Linear	$y = 1.381x$	-5.2005
Log	$y = -200.49\text{Ln}(x) + 2555.4$	0.1374
Power	$y = 3553.4x^{-0}.1619$	0.1180
Polynomial	$y = -2E\text{-}10x^5 + 5E\text{-}07x^4 - 0.0006x^3 + 0.2937x^2 - 48.214x$	0.7074

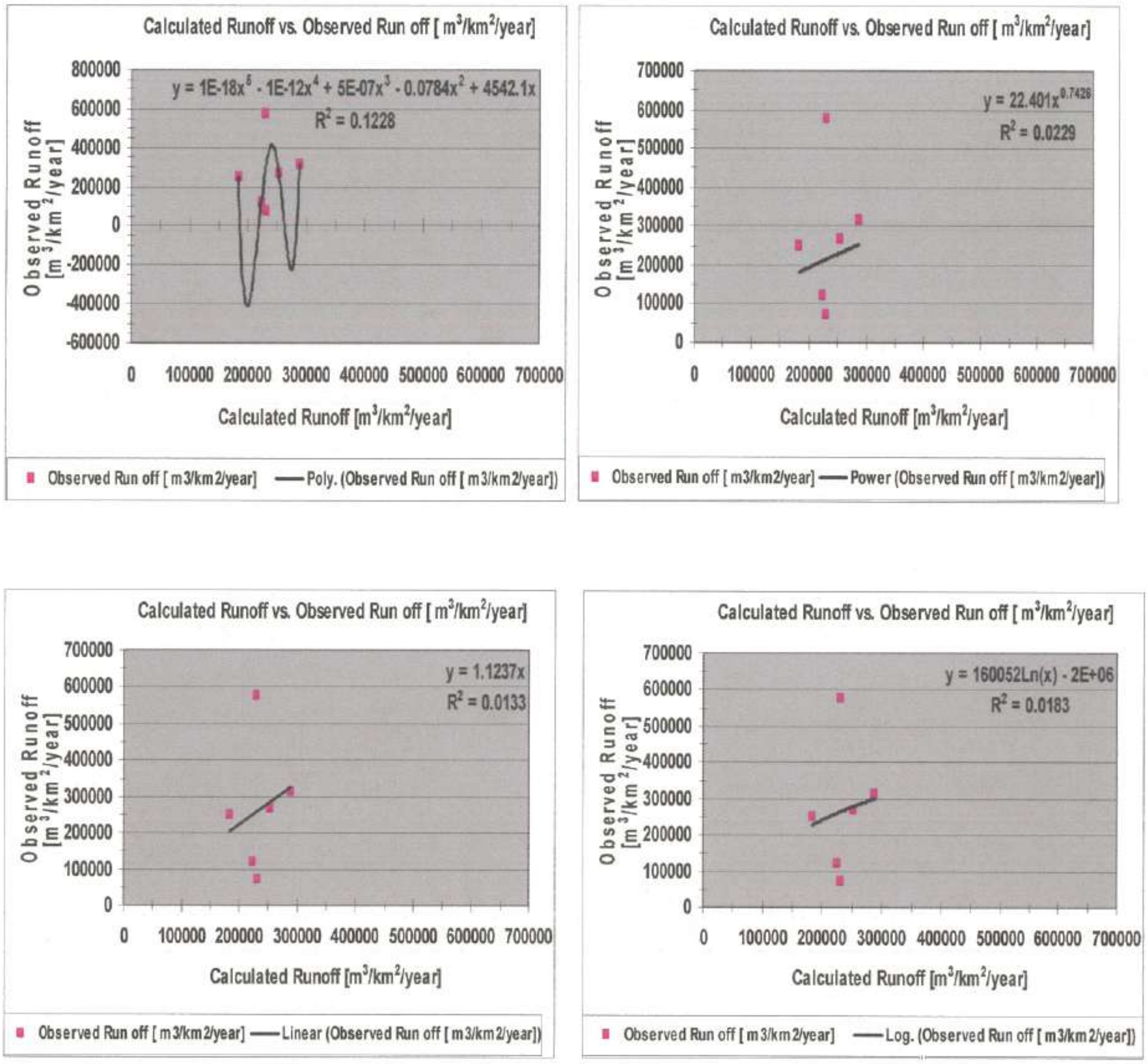


Fig.29: Plots of Calculated Verses Observed Runoff from the Watersheds

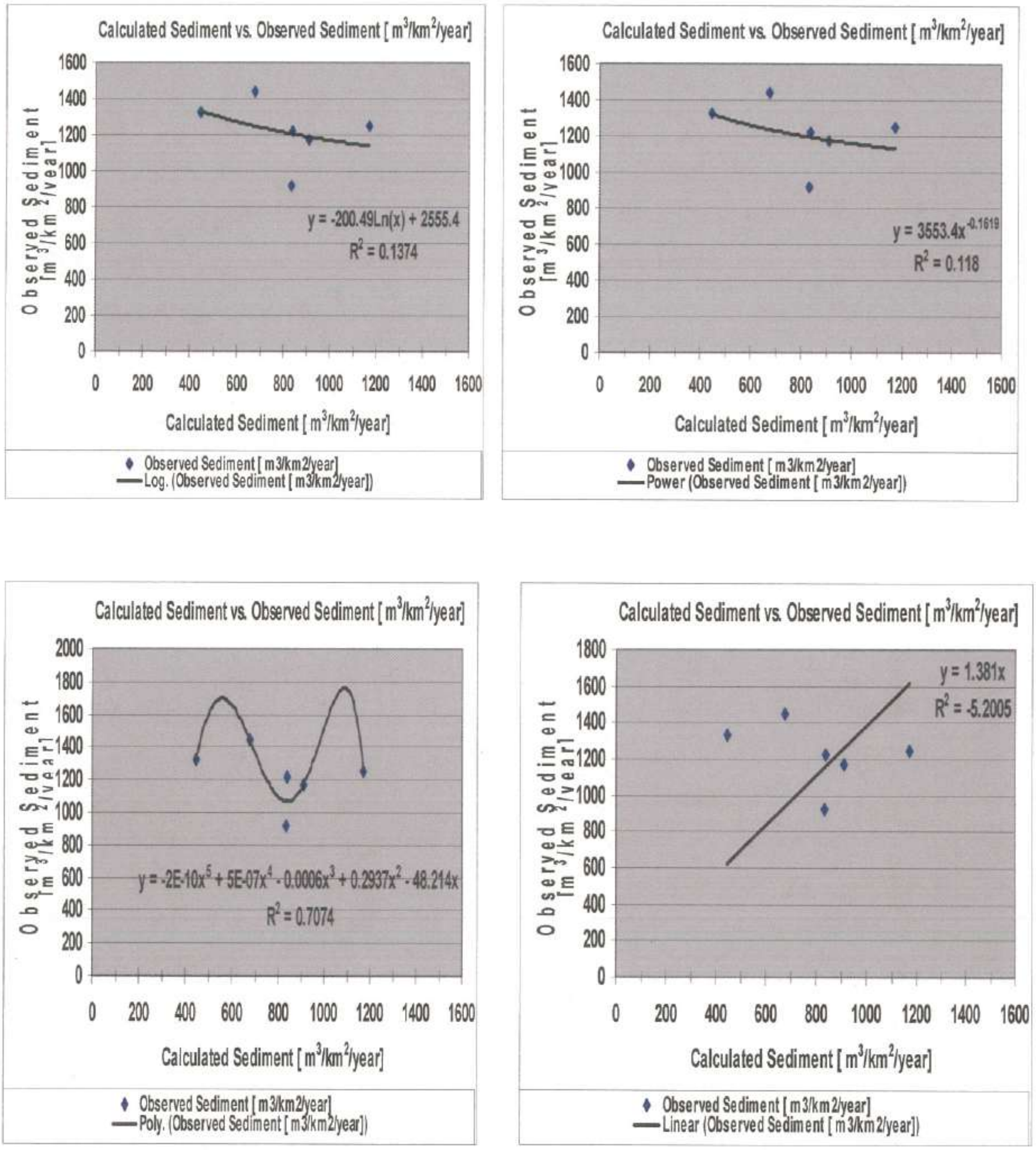


Fig.30: Plots of Calculated Verses Observed Sediment Yield from the Watersheds

8.1 Modification to the Garde's Equation

From the above discussions it appears that only sediment yield calculated by Garde's equations, can be substituted in the polynomial equation of the shape $y = -2E\text{-}10x^5 + 5E\text{-}07x^4 - 0.0006x^3 + 0.2937x^2 - 48.214x$ which can give the observed sediment yield of the watersheds.

- The arithmetic average of the sediment yield for all the three watersheds for both the calculated and observed value is as shown below.

- The average sediment yield calculated through Garde's equation is 813.34 $m^3/km^2/year$.
- The average sediment yield observed from the field is 991.5 $m^3/km^2/year$.
- Therefore actual sediment yield from the watershed = 1.219 X calculated from Garde's equation.

9.0 IDENTIFICATION OF SOIL CONSERVATION STRUCTURES IN THE WATERSHEDS

Since the sediment yield observed is nearly double to the actual design value of sriramsagar reservoir, it is pertinent to prepare a map on the soil conservation in the watersheds for the treatment purpose. There are two types of measures (i) Engineering Measures (ii) Agricultural Measures.

In the present study engineering measures are limited to identification of proper sites for construction of check dams in the watersheds, since they proved to be affective on large scale. The methodology followed is as follows.

(i) The drainage map was overlaid on the slope map (ii) The drainage pattern and the slope of the watershed area were carefully studied (iii) Check dams were located where the ground is fairly level after steeper slopes on the upstream side, where the drainage path is nearly straight, and the soil mantle is fairly thick. The resulting maps are shown in the Fig.31, 32&33.

The agriculture soil measures are identified based on the studies of Land use / Land cover maps and whose statistical details are shown from Fig.34 to35 & 36. From the Land use/Land cover details it can be observed that scrub area can be brought under afforestation compared to other land use units mapped in the watersheds. Therefore land under scrubs is shown against the land for the afforestation (Fig.37, 38 & 39), since the scrub is usually contains bushes and soil is exposed to open air many a times.

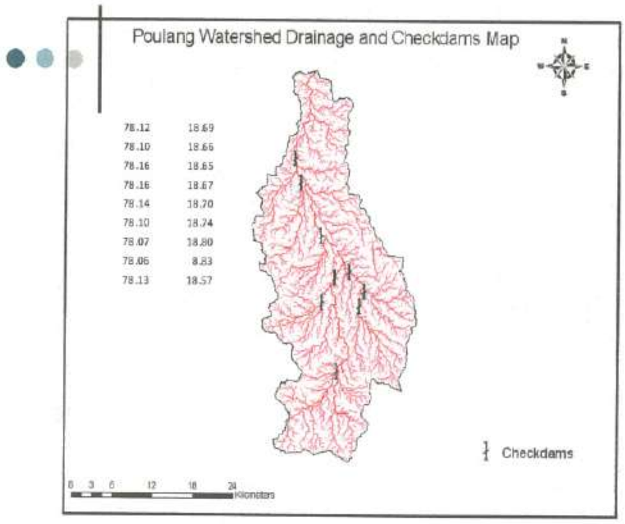


Fig.31: Location of Sites for Check Dams in the Poulang Watershed

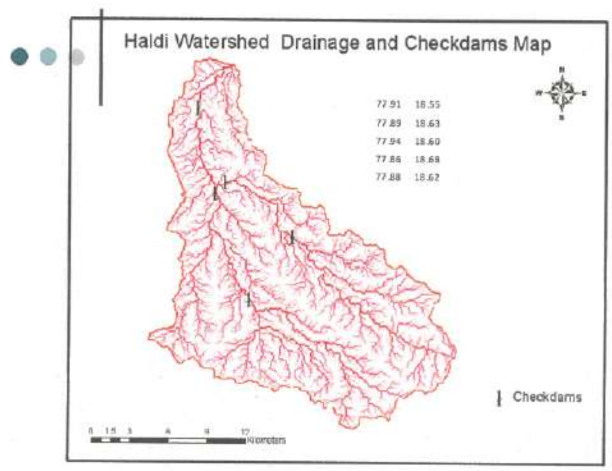


Fig.32: Location of Sites for Check Dams in the Haldi Watershed

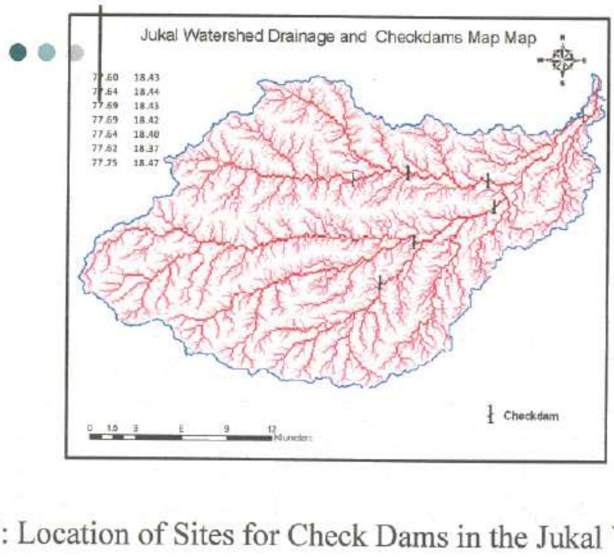
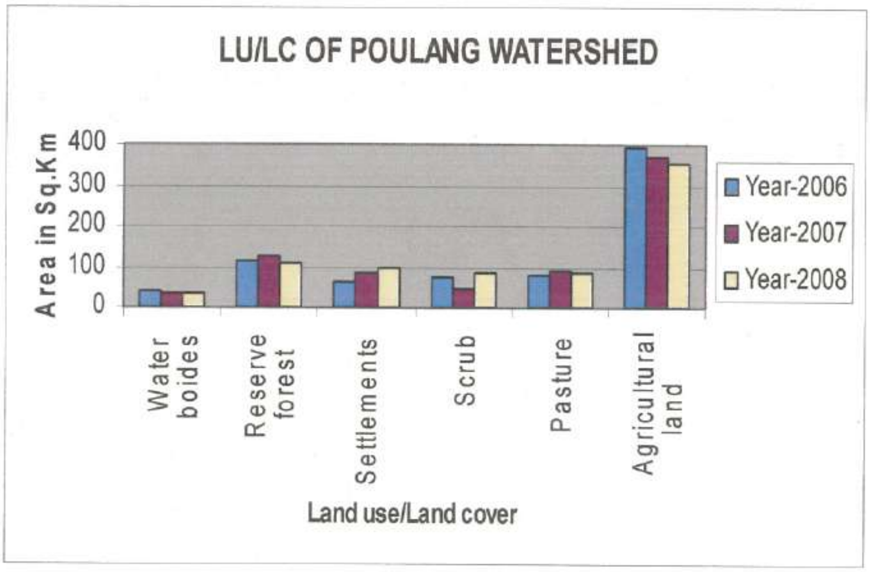
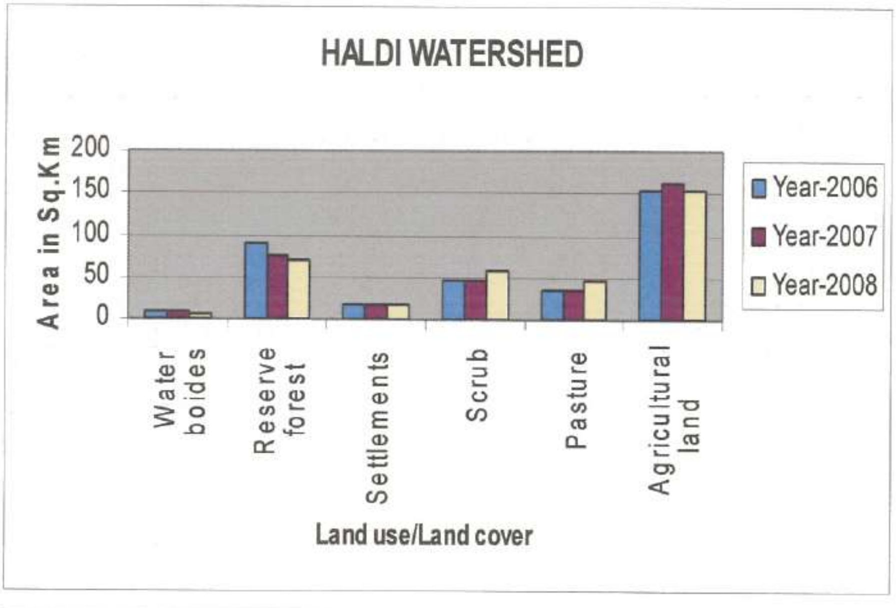


Fig.33: Location of Sites for Check Dams in the Jukal Watershed



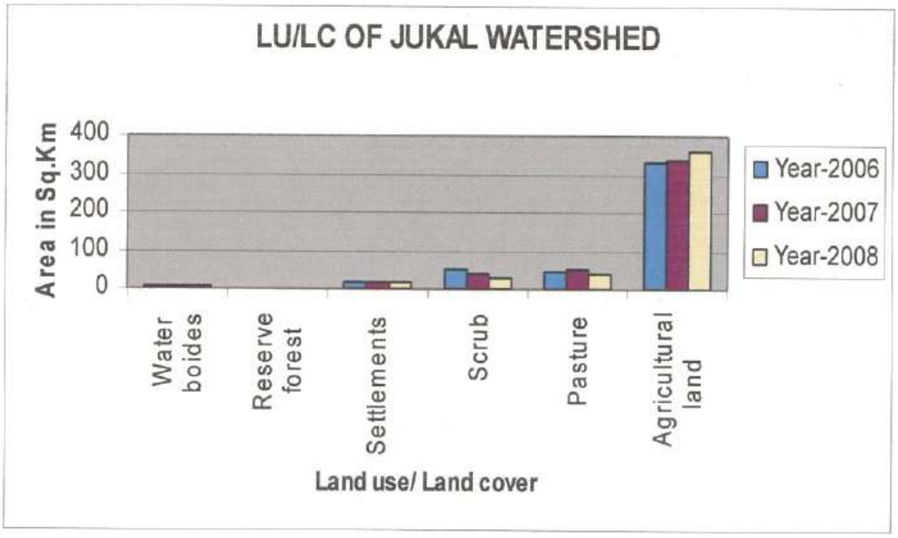
Area (sq.km)	Year_2006	Year_2007	Year_2008
water bodies	38	34	35
Reserve forest	113	127	108
Settlements	63	88	96
Scrub	76	47	86
Pasture	79	94	83
Agriculture land	394	373	355
Total area	*763*	*763*	*763*

Fig.34: Land Use/Land Cover Of Poulang Watershed Years -2008-07-2006



Area(sq.km)	Year_2006	Year_2007	Year_2008
w ater bodies	8	8	6
Reserve forest	89	76	69
Settlements	18	18	17
Scrub	46	47	57
Pasture	35	36	47
Agriculture land	153	163	153
Total area	*349*	*349*	*349*

Fig.35: Land Use / Land Cover Of Haldi Watershed Years -2008-07-2006



Area (Sq.km)	Year_2006	Year_2007	Year_2008
water bodies	3	4	3
Reserve forest	0	0	0
Settlements	18	19	18
Scrub	51	38	28
Pasture	46	54	42
Agriculture land	334	337	361
Total area	*452*	*452*	*452*

Fig.36: Land Use/Land cover of Jukal Watershed Years -2008-07-2006

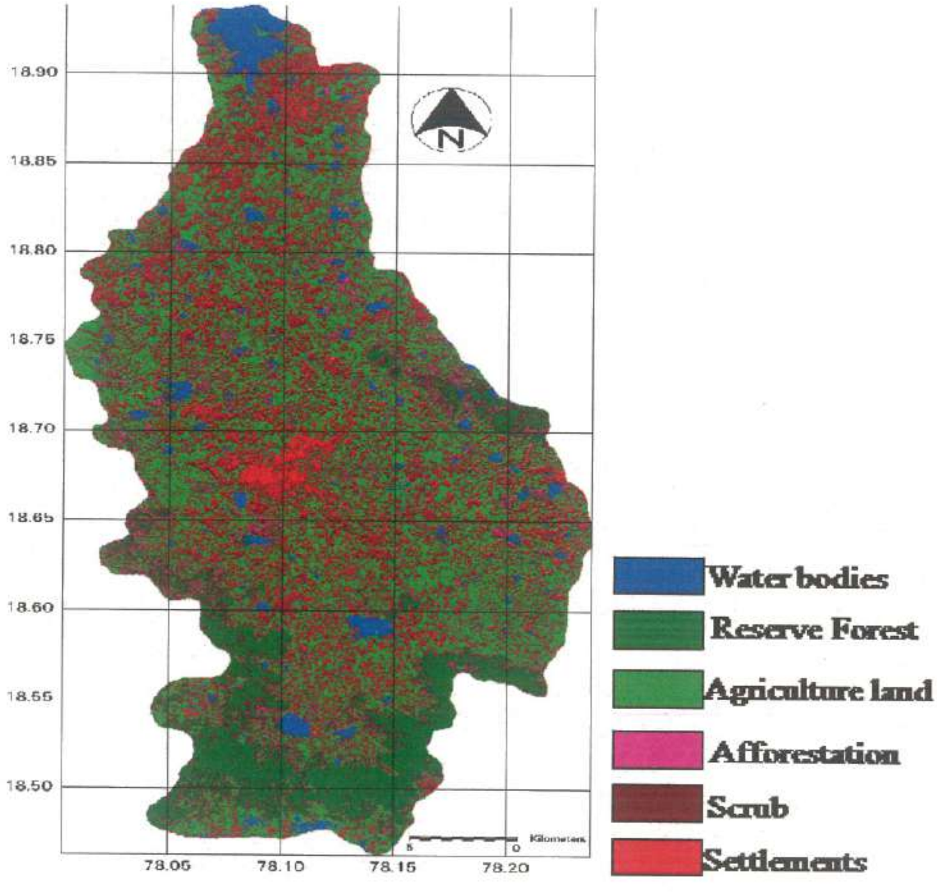


Fig.37: Action Plan Map of the Poulang Watershed

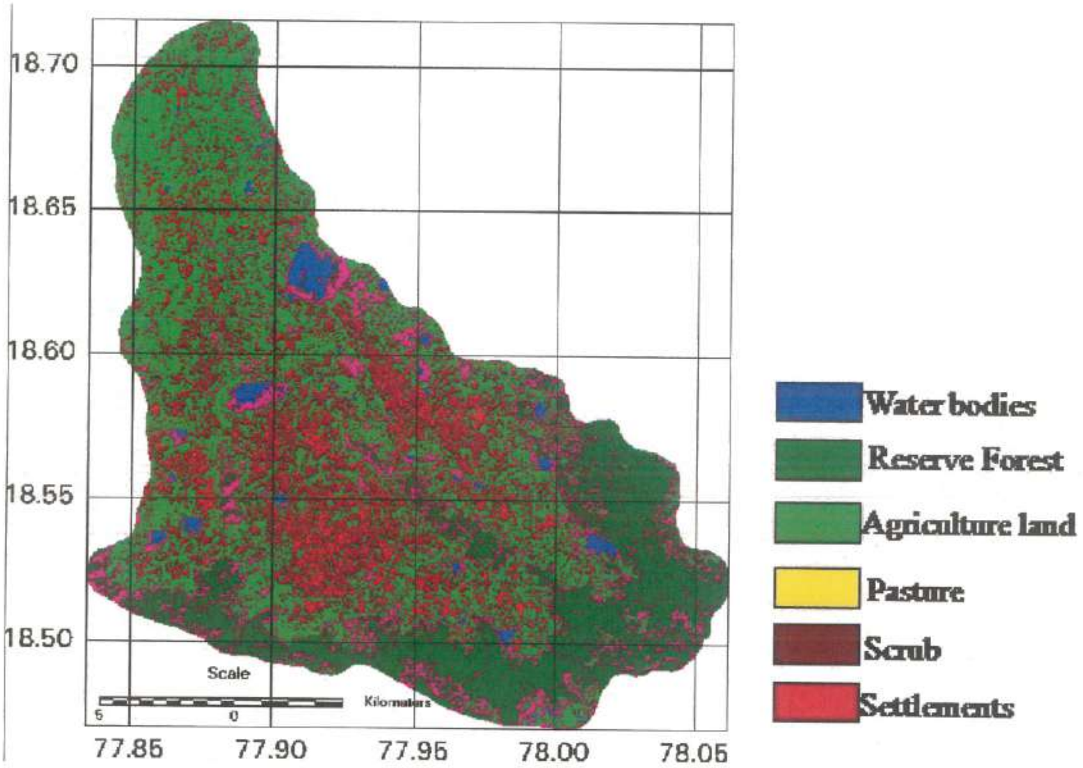


Fig.38: Action Plan Map of the Haldi Watershed

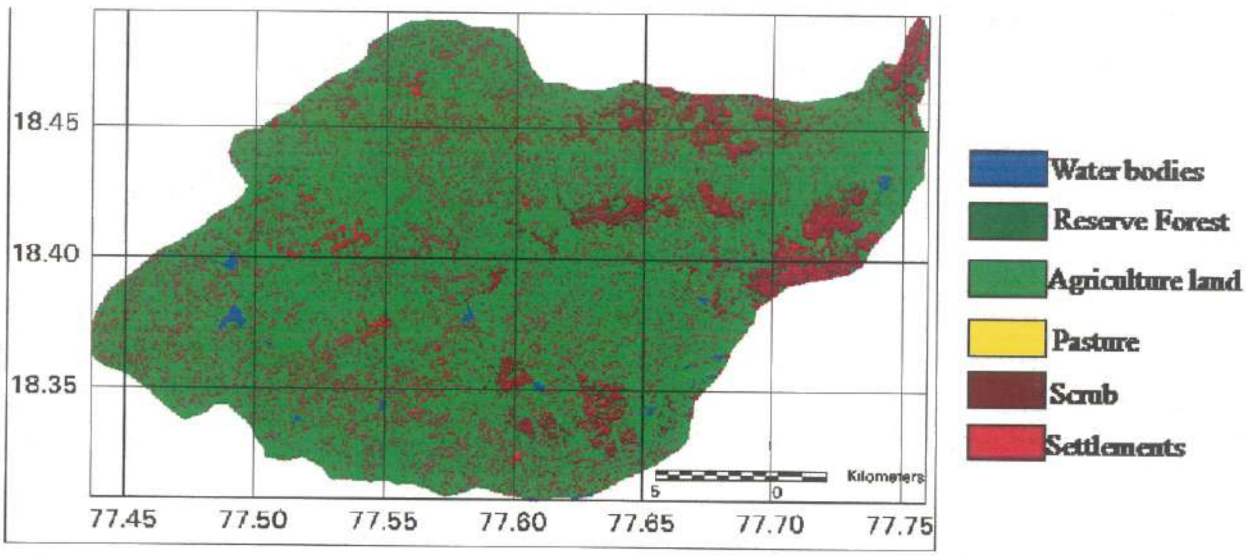


Fig.39: Action Plan Map of the Jukal Watershed

10.0 CONCLUSIONS

(i) On an average the actual observed sediment yield from the watersheds is the order of 991.5 m^3/km^2/year, while that of the calculated figure from Garde's equation is 813.31 m^3/km^2/year.

(ii) Other calculated sediment yield figures obtained from equation such as Khosla, Druvanarayana and USLE are no where near the observed sediment yield.

(iii) Therefore the Garde's equation is recommended with the modification that, around 20% is added to the calculated sediment yield value obtained from the Garde's equation.

(iv) Using RS & GIS techniques, sites for major check dams are identified in the watersheds apart from identification of scrub lands where afforestation is proposed.

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