‘SOIL EROSION MAPPING OF MICRO-WATERSHEDS OF BISALPUR RESERVOIR USING REMOTE SENSING & GIS’

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OBJECTIVES OF STUDY

Develop methodology for soil erosion mapping of Bisalpur Reservoir using Remote Sensing data using GIS.

Delineation of watershed & micro-watersheds of Bisalpur Reservoir.

Developing soil erosion maps.

SOIL EROSION

- Soil erosion is the wearing away of the land surface by physical forces such as rainfall, flowing water, wind or other natural or anthropogenic agents that abrade, detach & remove soil or geological material from one point on the earth's surface to be deposited elsewhere.

FACTORS OF SOIL EROSION

Climatic conditions: precipitation, frequency of extreme rainfall events, ecological disasters (forest fires).

Topological Factors: Slope, rate of surface runoff generation, flow velocity .

Soil characteristics: Particle size composition, thin layer of topsoil, texture, low organic matter content.

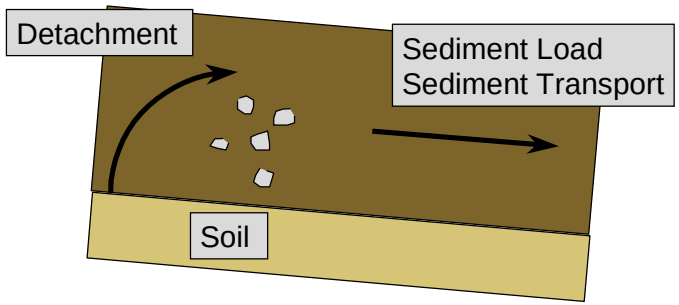
Soil usage: land cover patterns (sparse vegetation), inappropriate agricultural practices, deforestation, overgrazing, constructional activities.

EFFECTS OF SOIL EROSION

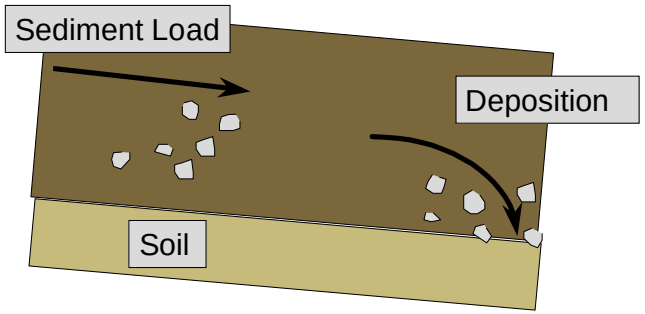
- Soil & nutrients loss , hindering crop productivity, as decreased yield.
- Increased soil compaction to loss of organic matter & soil structure
- Changes in mechanical & mineral compositions of soil
- Sedimentation & siltation of reservoirs, reducing their storage capacity & life span,
- On river bed & banks, widening of flood plains during floods.
- Landscape degradation
- Water pollution

PROCESS OF SOIL EROSION

DETACHMENT

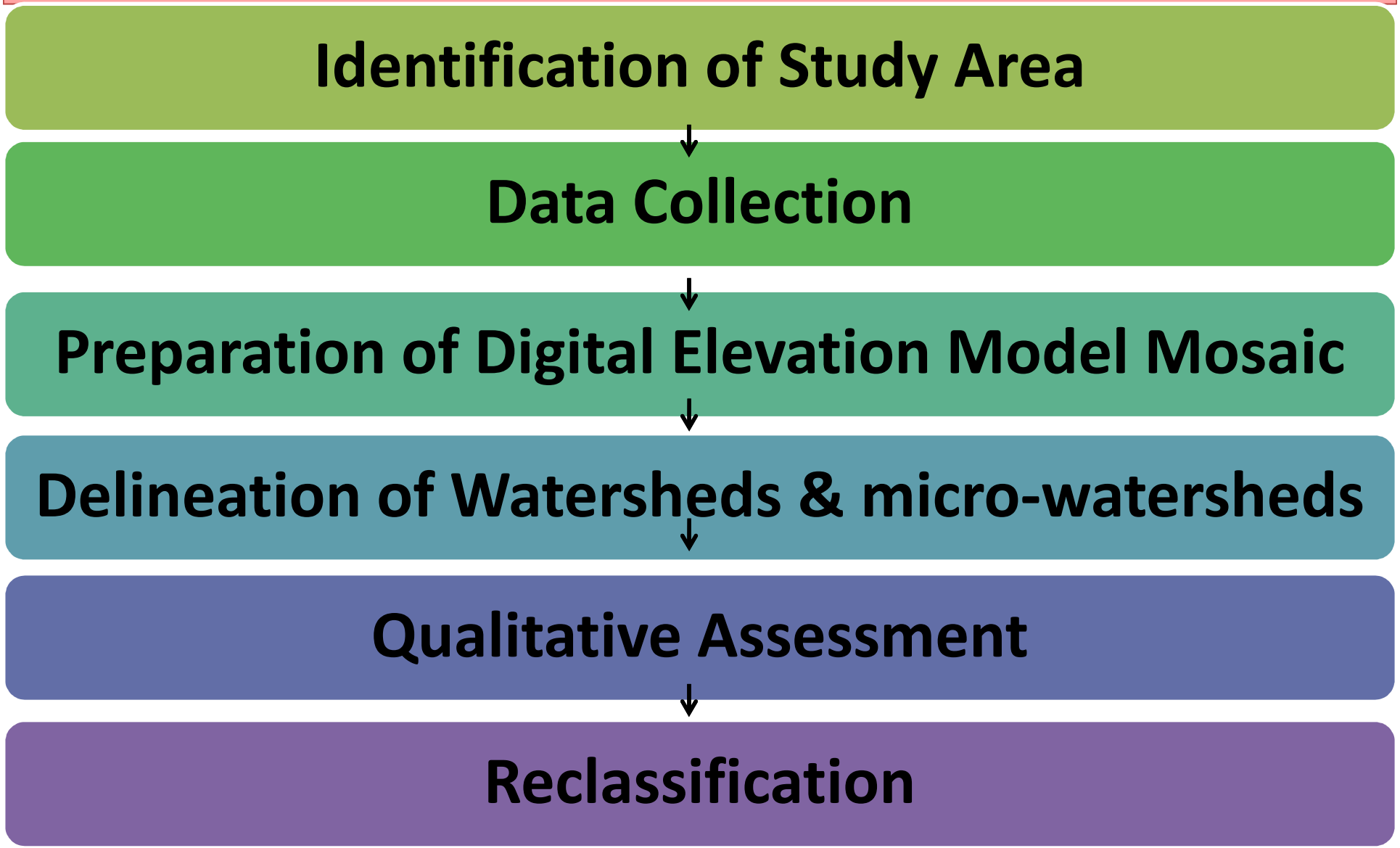


DEPOSITION

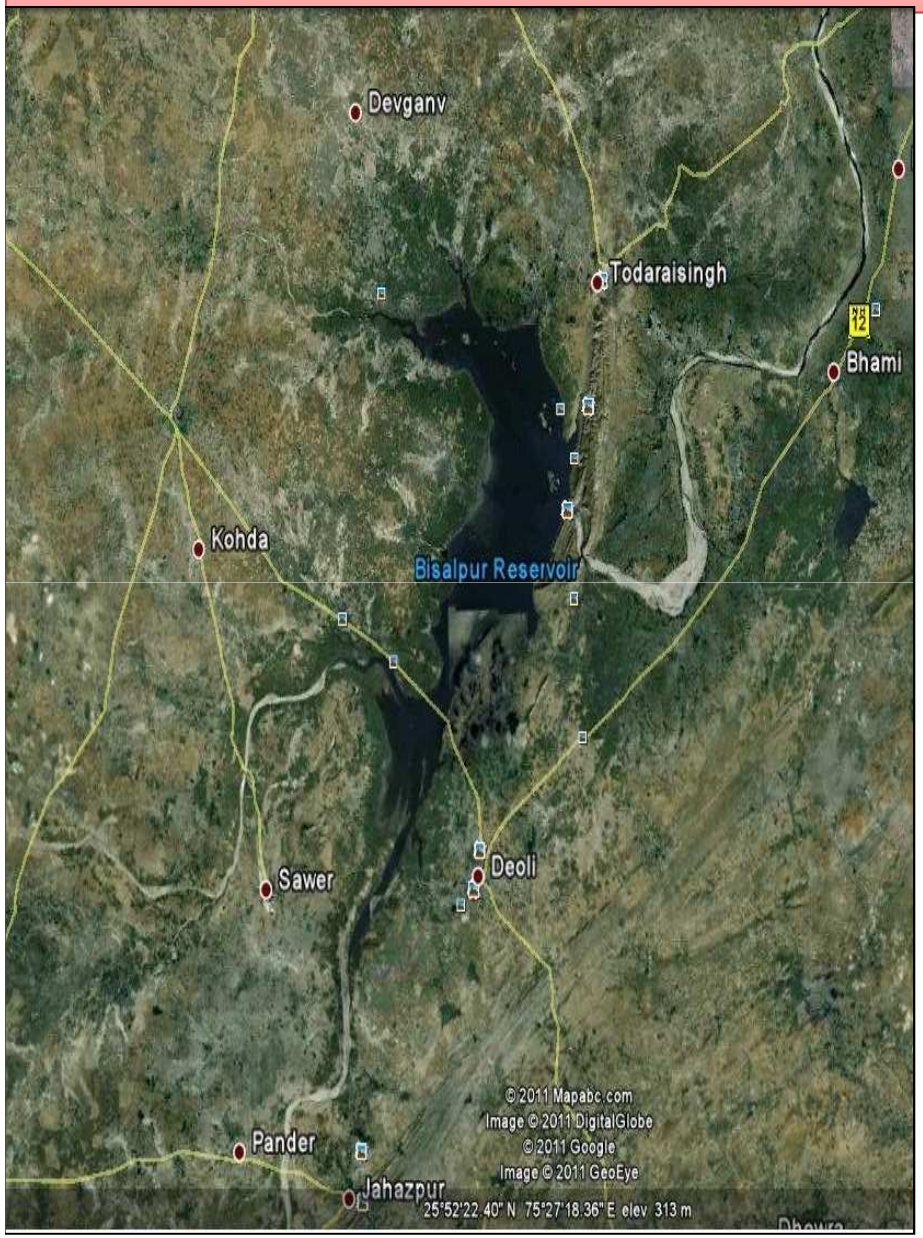


Source: Fares (2002)

METHODOLOGY



STUDY AREA- BISALPUR RESERVOIR



Source : Google Earth

It is located on Banas River, 120 km south-west of Jaipur City, constructed in mid-1990s by DOI:

*To conserve available water of Banas River.

*To provide potable water supplies to Ajmer, Jaipur, Tonk Cities & other towns in the region,

*To provide supplemental irrigation for agricultural lands downstream of the dam site.

*To reduce dependence on the existing ground water sources of cities.

*It is imperative to locate & measure severity of soil erosion for proper planning to conserve or to opt for alternative uses.

GENERATION OF INPUT GIS DATABASE

- **Identification of Study Area**:

Bisalpur reservoir coordinates were obtained using Google Earth.

- **Soil erosion factors studied are:**
  - Vegetation
  - Rainfall
  - Slope
  - Land Use and Land Cover
  - Soil Type

RAINFALL DATA

- Precipitation data of various rainguage stations falling in the micro-watersheds' areas was collected from http://waterresources.rajasthan.gov.in site, available from year 1957 to 2011.
- 3 Study years were selected from seven years data from 2005-2011.
- Rainfall Data was ranked from the maximum value to minimum, as mentioned below:
- Year 2007 with Average rainfall as 434 mm.
- Year 2008 with Minimum rainfall as 293 mm.
- Year 2011 with Maximum one as 651 mm.

Rainfall Data of Ajmer Rainguage Station

STATION :	AJMER			DISTRICT :		AJMER		STATE :		RAJASTHAN	
CATCHMENT NO.	108			LATITUDE :		26° 27' N		LONGITUDE :		74° 37' E	
DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	45.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	1.0	0.0	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	1.0	35.0	1.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0
11	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.0	2.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	3.2	9.4	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0
15	0.0	22.0	0.0	0.0	0.0	20.0	0.2	2.6	0.0	0.0	0.0	0.0
16	0.0	6.0	0.0	0.0	0.0	0.0	20.0	30.2	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.6	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	10.6	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	1.6	0.0	2.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	70.0	2.0	30.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	3.0	38.2	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
29	0.0		0.0	0.0	0.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0		0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	0.0
31	0.0		0.0		0.0		0.0	1.0		0.0		0.0
MONTHLY RAINFALI	0.0	28.0	0.0	0.0	0.0	100.6	43.2	218.8	101.0	0.0	0.0	0.0
RAINYDA	0	2	0	0	0	3	4	12	6	0	0	0
NO.OFOBS--ERVATI	31	28	31	30	31	30	31	31	30	31	30	31
HIGHEST DAILY RAINFALL FOR 2011 WAS					70.0	mm ON	24-Jun					
ANNUAL RAINFALL =			491.6	ANNUAL RAINY DAYS =			27	ANNUAL NO OF OBSERVATIONS =				365

Rainfall Data of Rainguage Stations of micro-watersheds

SNo	Stations	District	Latitude	Longitude	M2005	M2006	M2007	M2008	M2009	M2010	M2011
1	Beawar	Ajmer	26.1	74.316	336	602	336	352	307	666	604
2	Jawaja	Ajmer	25.95	74.22	306	427.2	306	128	15	199	291
3	Kekri	Ajmer	25.97	75.15	431	376	431	218	428	548	1052
4	Sawar	Ajmer	26.07	75.02	426	510	426	339	271	402	889
5	Sarwar	Ajmer	25.75	75.022	362	495	362	483	551	593.5	634
6	Tatgarh	Ajmer	25.68	73.97	366	685	366	219	218	490.2	620.5
7	Vijaynaga	Ajmer	25.92	74.58	585	528	585	167	178	503	486
8	Masuda	Ajmer	26.12	74.53	243	701	243	229	189	503.6	639.8
9	Narayansa	Ajmer	26.0167	74.5667	274	507	274	171	156	396	457
10	Bhinai	Ajmer	26.067	74.767	454.1	423	454.1	195.5	198.5	768	847.5
11	Goela	ajmer	26.117	74.95	255	438	255	232	237	352	693
12	Asind	Bhilwara	25.734	74.334	397	421	397	178	370	316	544
13	Banera	Bhilwara	25.5	74.67	350	784	350	342	243	651	655
14	Bhilwara	Bhilwara	25.35	74.634	444	1076	444	264	300	478	667
15	Jahajpur	Bhilwara	25.6	75.2834	545	765	545	344	323	624	916
16	Mandal	Bhilwara	25.484	74.584	156	845	388	308	316	525	613
17	Raipur	Bhilwara	25.4	74.167	427	902	329	298	354	396	657
18	Hindoli	Bundi	25.584	75.5	461	508	461	466	534	653	726
19	Gudha	Bundi	25.5	75.45	435.6	642.7	435.6	302	277.6	664	495
20	Rashmi	Chittorgar	25.067	74.35	519	679	573	222	450	559	734
21	Desuri	Pali	25.28	73.55	290	1079.2	553.3	314	417	525	687
22	Kharchi	Pali	25.67	73.58	225.5	372.2	405	325	164	396	145
23	Sojat	Pali	25.93	73.67	235	400	557	293	154	520	519
24	Amet	Rajsaman	25.32	73.93	647	766	607	336	298	334	533
25	Bhim	Rajsaman	25.75	74.08	410	605	410	205	339	472	713
26	Kumbhalg	rajsamanc	25.17	73.57	657	860	657	344	398	899	885
27	Railmagra	Rajsaman	25.03	74.13	623	860	621	370	436	564	857
28	Deoli	Tonk	25.8666	75.6	565	582	565	335	367	707	732
29	TodaraiSir	Tonk	26.0333	75.4833	470	328	470	462	192	419	847
30	Lamba Ha	Tonk	26.15	75.283	227	207	227	260	202	367	543
31	Panwar Sa	Tonk	25.767	75.43333	350	376	350	167	208	359	398
32	Bisalpur D	Tonk	25.9213	75.45552	525	530	525	510	306	606	773

Normalized Difference Vegetation Index

- NDVI is an index to monitor vegetation derived from satellite data & used in assessing the vigour and productivity of the vegetation as defined by Chandrasekar et al. (2006) .
- NDVI thus is graphical indicator that assesses live green vegetation varying between -1.0 and +1.0.
- Vegetation cover acts as barrier to soil erosion by binding and holding soil, also breaking water force.
- Negative values of NDVI (values approaching -1) correspond to water.
- Values close to zero (-0.1 to 0.1) correspond to barren areas of rock, sand, or snow.
- Low, positive values represent shrub & grassland (~ 0.2 to 0.4)
- High values indicate temperate & tropical rainforests (values approaching 1)
- NDVI data was downloaded via REVERB metadata & service discovery tool from NASA from Vegetation Indices 'Vegetation Indices 16-Day L3 Global 250m MYD13Q1'.

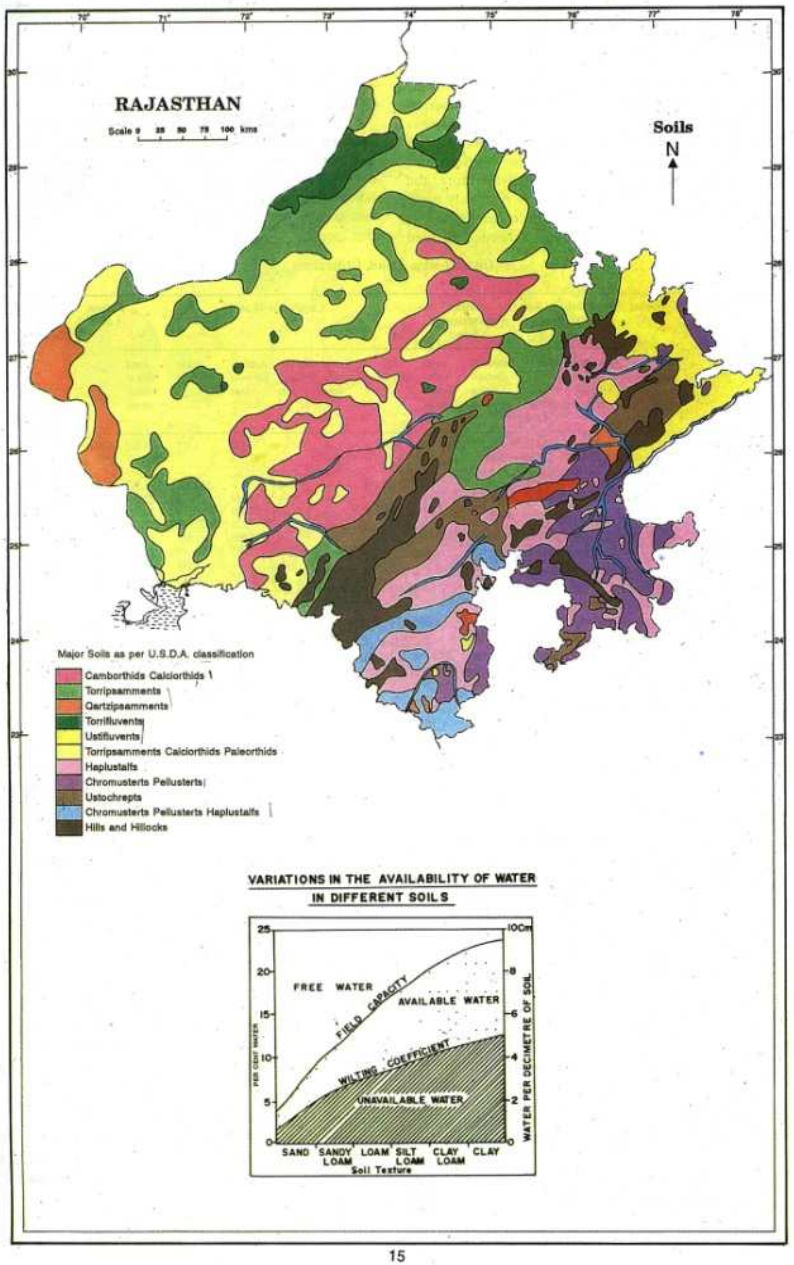
Land Use and Land Cover Type

- Soil erosion depends on land cover pattern that how land use contributes to soil erosion.
- Soil erosion is more on those where bare land exists & vegetation is less.
- Urban areas where all the land usually is cemented covers bare soil preventing any erosion.
- Vegetated Lands with organic matter bind soil & thus prevents soil detachment.
- MODIS Terra + Aqua Land Cover Type Yearly L3 Global 500 m SIN Grid product incorporates 5 different land cover classification schemes.
- Land Cover Type 3: MODIS-derived scheme was selected for study area.

Class	IGBP (Type 1)	UMD (Type 2)	LAI/fPAR (Type 3)	NPP (Type 4)
0	Water	Water	Water	Water
1	Evergreen Needleleaf forest	Evergreen Needleleaf forest	Grasses/Cereal crops	Evergreen Needleleaf vegetation
2	Evergreen Broadleaf forest	Evergreen Broadleaf forest	Shrubs	Evergreen Broadleaf vegetation
3	Deciduous Needleleaf forest	Deciduous Needleleaf forest	Broadleaf crops	Deciduous Needleleaf vegetation
4	Deciduous Broadleaf forest	Deciduous Broadleaf forest	Savanna	Deciduous Broadleaf vegetation
5	Mixed forest	Mixed forest	Evergreen Broadleaf forest	Annual Broadleaf vegetation
6	Closed shrublands	Closed shrublands	Deciduous Broadleaf forest	Annual grass vegetation
7	Open shrublands	Open shrublands	Evergreen Needleleaf forest	Non-vegetated land
8	Woody savannas	Woody savannas	Deciduous Needleleaf forest	Urban
9	Savannas	Savannas	Non-vegetated	
10	Grasslands	Grasslands	Urban	
11	Permanent wetlands			
12	Croplands	Croplands		
13	Urban and built-up	Urban and built-up		
14	Cropland/Natural vegetation mosaic			
15	Snow and ice			
16	Barren or sparsely vegetated	Barren or sparsely vegetated		
254	Unclassified	Unclassified	Unclassified	Unclassified
255	Fill Value	Fill Value	Fill Value	Fill Value

(Source: LP DAAC)

SOIL MAP OF RAJASTHAN



- Soil Map of Rajasthan was obtained from Rajasthan Pollution Control Board showing Soil Type.
- Soil erosion depends on many characteristics like its particle size composition and erodibility, thin layer of topsoil, silty texture & low organic matter content.

(Source: Rajasthan Pollution Control Board)

Digital Elevation Model

DEM is the statistical representation of the continuous surface of the ground by large number of selected points with known x, y & z coordinates in an arbitrary coordinate field.

Global Digital Elevation Model are generated from a pair of images from the ASTER (Advanced Space-borne Thermal Emission & Reflection Radiometer) multi-spectral remote sensing satellite with spatial resolution of 30 meters .

DEM was prepared in WGS-1984, UTM Zone 43N projection ensuring all spatial data to be in the same projection.

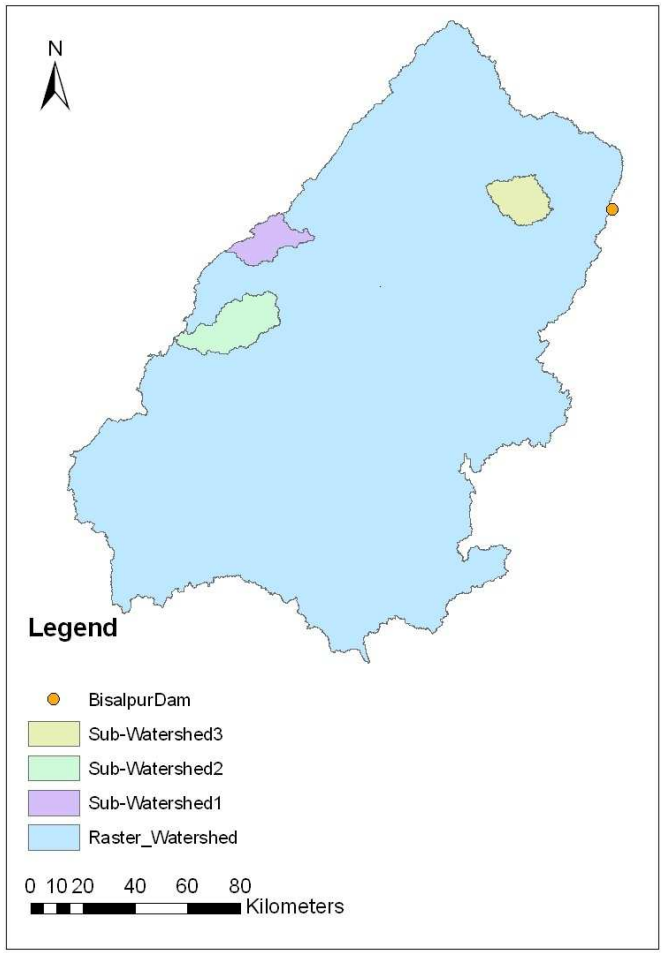
Flow direction & flow accumulation rasters were generated.

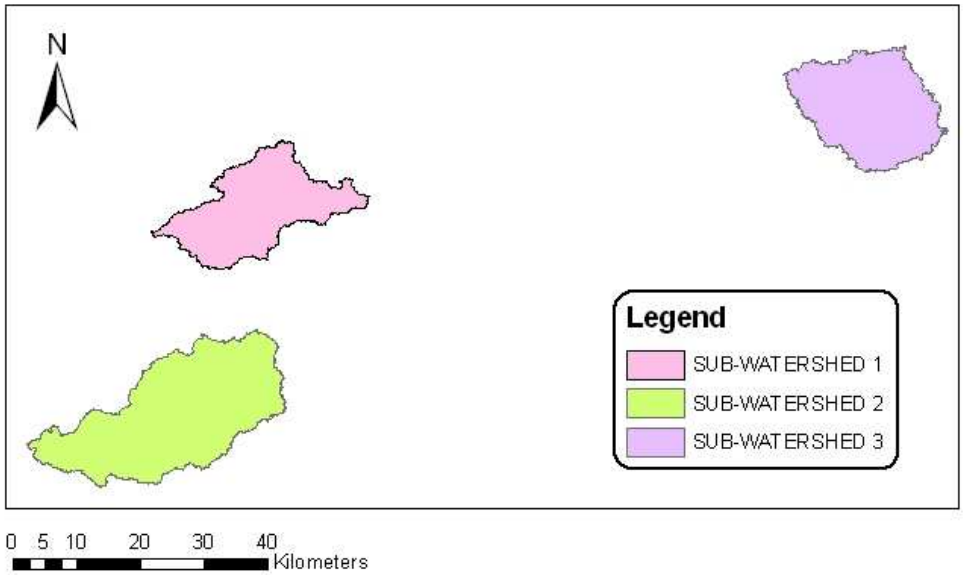
Delineation of Watershed & Micro-watersheds

- A watershed is the upslope area contributing flow to a given location.
- A micro-watershed is the part of major watershed.
- Watershed was delineated from flow direction raster using Watershed function.
- Pour points were used to delineate watershed.
- 3 micro-watersheds were delineated by adding sub-pour-points at different locations from major Watershed.

S.No.	Title	Area (Km^2)	Perimeter (Km)	Pour-point Coordinates
1	Watershed	27690	1336	75° 27'28.9" E 25° 51'11.4" N
2	Sub-Watershed 1	303.6	119.4	74° 18' 44.8" E 25° 46'18.5" N
3	Sub-Watershed 2	520.7	152.3	74° 10' 53" E 25° 27'45.8" N
4	Sub-Watershed 3	321	109.3	75° 13' 15.35" E 25° 51'45.58" N

WATERSHED & MICRO-WATERSHEDS



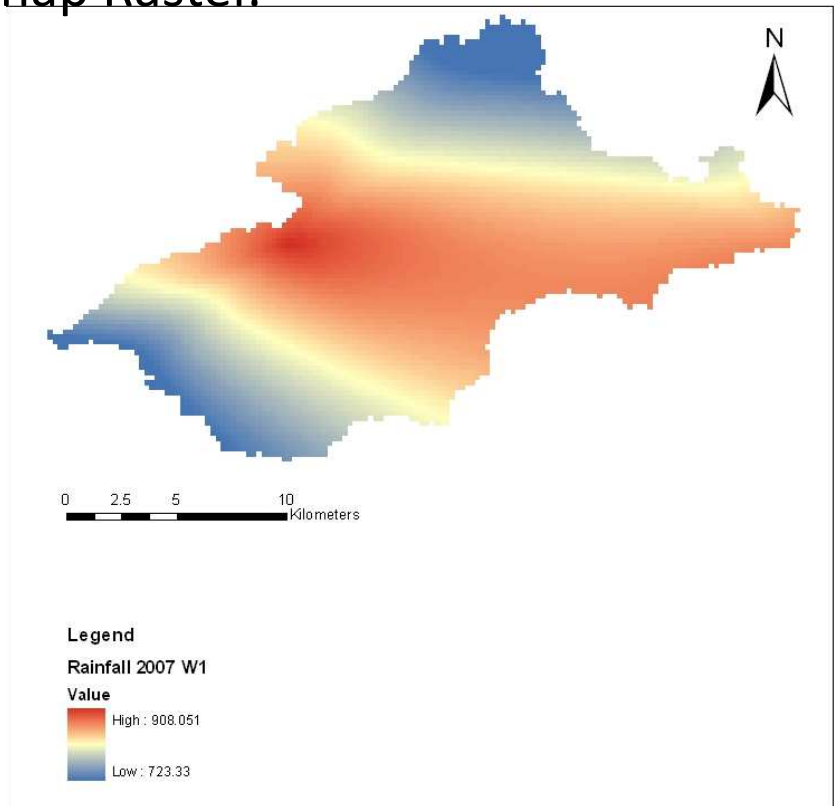


QUALITATIVE ASSESSMENT

- A Qualitative Assessment Model was developed using studying Soil Erosion factors like Rainfall, Vegetation Pattern, Soil Characteristics, Slope Factor, Land Use & Land Cover Patterns were taken as input for all 3 micro-watersheds.
- Each factor was reclassified on basis of severity of Soil Erosion into 5 classes ranging from Very Slight erosion to Highly Severe one.

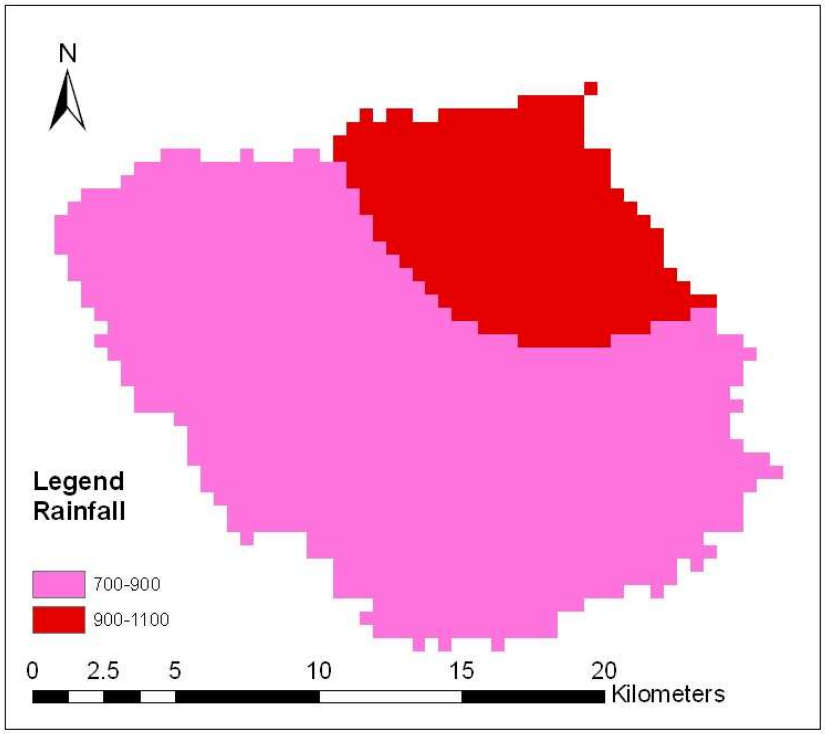
RAINFALL & ITS RECLASSIFICATION

- Rainfall data was converted into shapefiles & interpolated to obtain Raster map for whole area using Snap Raster.



Rainfall for micro-watershed 1 for 2007

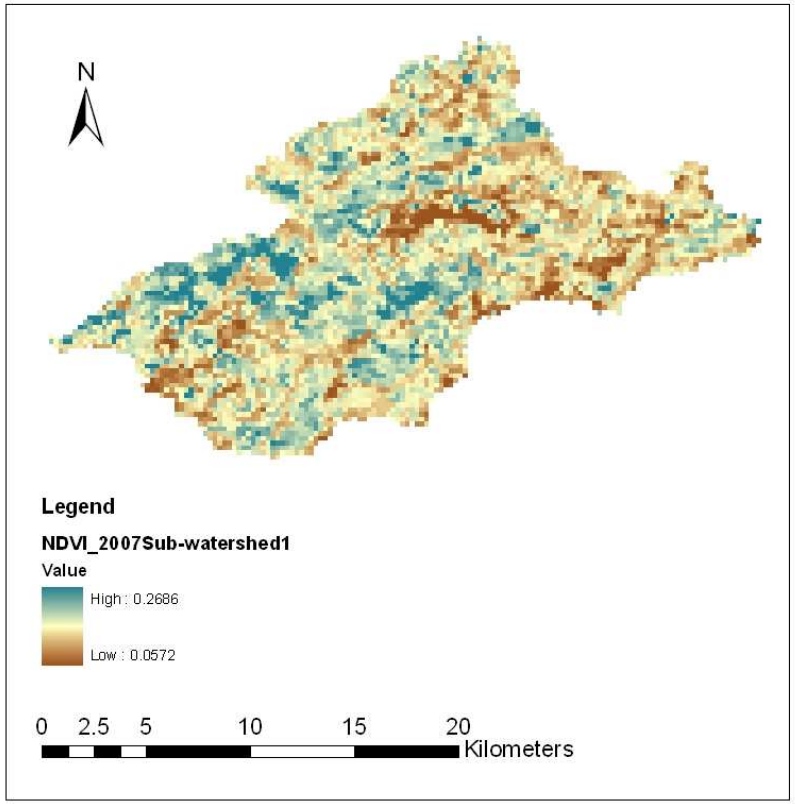
- Rainfall ranged from 164-1048 mm & classified into 5 classes.



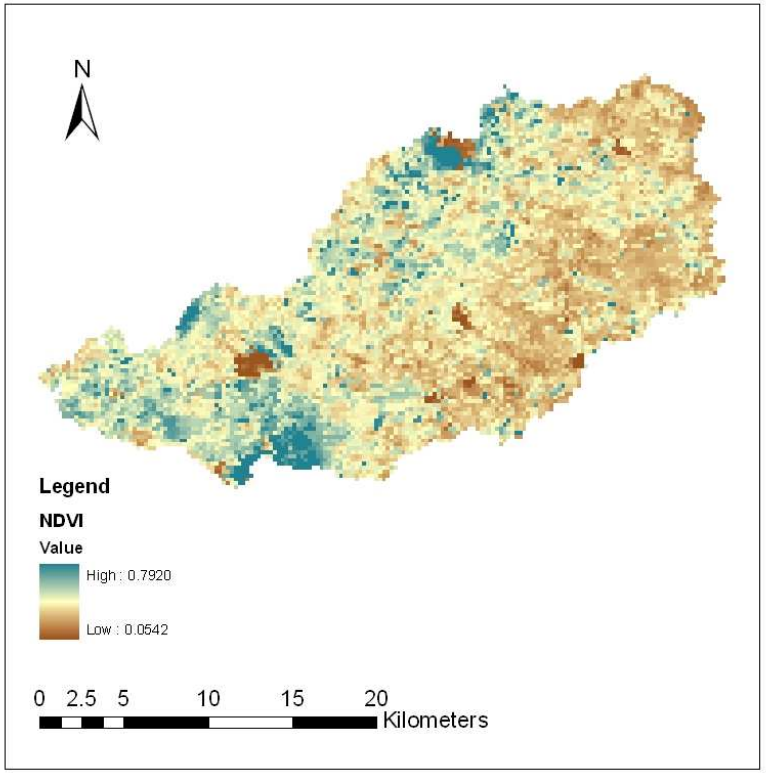
Micro-watershed 2 for year 2011

NDVI

- NDVI Data of micro-watersheds.



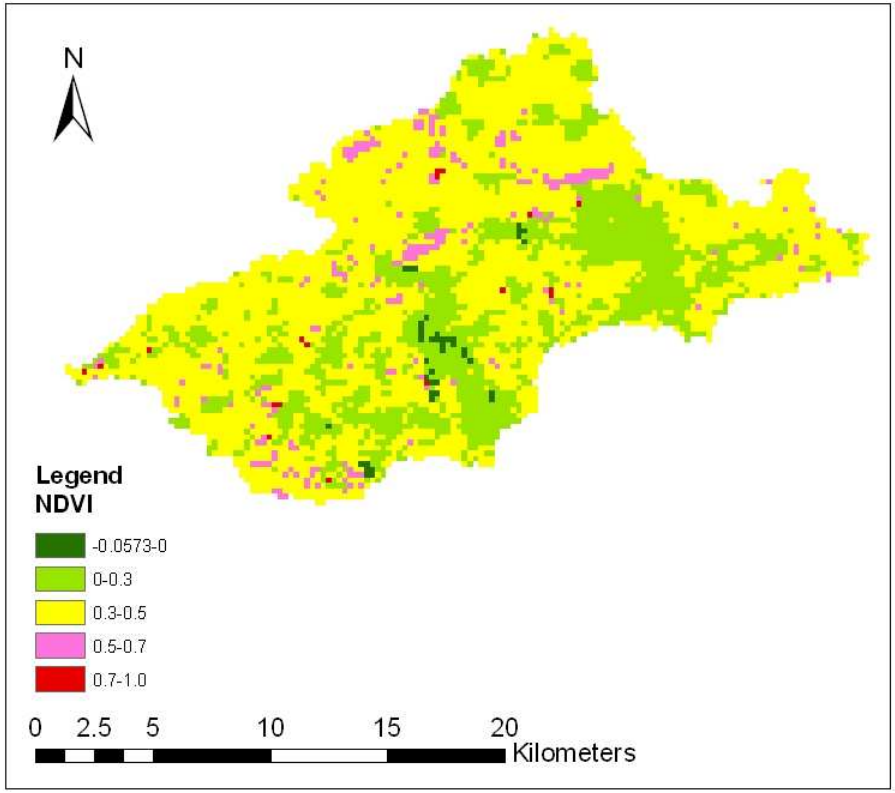
NDVI for micro-watershed 1



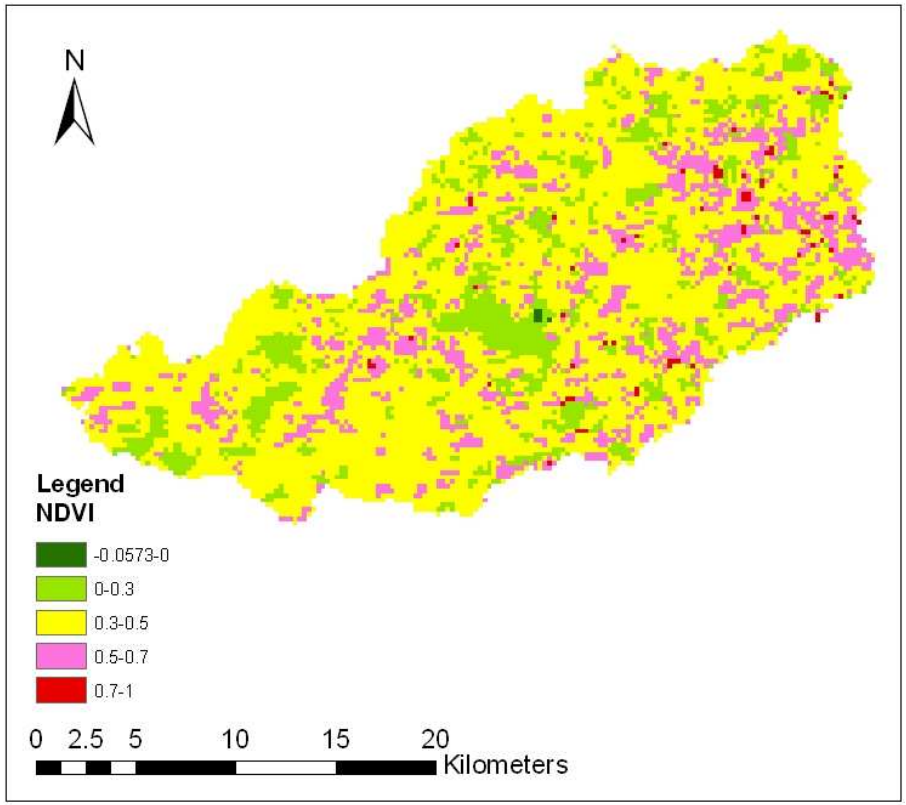
NDVI for micro-watershed 2

RECLASSIFICATION

- NDVI ranged from -0.0573 to 0.9581
  (negative value signifies presence of water over pre-vegetated area)



NDVI for micro-watershed 1 for year 2007



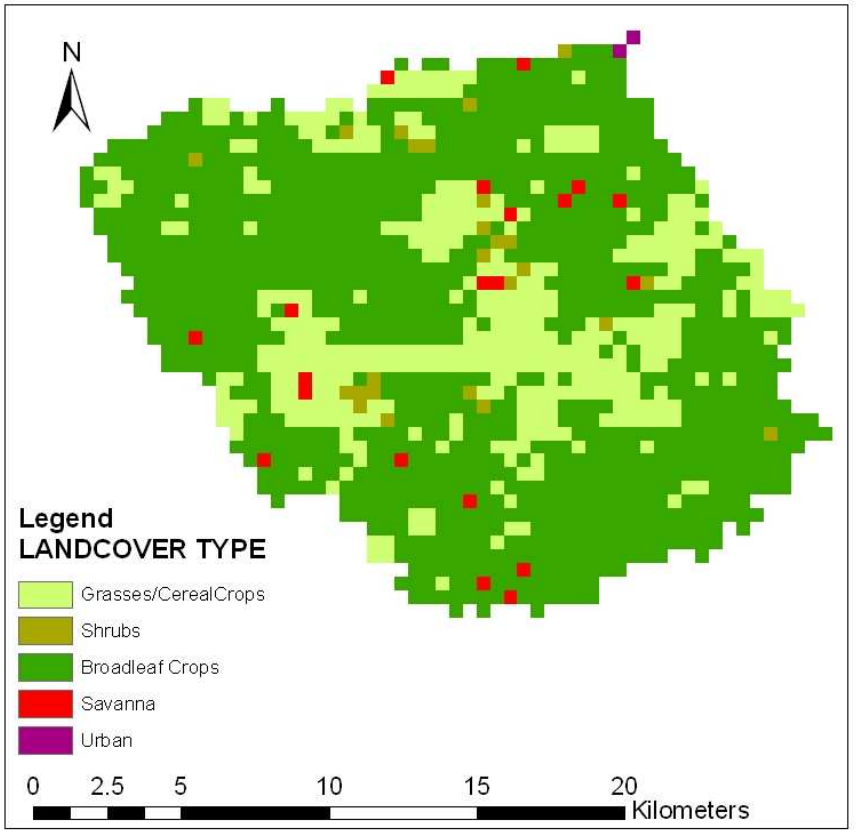
NDVI for micro-watershed 2 for year 2007

Land Use & Land Cover

- Land Use & Land Cover pattern for micro-watersheds map were prepared & classified on basis of severity to erosion.
- Land Cover type showed presence of Water, Grasses/Cereal Crops, Shrubs, Broadleaf Crops, Savannas & Urban Area in micro-watersheds.

- 5 Land cover type are:

- Savannas : Very slightly eroded,
- Urban type: Slightly eroded,
- Shrubs: Moderately eroded,
- Grasses: Severely eroded,
- Broadleaf crops: Very severely eroded.



Land Cover Type for micro-watershed 3

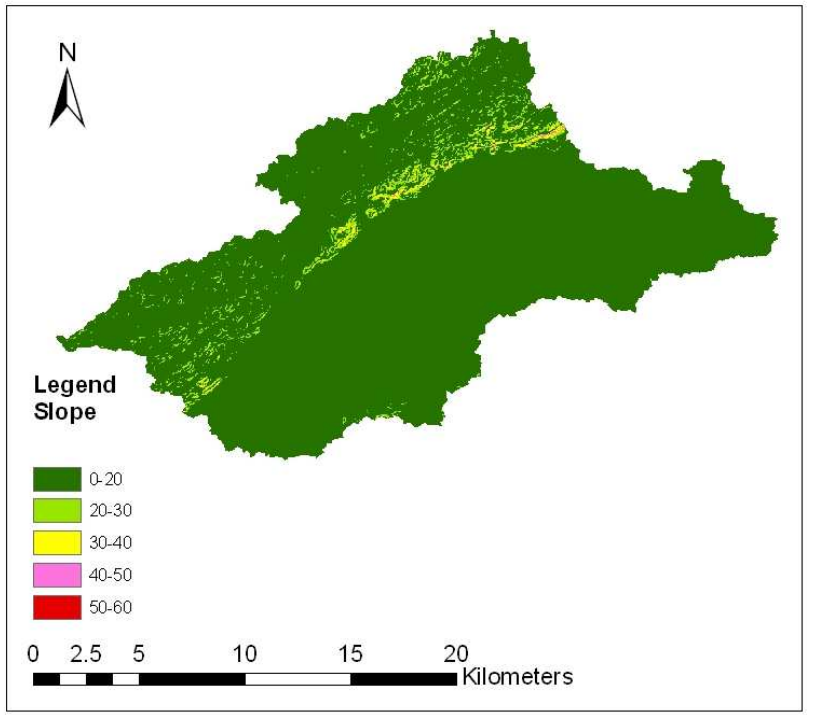
SOIL

- Soil Type was studied to analyse soil erodibility, texture & susceptibility to erosion.
- Soil vulnerability depends on soil type, organic matter content etc.
- Erosion vulnerability was classified for each micro-watershed studying characteristics of soils.

- Soils falling in study regions of micro-watersheds are:
- **Micro-watershed 1**: Ustrochrepts and Hills & Hillocks.
- **Micro-watershed 2**: Hills and Hillocks
- **Micro-watershed 3**: Camborithids and Torripsamments

SLOPE

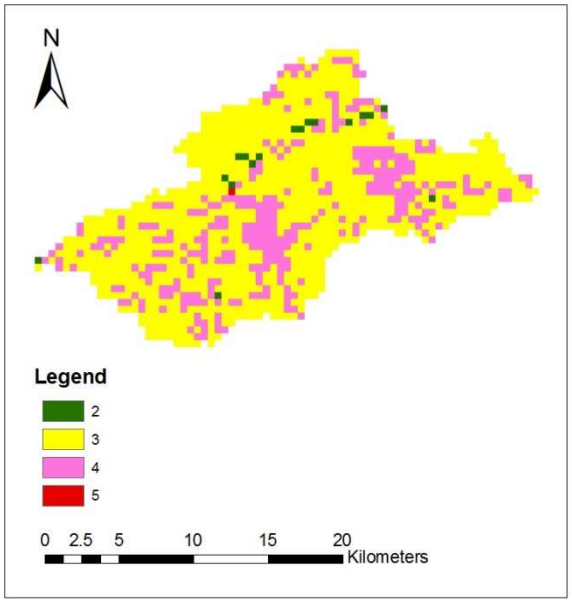
- Soil erodes more when slope is steep.
- This factor was studied by using Slope Function in Hydrology Tool in ArcMap.
- Slope Raster Map was obtained after extraction by mask.
- Data was classified from the highest value to the lowest one.
- Slope ranged from 0 to 56.407.
- Maximum Slope was in micro-watershed 1 as 56.407.
- Now to classify the slope factor in micro-watersheds, data was divided into 5 classes.



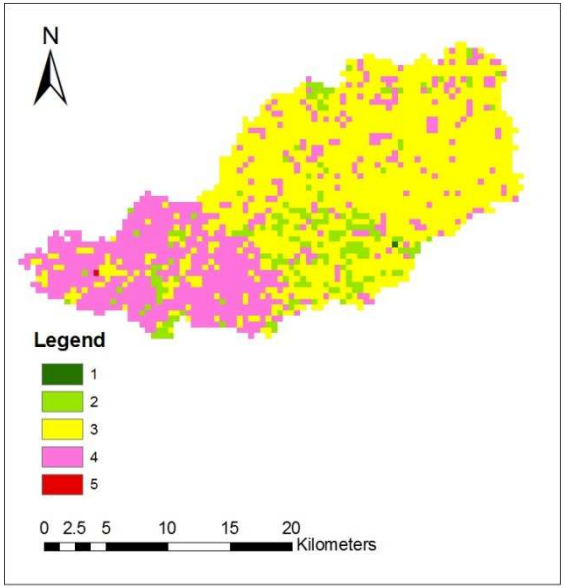
Soil Erosion Mapping

- Qualitative Soil Erosion model was developed using Weighted Sum of Overlay Tool.
- It combines multiple Raster inputs & add up the sum for integrated analysis providing suitable modelling.
- It works by multiplying the designated field values for each input raster by specified weight.
- It sums up all the input factors resulting into output raster.
- All the factors after classifying into 5 erosion classes were given as input raster for weighted sum.
- Every factor was given equal weight as all contribute equally towards erosion.
- The weighted sum output raster range was reclassified into 5 erosion classes ranging from Very Slight, Slight, Moderate, Severe and Very Severe Erosion.
- Soil Erosion Maps for all three years for three micro-watersheds were generated.

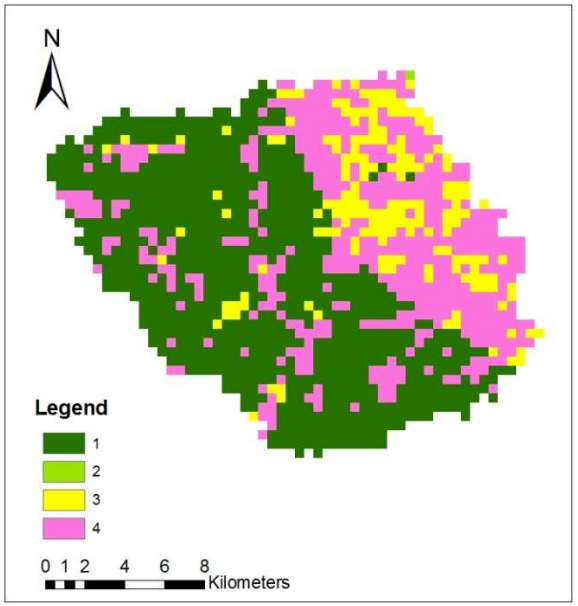
RESULTS



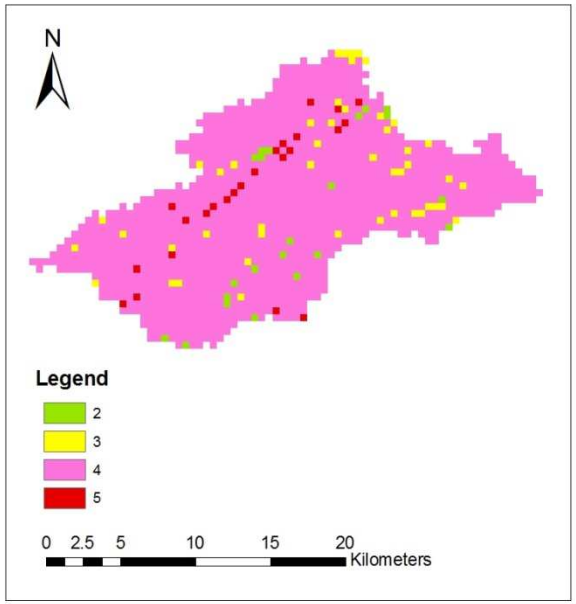
Micro-watershed 1 (2007)



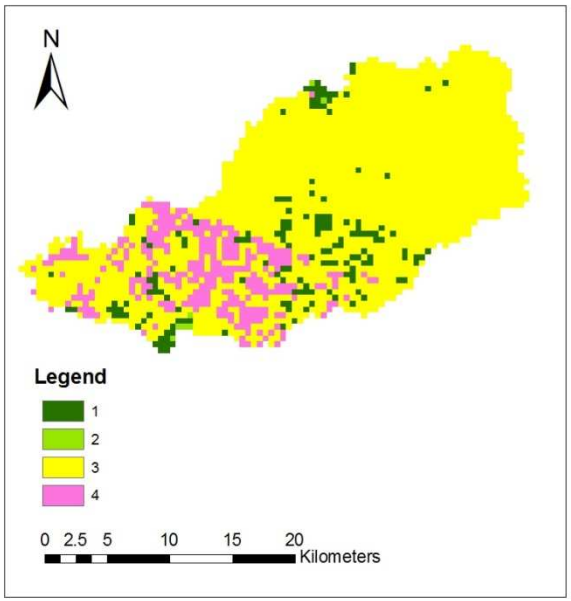
Micro-watershed 2 (2007)



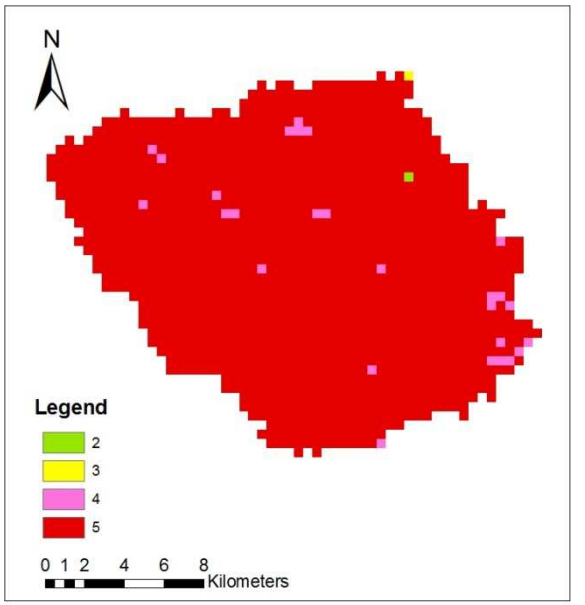
Micro-watershed 3 (2008)



Micro-watershed 1 (2011)



Micro-watershed 2 (2008)



Micro-watershed 3 (2011)

RESULTS

- Year 2007 with moderate rainfall in all the seven years from 2005 to 2011, has shown moderate soil erosion for all three micro-watersheds.
- Year 2008 has suffered moderate soil erosion for micro-watersheds 1 and 2 while very slight in micro-watershed 3.
- Year 2011 with the highest rainfall so observed has very severe erosion in micro-watershed 3, severe erosion in micro-watersheds 1 and 2, with some areas under slight erosion in micro-watershed 2.

DATA ANALYSIS

- Severe Soil erosion is found maximum in micro-watershed 3 and in highest rainfall years, thus proves rainfall act as strong factor causing Soil erosion.
- Soil erosion is again maximum in micro-watershed 3 with lowest NDVI values, referring absence of vegetation contributing to soil erosion.
- Soil erosion is maximum in the areas with land cover type with sparse vegetation and the steepest slope.

CONCLUSION

- Thus Remote Sensing & GIS have proved as productive tool for Soil Erosion study of all 3 micro-watersheds of Bisalpur reservoir.
- Objective of the study has been achieved as methodology for simple qualitative soil erosion mapping has been developed using remote sensing data with GIS.
- Watershed & micro-watersheds have been successfully delineated.
- Qualitative Assessment has identified Soil erosion prone areas by combined weightage of soil erosion factors.
- Soil loss intensity maps have been developed.

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