08MTRS-32

REMOTE SENSING & GIS IN WATER RESOURCES

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08MTRS-32: REMOTE SENSING & GIS IN WATER RESOURCES

1. **Surface Water Resources:** Hydrological Cycle: (Rainfall, Infiltration, Runoff, Evapotranspiration) – Global distribution of Surface Water bodies – Surface Water Budgeting/Quantification using Satellite Infrared data – Spectral Response Pattern of Water.
2. **Drainage morphometric analysis:** Drainage mapping and analysis (from Satellite data, Automated Drainage Mapping using DEM, Drainage Morphometric Analysis) Water Quality Mapping and Monitoring using Remote Sensing.
3. **Groundwater :** Basic Principles of Groundwater Hydrology
4. **Crystalline Aquifer Systems:** Characteristics, Mapping of Crystalline Aquifer Systems, Lithological, Regolith and Fracture Pattern Mapping and Modelling, Geophysical Surveys and GIS based Geospatial modelling of Crystalline Aquifer System
5. **Sedimentary Aquifer Systems:** Characteristics, Artesian and subartesian conditions, Mapping Techniques using Geoinformatics.
6. **Geomorphic Aquifer System:** Hydro geomorphic mapping through Satellite Raw and Digitally processed data – Ground water quality (Rock – water interaction, pollution etc).
7. **Natural and Artificial Recharge:** Site Selection for Natural and Artificial Recharge on Geological criteria, Detection of Site Specific Mechanism for recharge through GIS Applications)
8. **Groundwater Modelling:** Geospatial Modelling of Groundwater Systems – Stochastic – Flow – Linear – Finite - element Modelling.
9. **Integrated Watershed Development and Management:** Conjunctive analysis of Surface and Groundwater – GIS based Watershed wise Water budgeting – Integrated Watershed Planning – Water Resources Information System.
10. **Case studies:** Remote sensing and GIS in water resources – Case studies.

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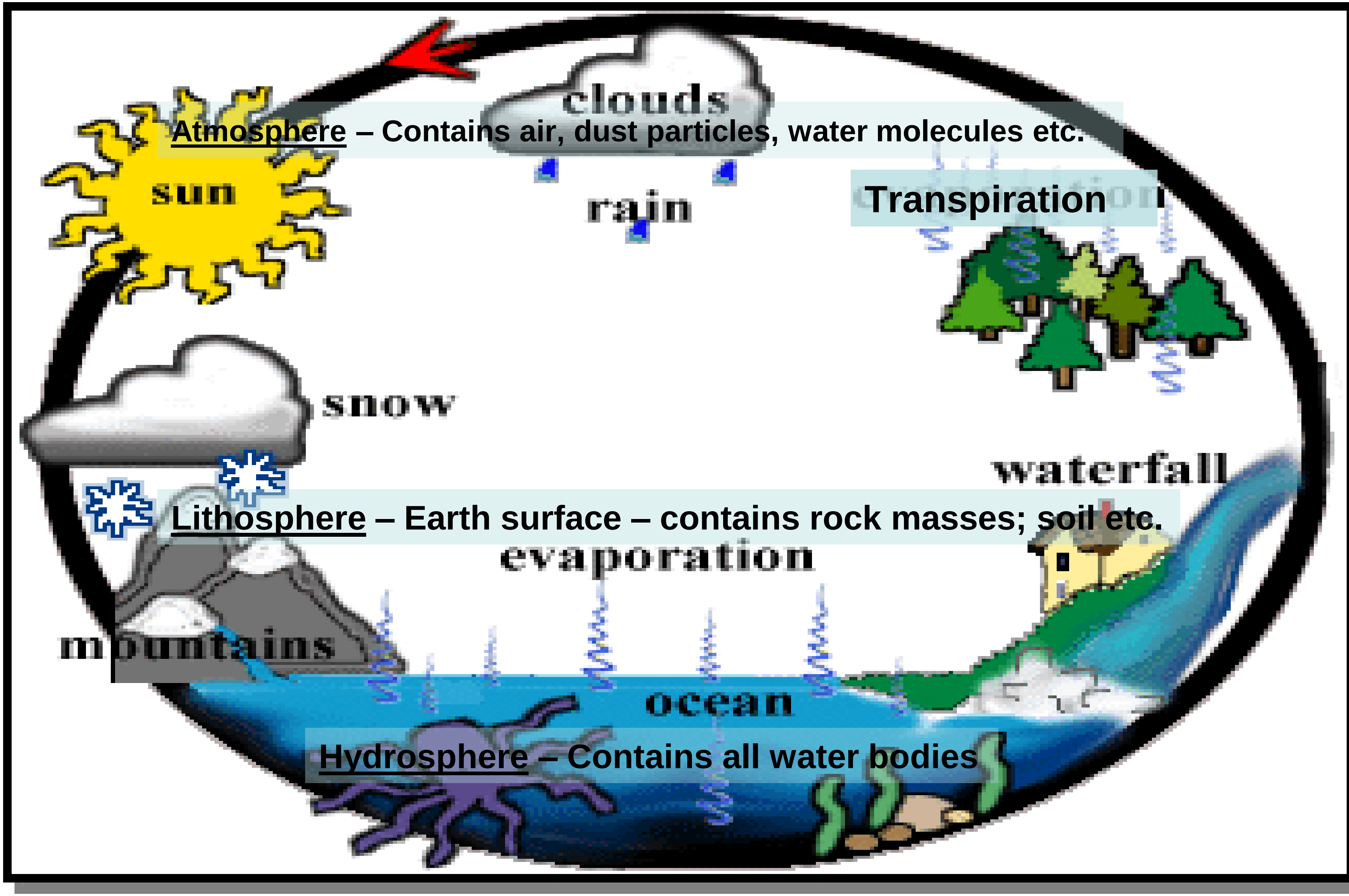
UNIT – 1

1. **Surface Water Resources:** Hydrological Cycle: (Rainfall, Infiltration, Runoff, Evapotranspiration) – Global distribution of Surface Water bodies – Surface Water Budgeting/Quantification using Satellite Infrared data – Spectral Response Pattern of Water.

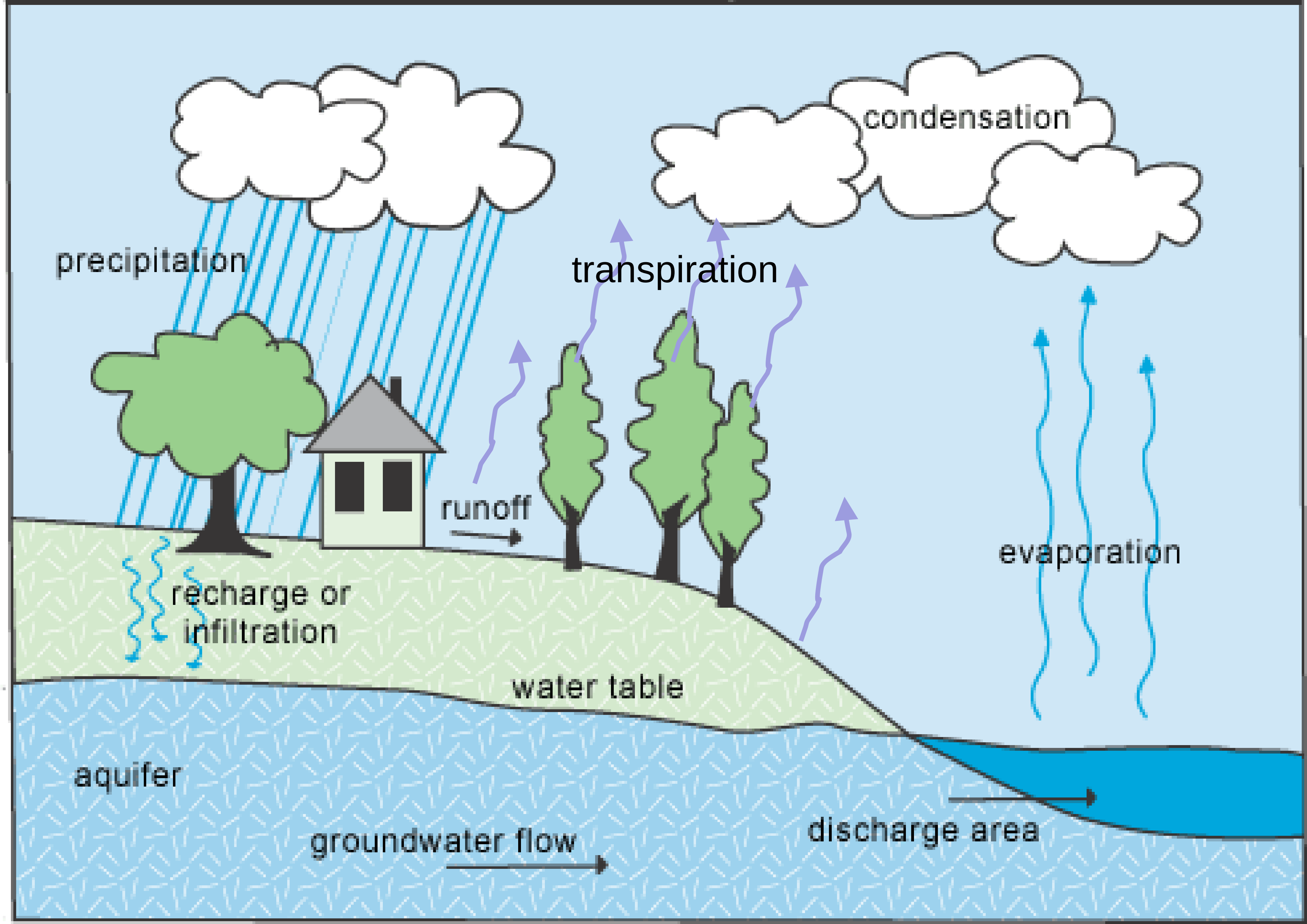
Hydrological Cycle

Hydrological Cycle is defined as follows:

- General continuous gigantic circulation of water from seas (Hydrosphere) to the atmosphere, to the ground (Lithosphere) and back to the seas (Hydrosphere) again
- in its different forms, i.e., liquid-vapour-solid and
- also with different quality and quantity – with high dissolved solids – pure – minimum dissolved solids and bacteria.

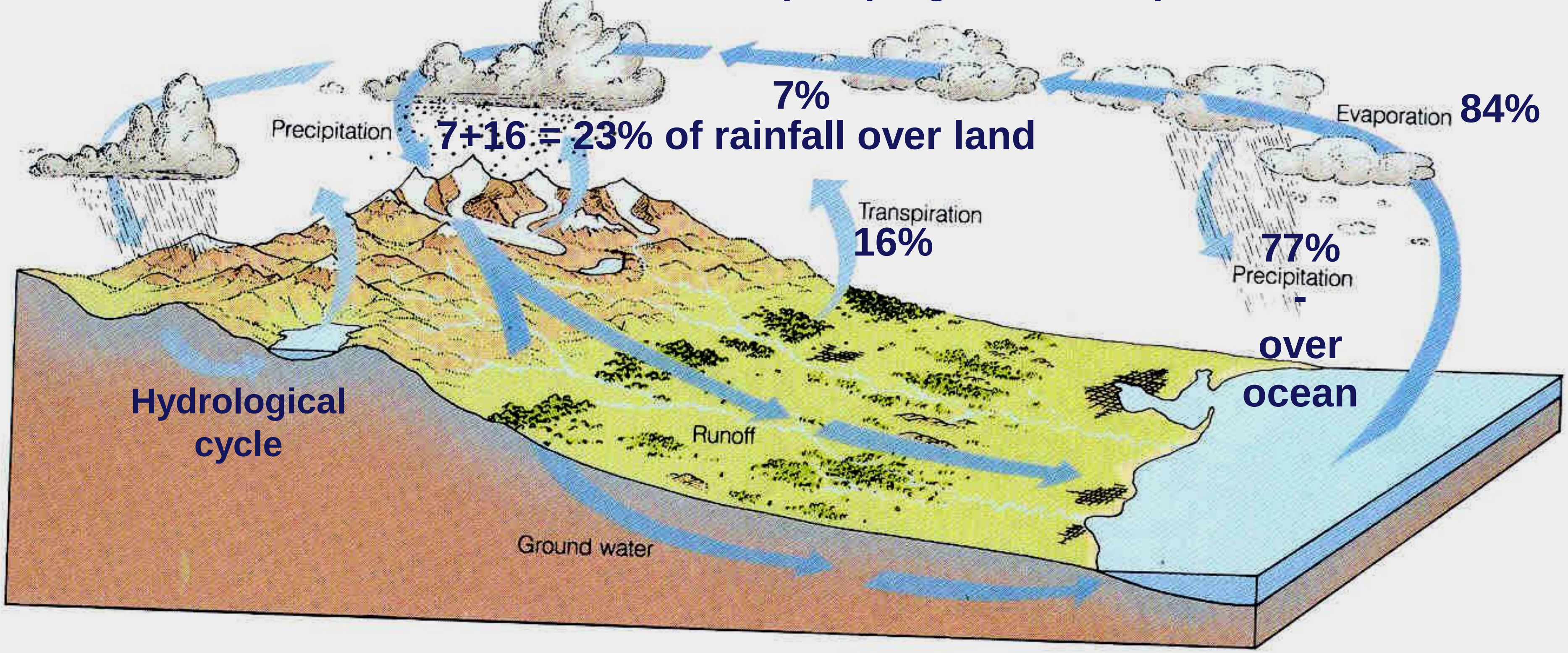

clouds
Atmosphere – Contains air, dust particles, water molecules etc.
sun
rain
Transpiration
snow
waterfall
Lithosphere – Earth surface – contains rock masses; soil etc.
evaporation
mountains
ocean
Hydrosphere – Contains all water bodies

Water Cycle


condensation
precipitation
transpiration
runoff
evaporation
recharge or
infiltration
water table
aquifer
groundwater flow
discharge area

THE CIRCULATION OF WATER IN THE HYDROLOGIC SYSTEM

Mean Annual Global Rainfall is 85.7 cm (Keeping it as 100%)



The constant circulation / movement of water particles from sea through the atmosphere , to the land (lithosphere) back to sea and it's ultimate return to the atmosphere by the way of transpiration and evaporation is called as "Hydrologic cycle".

The energy from both solar system and gravitational force, governs the movement.

Ocean is the major source of water

Solar energy converts water in to vapour and forms clouds in the atmosphere

Condensation leads to precipitation on land surface

Part forms surface run off flow and part gets recharged into the sub surface

Finally drains into the ocean

Water on the land can be classified into two categories

SURFACE WATER:

River, Stream, Lakes, Ponds, Ice etc.,

SUB SURFACE:

Beneath the ground

Earth: The Water Planet

- 74% of the Earth's surface is water – The overall distribution of this water on the Earth surface is as follows:

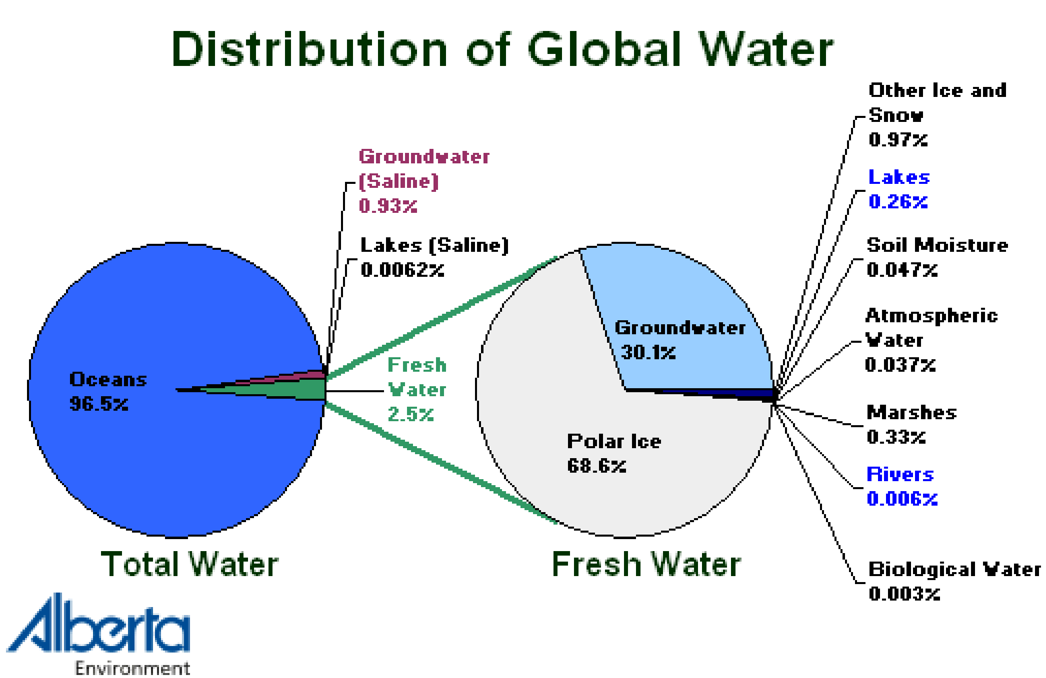
- 97% of the Earth's volume of water is in the saline oceans
- 2.2% is in the permanent icecap
- Only 0.02% is in freshwater streams, rivers, lakes, reservoirs
- Remaining water is in:
  - underground aquifers (0.6%),
  - atmosphere, in the form of water vapor (0.001%)

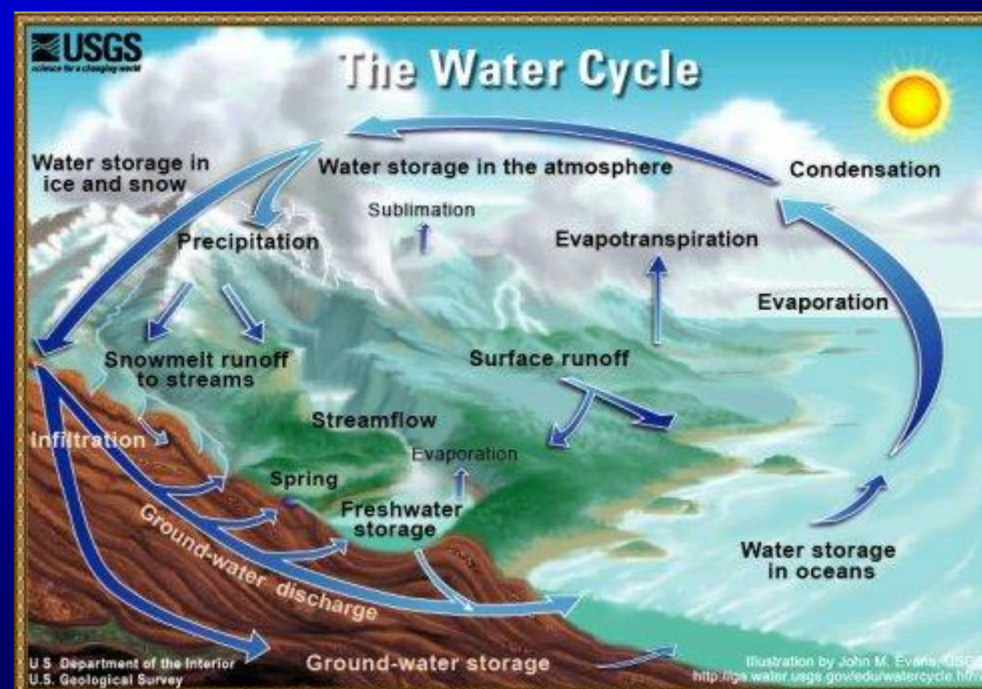
SOURCES OF WATER

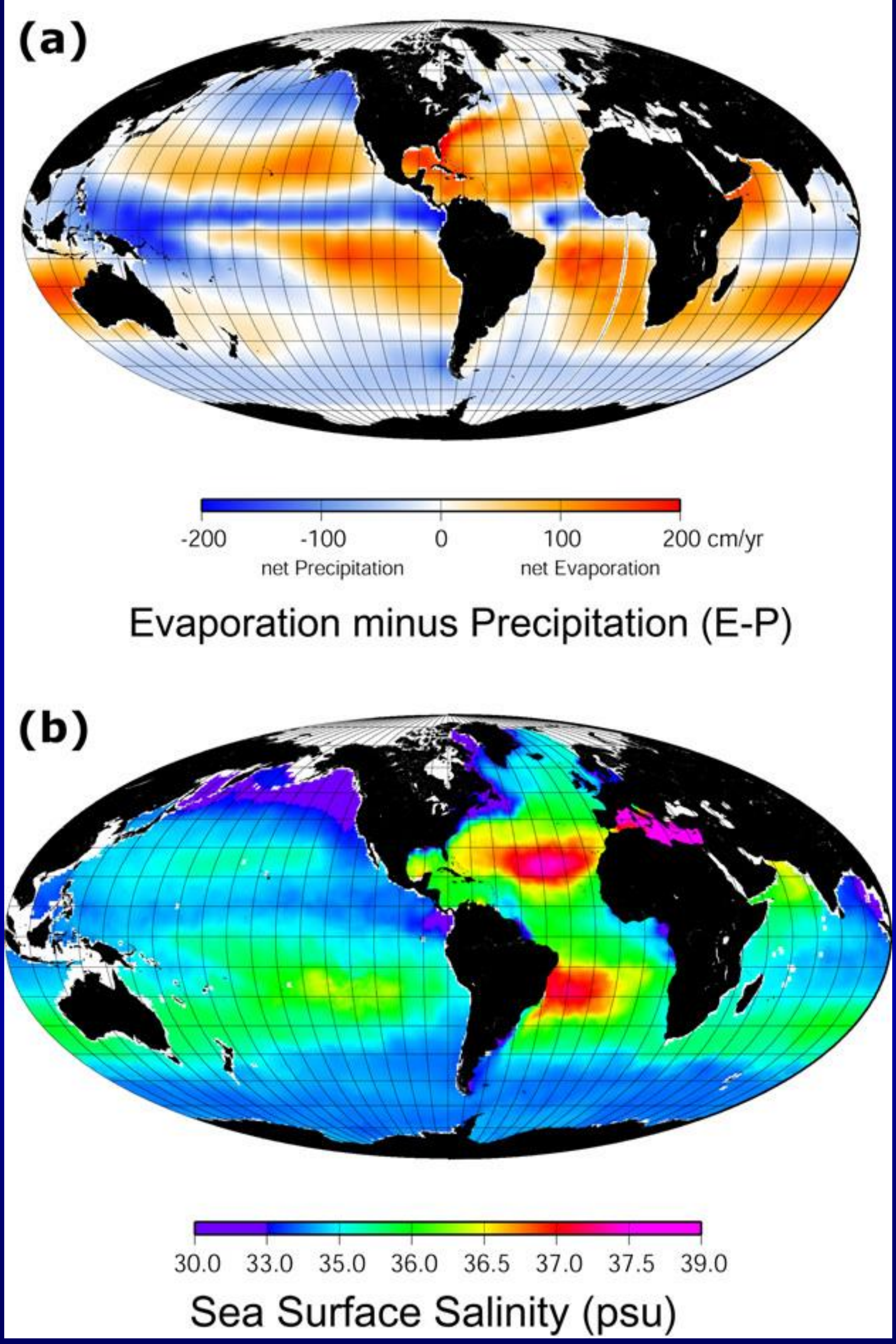
Meteoric Water: Meteoric water derived from precipitation (rainfall)

Juvenile (Magmatic water) water: Juvenile water formed in the cracks (or) pores of rocks due to condensation of stream emanating from magmas.
Eg. Hot springs or Geysers

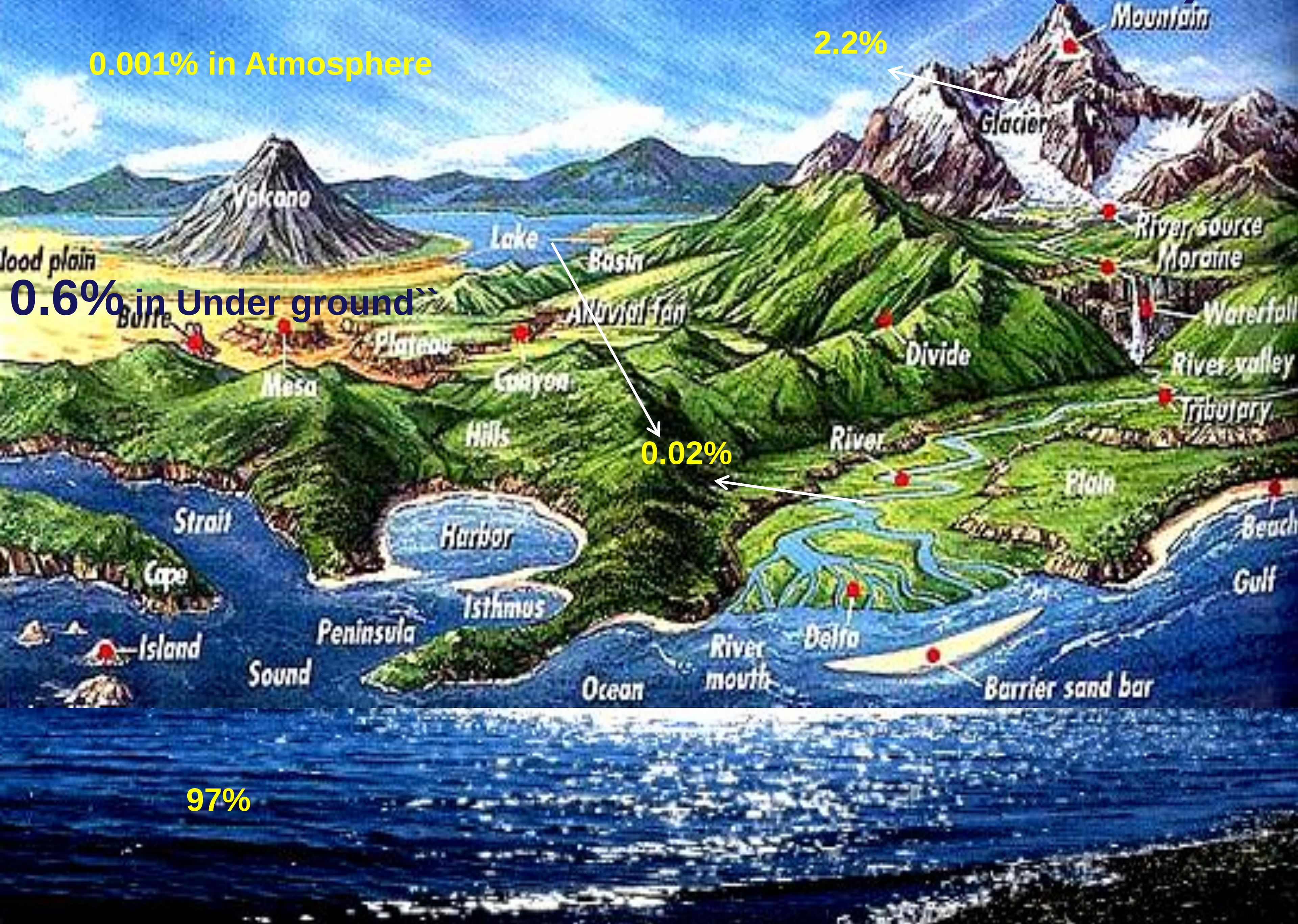
Connate water: The water is entrapped in the rocks during their formations due to sedimentation in an aqueous environment, also known as fossil water.


Distribution of Global Water
Oceans 96.5%
Groundwater (Saline) 0.93%
Lakes (Saline) 0.0062%
Fresh Water 2.5%
Groundwater 30.1%
Polar Ice 68.6%
Other Ice and Snow 0.97%
Lakes 0.26%
Soil Moisture 0.047%
Atmospheric Water 0.037%
Marshes 0.33%
Rivers 0.006%
Biological Water 0.003%
Total Water
Fresh Water
Alberta Environment


USGS
The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
U.S. Department of the Interior
U.S. Geological Survey


(a)
-200
-100
0
100
200 cm/yr
net Precipitation
net Evaporation
Evaporation minus Precipitation (E-P)
(b)
30.0
33.0
35.0
36.0
36.5
37.0
37.5
39.0
Sea Surface Salinity (psu)

Volume of available water in Earth (in %)

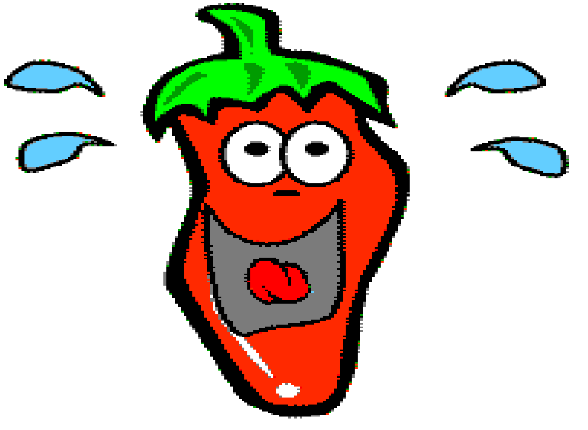


EVAPORATION

Evaporation is when the sun heats up water in rivers or lakes or the ocean and turns it into vapour or steam which rises in to the air.

TRANSPIRATION

Do plants sweat? Kind of. Transpiration is the process by which plants lose water from their leaves. The water rises in to the air.



CONDENSATION

Water vapour in the air gets cold and changes back into liquid, forming clouds. This is called condensation.

PRECIPITATION

Precipitation occurs when so much water has condensed that the air cannot hold it anymore. Water falls to the earth in the form of rain, hail, sleet or snow.

The major energy sources of Hydrological Cycle are:

- The influence of
  - Solar heat – **evaporation, transpiration**
  - Temperature and pressure difference in atmosphere – displacement, accumulation, condensation, **precipitation**
  - Gravity – rainfall, flowing of water – as running water/surface water flow/**runoff** and **groundwater movement/flow**
- Thus, it is an intricate combination of evaporation, transpiration, precipitation, runoff and groundwater flow.

- This Circulation Continues for ever and there by a **BALANCE** is maintained between the **precipitation** and **evaporation** process.
- But ocean receives all salts into it continuously, resulting into more concentrations of salts.
- In one stage, at the Destructional Margin, the dried up oceanic plate contains salt + marine resources will get recycled – taken into very deep – melted with magma by tectonic activities and regenerated as fresh plates in constructional margins.
- **Most part** of the precipitation falls directly on the **seas** and **a portion** falls on the **land surfaces;**
- In different forms such as snow, fog, rainfall, etc.

The falling water is **temporarily retained** in the form of **glaciers**, some amount by **soil, surface depressions, [** (puddle, mere, pool, pond, tank, lake, lagoon, reservoir, basin, tarn, sea, ocean, (marine, naval), **running waters,** e.g.

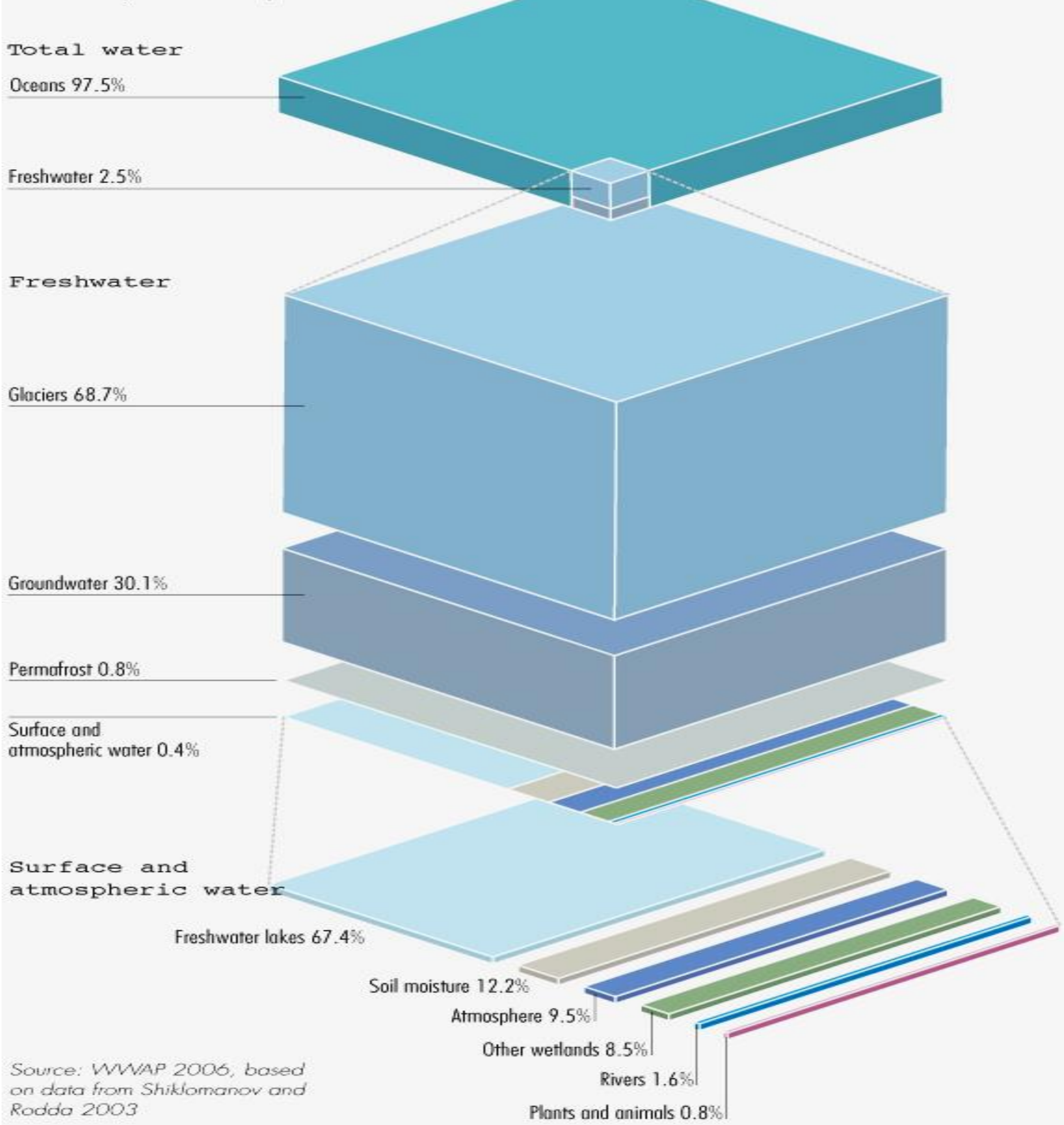
- Stream
- Spring
- River,
- Rivulets,
- Brook,
- Creek,
- Gully,
- Torrent,
- Watercourse,
- Tributary,
- Branch
- Distributary,
- Flow,
- Channel
- Drain,
- Drainage
- Waterway,
- Canal,
- Ditch
- Flood …**],**

vegetation, other living beings and objects until it is returned to the atmosphere by evaporation and transpiration.

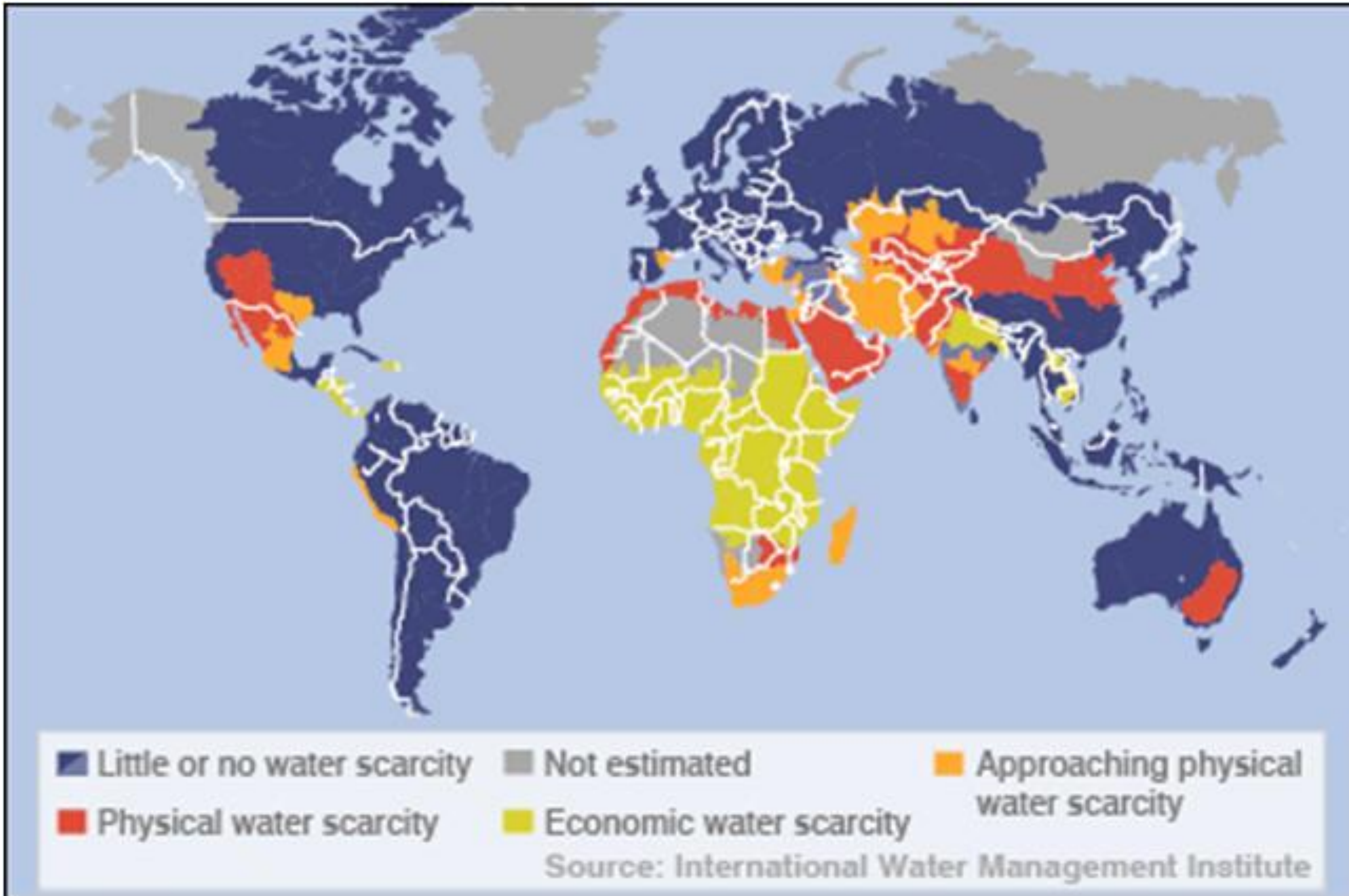
- The **remainder** is moving in underground channels as groundwater
- Finally these surface and ground water are reaching sea - subject to evaporation and transpiration throughout their travel.
- The volume of moisture involved in this earth phase cycle is relatively constant
- Mean annual global precipitation is 85.7 cm, we keep it as 100 units.
- Then, from oceans 84 units of water gets evaporated and lifted to the atmosphere – evaporation.
- At the same time, 16 units of water over the continents are lifted to the atmosphere – evapo-transpiration.
- From the above said 84 units, 77 units of water vapour is condensed and falling as rainfall over the oceans itself
- Remaining 7 units of water vapour is advancing towards landside.
- So, totally 7+16 = 23 units of water vapour is condensed and falling over the continental regions.
- This way the water balance is maintained throughout the year continuous without any interruption.
- This cycle has slowed-down, when
  - Plants and animals use water for cell building
  - Ice caps and snow fields detain it in solid form
  - Chemical action incorporates it in other compounds
  - groundwater is trapped
  - Cloud seeding / artificial nucleation is done (using silver iodide crystals, dry ice, portland cement)

3	a) SATURATION	1) Movement of water in to the soil from the surface
10	b) EVAPORATION	2) Water stored in rocks
8	c) TRANSPIRATION	3) When the soil is full of moisture/water
6	d) HYDROLOGY	4) Most water returns to the sea by running overland.
9	e) PERCOLATION	5) Water vapour changes back to water and forms as water droplets which are visible as clouds.
2	f) GROUNDWATER	6) The study of water
1	g) INFILTRATION	7) Moisture falls to the earth (as rain, snow, hail)
7	h) PRECIPITATION	8) The transfer of water from plants to the air as gas.
4	i) SURFACE RUN OFF	9) Movement of water into underlying rocks.
5	j) CONDENSATION	10) Transfer of water from the sea to the air

Global distribution of Surface and Ground water bodies



Global distribution of water bodies

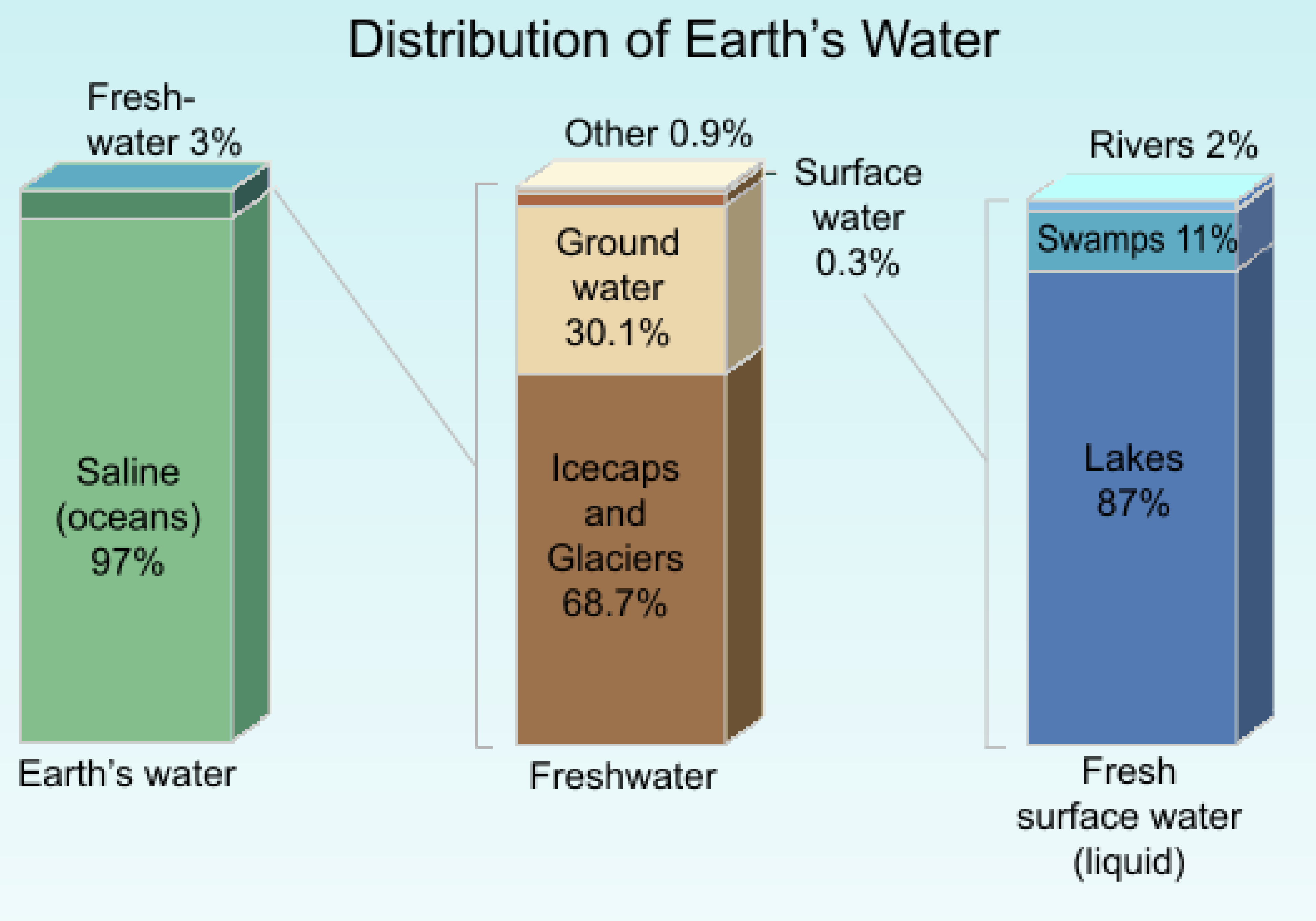


-atmosphere holds only very small percentage of Earth's water supply at any given time

World Water Supply

Source	% of Supply
Oceans	97.08
Ice Sheets and Glaciers	1.99
Ground Water	0.62
Atmosphere	0.29
Lakes (Fresh)	0.01
Inland Seas / Salt Water Lakes	0.005
Soil Moisture	0.004
Rivers	0.001

-rapid recycling of water must occur between earth's surface and atmosphere


Distribution of Earth's Water
Fresh-water 3%
Saline (oceans) 97%
Earth's water
Other 0.9%
Surface water 0.3%
Ground water 30.1%
Icecaps and Glaciers 68.7%
Freshwater
Rivers 2%
Swamps 11%
Lakes 87%
Fresh surface water (liquid)

UNIT – 2
DRAINAGE MORPHOMETRY

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UNIT – 2

2. **Drainage morphometric analysis:** Drainage mapping and analysis (from Satellite data, Automated Drainage Mapping using DEM, Drainage Morphometric Analysis), Water Quality Mapping and Monitoring using Remote Sensing.

Sources/Types of surface water

- Meteoric water - Rain water
  - Derived from precipitation /rainfall
- Juvenile - Magmatic water
  - Formed in cracks / pore spaces of rocks due to condensation of steam emanating from magma
- Connate water - Fossil water
  - Entrapped in the rocks during their formations due to sedimentation in an aqueous environment

Drainage

- Fundamentally the earth's surface is organized into watersheds.
- Watershed managers and planners are interested in different types of environmental conditions within distinct segments of watersheds (e.g., hillslopes, terraces, floodplains, etc...), while hydrologists and geomorpho-logists are interested in the spatial variability in processes throughout a watershed.
- The fundamental unit of virtually all watershed and fluvial investigations is the **drainage basin**
- An individual drainage basin (a.k.a. catchment or watershed) is a finite area whose runoff is channelled through a single outlet.
- In its simplest form, a **drainage basin** is an area that funnels all runoff to the mouth of a stream.

- So simply, a drainage basin is defined as an area defined by a topographic boundary that diverts all runoff to a single outlet.
- Drainage basins may be delineated on a topographic map by tracing their perimeters or **drainage divides**.
- A drainage divide is simply a line on either side of which water flows to different streams. i.e., The topographic boundary that separates runoff between two basins is the drainage divide.
- Locally, the most famous drainage divide is the Continental Divide.
- Each drainage basin is entirely enclosed by a drainage divide.

- Drainage basins are commonly treated as physical entities.
- For instance, flood control along a particular river invariably focuses on the drainage basin of that river alone.
- Because drainage basins are discrete landforms suitable for statistical, comparative, and analytical analyses, innumerable means of numerically and qualitatively describing them have been proposed.

- Watershed managers, Hydrologists, Geo-morphologists, planners… are interested in such spatial variables of watersheds.
- Obtaining this information requires delineation of the drainage system, which includes the stream channel network and smaller catchments within the basin.
- In addition, every watershed can be characterized by geometric properties related to its linear, areal and relief properties.
- These properties are related to the position of a stream within the watershed, and can be used to compare watersheds.

Spatial parameters prove valuable, however, in determining whether basins are sufficiently similar for direct comparison.

For example, to study the effects of fire, one might compare a vegetated watershed with a burned watershed.

For this comparison to isolate the effects of fire, other spatial factors (drainage area, relief, etc.) should remain relatively constant between drainage basins.

In addition, spatial variables are used to calculate a wide variety of more sophisticated parameters.

Sources of surface water – contd…

- Snow –
  - **Sleet** (rain combined with hail or snow),
  - **Glaze** (glassy coating of ice, typically caused by rain freezing on impact),
  - **Hail** (pellets of frozen rain falling in showers from cumulonimbus clouds),
  - **Snow** (atmospheric water vapour frozen into ice crystals and falling in light white flakes or lying on the ground as a white layer),
  - **Mist** (a cloud of tiny water droplets in the atmosphere, at or near the earth's surface, limiting the visibility to a lesser extent than fog)
  - **Fog** (a thick cloud of tiny water droplets suspended in the atmosphere at or near the earth's surface which obscures or restricts visibility)
- Rainfall –
  - **Drizzle -** light rain falling in very fine drops,
  - **Raindrops** – Sparse / Medium / Dense, Heavy downpour, and
  - **Cyclonic rainstorm** – Heavy rainfall with cyclonic wind
- Groundwater table –
  - Influent stream - through Springs and Ooze-outs.
- Geysers & Hot-springs.

Drainage morphometry

- The measurement of drainage density provides a hydrologist or geomorphologist with a useful numerical measure of landscape dissection and runoff potential.
- On a highly permeable landscape, with small potential for runoff, drainage densities are sometimes less than 1 kilometer per square kilometer.
- On highly dissected surfaces densities of over 500 kilometers per square kilometer are often reported.
- Closer investigations of the processes responsible for drainage density variation has discovered that a number of factors collectively influence stream density.
- These factors include climate, topography, soil infiltration capacity, vegetation, and geology. Linking of Geomorphological parameters with hydrological characteristics of basin provides a simple way to understand the hydrologic behavior of different basins.
- The geomorphological properties which are important from hydrological studies point of view includes linear, aerial and relief aspect of watersheds.
- G.I.S. analysis made the computation of parameter required for morphometric analysis easier & less time consuming than manual method like area measurement, Length measurement & calculations etc.

This quantitative analysis of drainage networks was developed –

- To enable compressions to be made between different drainage basins.
- To enable relationships between different aspects of drainage pattern of same basin.
- To define certain useful properties of drainage basins in numerical terms.
  - 1. Stream Order
  - 2.

- Certainly a channel with perennial flow is a stream. But, toward the end of the drainage network streamflow is typically ephemeral; flow occurs only after precipitation or snow melt. Channels may be well defined, but we will assume that all channels are streams.

1. **Stream Order / Stream Number :-** An important quantifiable characteristic of stream networks is related to the hierarchical arrangement of stream channels.

- The most commonly used is the method proposed by the famous hydrologist **Robert Horton.**
- According to this system, a stream segment with no tributaries is designated as a first-order stream.
- When two first-order segment join, they form a second-order stream; two second-order segments join to form a third-order segment, and so forth. When a lower order segment joins a higher order segment, there is no change in river order.

Comparison of two principal methods of defining stream orders - **Strahler Order system** and **Shreve Magnitude system**

Shreve Magnitude system designates streams that lack a tributary as magnitude 1. Where streams join, their magnitudes are added together. Therefore unlike the Strahler system, magnitudes increase at **all** junctions in the Shreve system. For instance, where a magnitude 2 stream joins a magnitude 3 stream, the magnitudes are added to form a magnitude 5 stream. Note that in such a case there is *no* magnitude 4 stream. A convenient component of the Shreve system is that a stream's magnitude corresponds to the number of magnitude 1 or 1st order streams contributing to the channel.

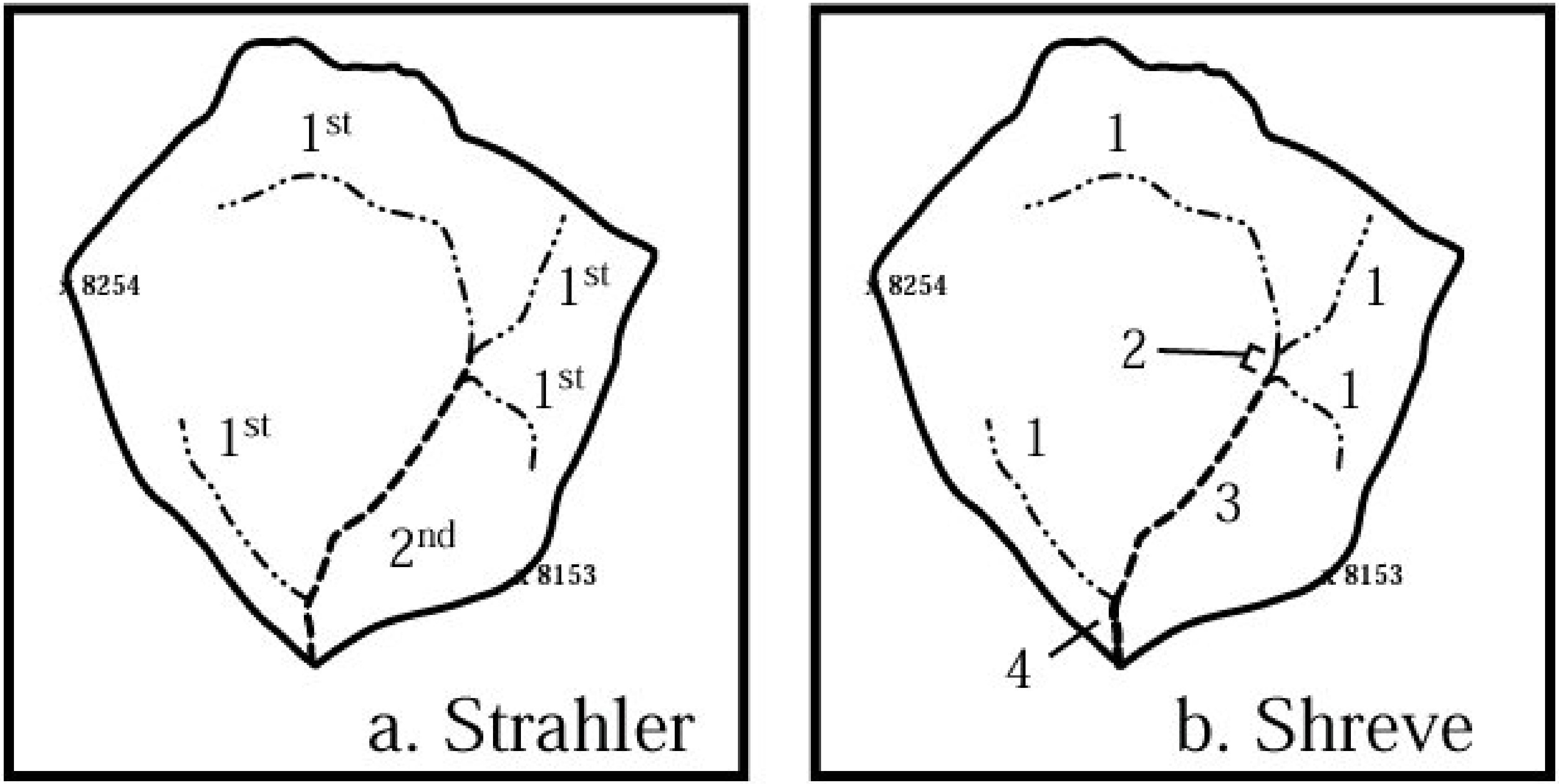


Figure : Stream order. Orders increase in the Strahler stream order system where two streams of equal order meet.

In the Shreve magnitude system, magnitudes increase through addition at all stream junctions.

Using the Shreve system, the number of magnitude 1 streams in a basin is equal to the basin's magnitude.

The number of 1st order streams in a basin of a given size is dependent upon a variety of climatic, geologic, and hydrologic factors.

For instance, holding all other variables constant we would expect that a drainage basin in an arid climate would have *more* 1st order streams than a watershed in a more humid climate.

Similarly, increasing relief is associated with increasing stream densities.

2. Stream Length : Stream length, or more appropriately channel length, is an important morphological variable.

The **law of stream lengths** suggests that the length of streams in successive stream orders increases following a geometric relationship.

Similarly, the number of streams within each order decreases with order in a linear fashion.

3. Law of Stream Numbers or Bifurcation Ratio (Rb): -
Not only are the numbers and lengths of particular stream orders important, but their ratios are quite instructive as well.

Consider a dendritic drainage pattern versus trellis. In an ideal dendritic drainage pattern, the number of 1st order tributaries would be exactly twice the number of 2nd order streams.

Thus, the number of 1st order streams will be exactly twice that of 2nd order streams.

In a trellis network, long main stem streams are fed by many low order streams. As a result, 1st order streams typically outnumber 2nd order streams by 3 to 5 times.

Bifurcation Ratio is the relation between no. of streams of one order and of next higher order.

i.e., The relationship between the number of streams in successive stream orders is called the **bifurcation ratio (Rb)**.

This is obtained by dividing no. of streams in one order by the no. of the stream in next highest order for all the orders of the stream. These calculations were also based on Strahler method.

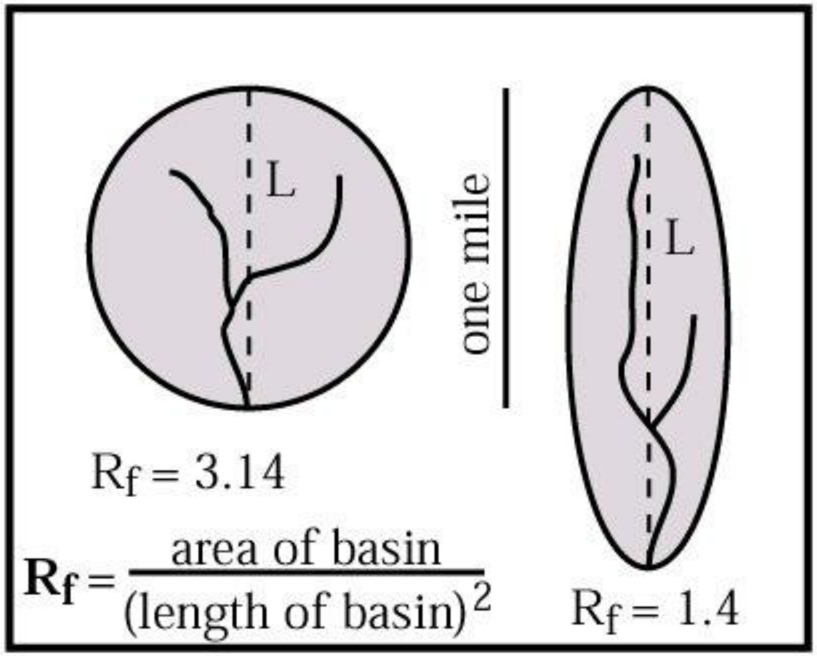
“The ratio between the number of streams of a given order to the number in the next order, has been found to vary around the value from 3 to 5 in basins where geology is reasonably homogeneous”.

$$R_b = \frac{S_{o-1}}{S_o}$$

where So is the number of streams in any given order and So-1 is the number of streams in the next lowest order.

4. Basin Shape (Rf): A measure of the elongation of a basin. As elongation increases for a given area, Rf decreases.

For a given area, as basin length increases
the value Rf decreases



The value Rf should be comparable among basins of very different size. To calculate Rf, simply measure the linear distance (L) between the mouth of the basin and the point most distant from the mouth and use the formula:

$$R_f = \frac{A_b}{L^2}$$

For instance, a **circular basin** with an area of 3.14 mi2 would have an Rf value of 3.14.
Whereas an **elliptical basin** 1.5 miles long, but with an area of 3.14 mi2 would have an Rf value of 1.4.

5. Ruggedness number (R): A combined measure of relief and stream density. As topography becomes more convoluted, the ruggedness number increases.

To calculate R, multiply the drainage density (D) by basin relief (H). Be sure to use the same unit of length as used in calculating drainage density (typically kilometers), R = DH

6. Relief / Height (H) / Basin Height : Relief is calculated by determining the difference between any two elevations.

Relative to a drainage basin, relief is measured by subtracting the elevation of the mouth of the basin from the highest point within the basin.

Some workers refer to this parameter as basin height.

7. Relief Ratio (Rh): A unitless measure of the overall gradient across a basin.

Calculated by dividing the relief (H) of a basin by its length (L).

Be sure to use values with equal units,

$$R_h = \frac{H}{L}$$

8. In addition, the **law of drainage areas** states that the area of the basin is related to stream order in a geometric series.

9. Perimeter Length (P): Perimeter length is the linear length of a drainage basin perimeter. One can measure this length with a string, map wheel / Rotometer, or digitizer.

Using a map wheel or digitizer/ rotometer, a pen-like device with a small wheel at the tip and large dial on top, perimeter can be calculated, by moving the wheel along a line, an arm on the dial is moved.

The length of the line, typically measured in inches, is read directly from the position of the arm on the dial.

Converting the dial units into ground distance is a simple matter.

For instance, if the wheel transcribed a distance of 2.5 inches on a 1:24000 scale map, one we can readily calculate that 2.5 inches multiplied by 2000 feet/inch equals 5000 feet.

Hence, the line we measured represents a distance of 5000 feet on the ground.

10. Drainage Density: -

The one important areal measurement is drainage density, which is simply defined as:

Dd = Sum of stream lengths / Basin Area. (Or) $D = \frac{\sum L_i}{A_b}$

where Li denotes stream lengths and Ab is drainage basin area

This is a useful measure of frequency and spacing of streams with in drainage basin.

Drainage density (Dd) is expressed in km. Channel length per sq.km of basin area.

Drainage density is an important index to geomorphologists and hydrologists because it provide a quantitative index of how dissected a drainage basin is.

The controls on drainage density are climate (which supplies precipitation for runoff and stream incision) and geology (resistance to erosion and as a control on runoff through infiltration).

11. Stream frequency :- It is the ratio of total no. of streams of any order & the area of the basin in which its lies. i.e.

$$F = Nu / Au$$

where, F – Stream frequency of any order 1- 4
Au – Area of basin where stream lies and
Nu – No. of streams of any order 1-4

12. Texture ratio:- It is the ratio of total no. stream of any order & perimeter of the area which it lays.

Hypsometric Curves:……..

GEOINFORMATICS (RS, DIP, DP, GPS & GIS) helps us to…

- Map the geologic, geomorphic and geodynamic elements
- Target both surface and groundwater resources easily
- Estimate the quantum of water available both in tanks and in the aquifers too.
- Determine the water quality and classify based on its suitability
- Identify the controlling parameters of ground water aquifers
- Suggest viable watershed management plans for sustainable development
- Locate suitable sites for recharge and
- Identify suitable mechanisms for recharge
- Install the planned recharge structures in correct place
- Monitor and maintain them, and similar other relevant activities.

Central Pivot irrigation system in Kansas using Ogallala Aquifer – Circular crop fields are covering 100s of sq.km

Research & Development studies conducted and **Pilot Models** developed on various aspects of Water Resources at Centre for Remote Sensing, Bharathidasan University are:

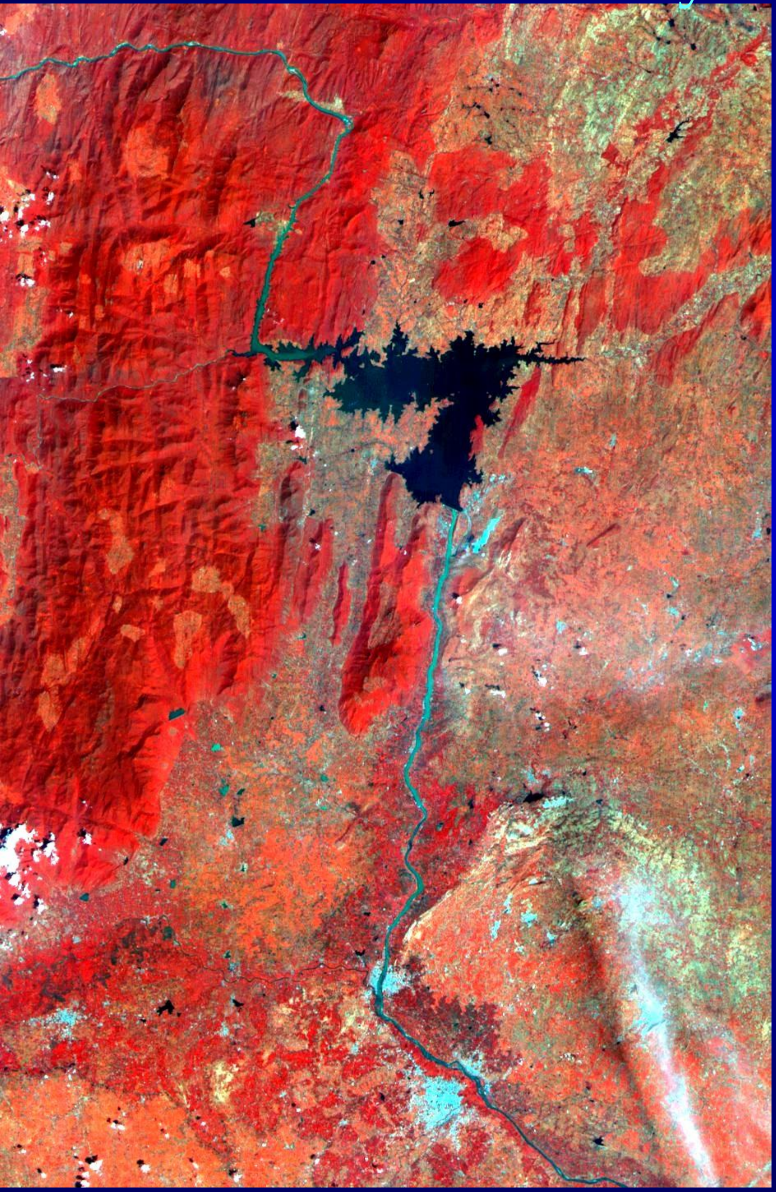
- ☛ Watershed wise Runoff Modelling
- ☛ Tank – Reservoir Storage Forecasting
- ☛ Surface Water Targetting
- ☛ Surface water Quality from Satellite data
- ☛ Soil Erosion – Reservoir Siltation and Remedial Measures
- ☛ Groundwater Modeling
- ☛ Groundwater Targetting
- ☛ Artificial Recharge.

IRS 1A BAND – 4 (NIR) DATA
(Raiapalayam – Sankarankovil area)

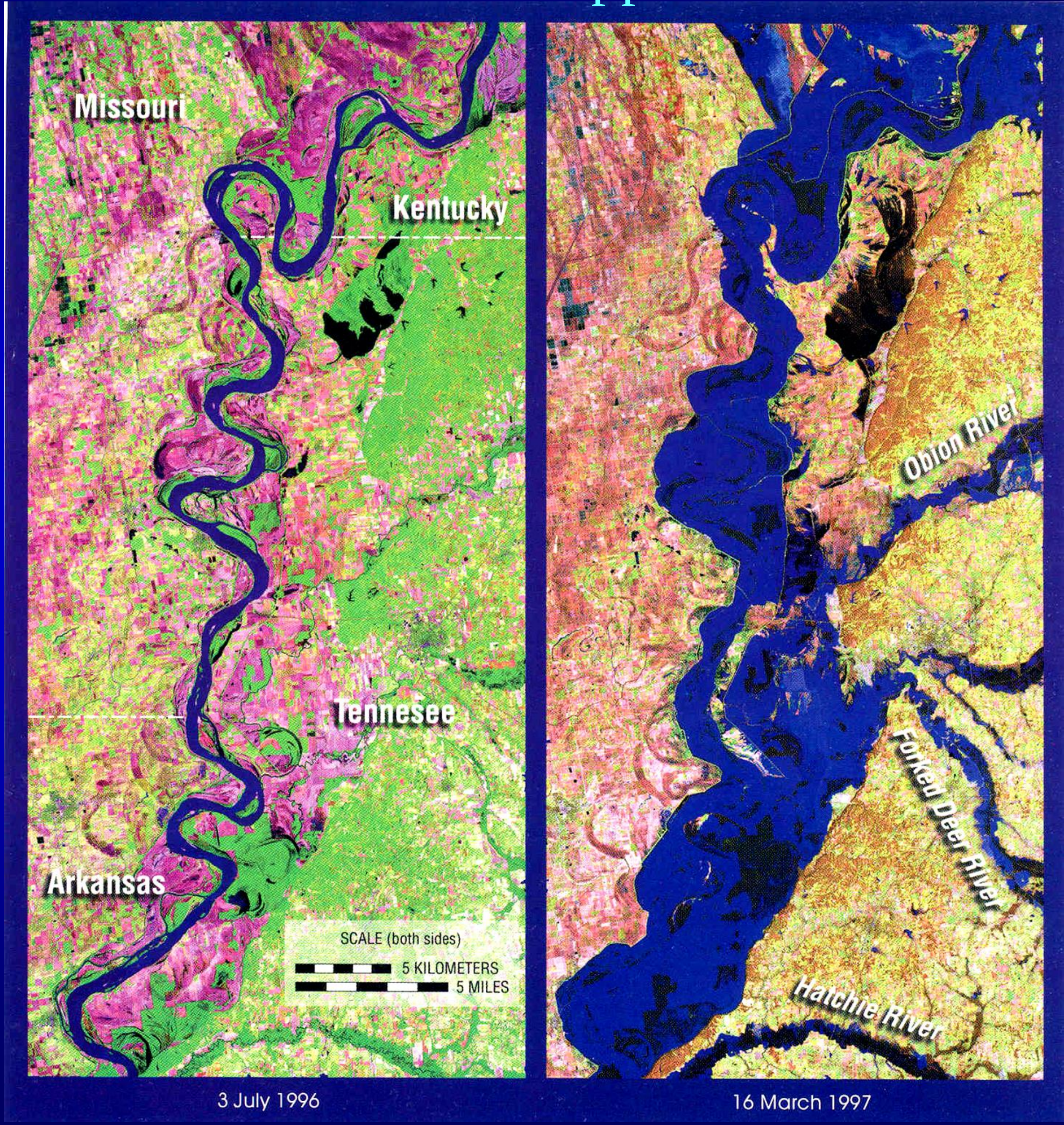
Surface Water

SURFACE WATER RESOURCES

Mettur Dam – Cauvery river



Mississippi River

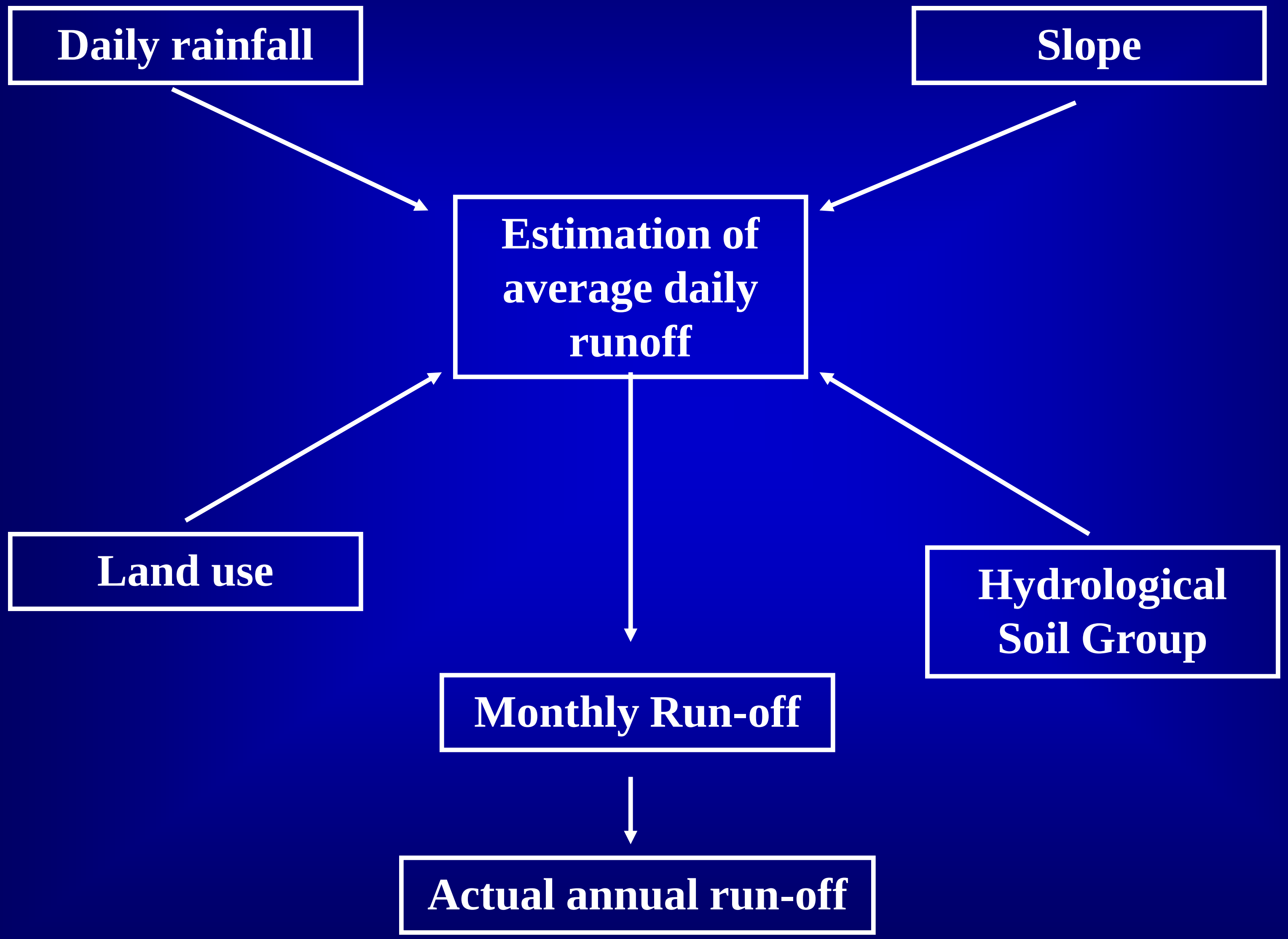


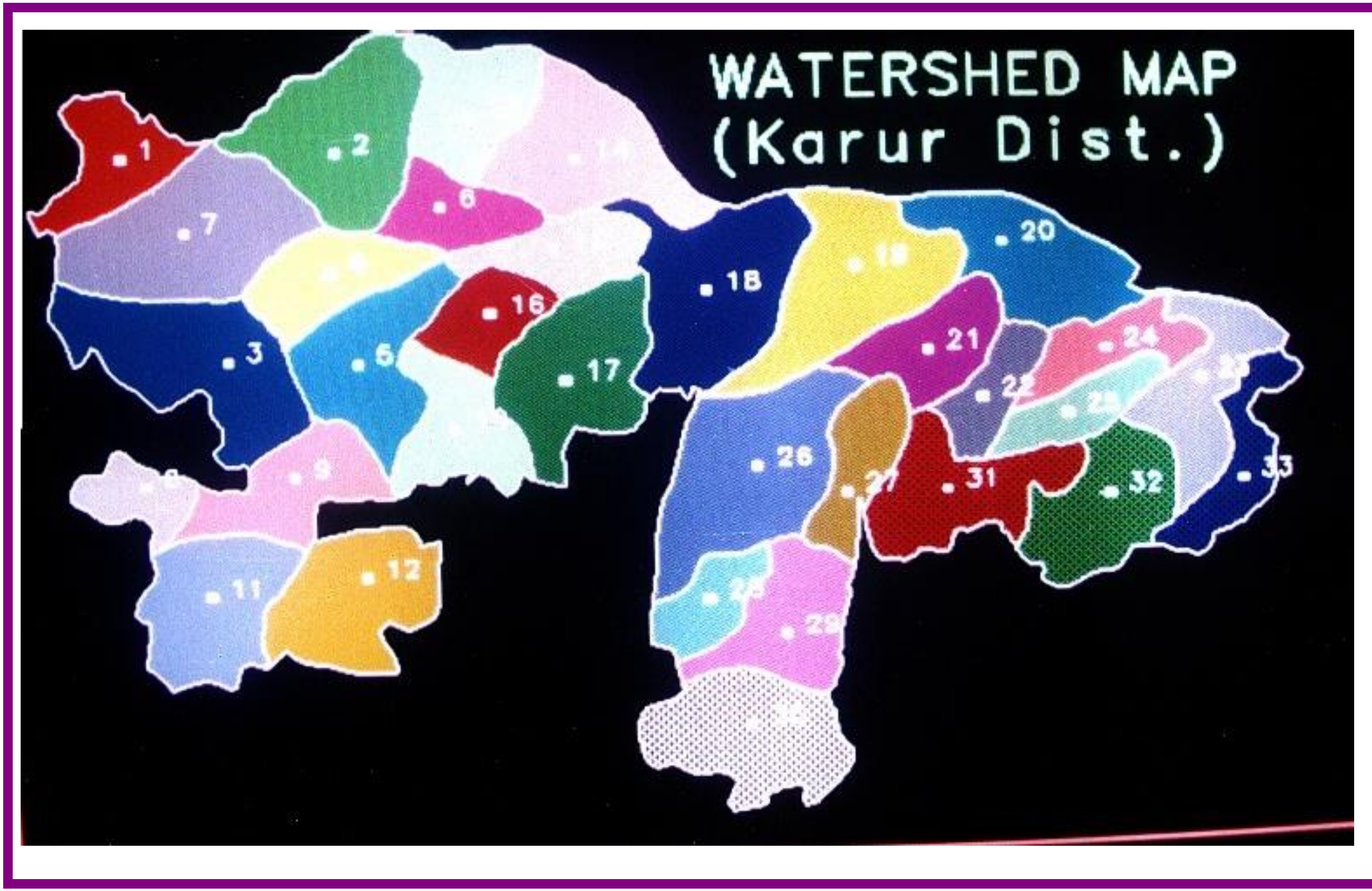
STUDY 1

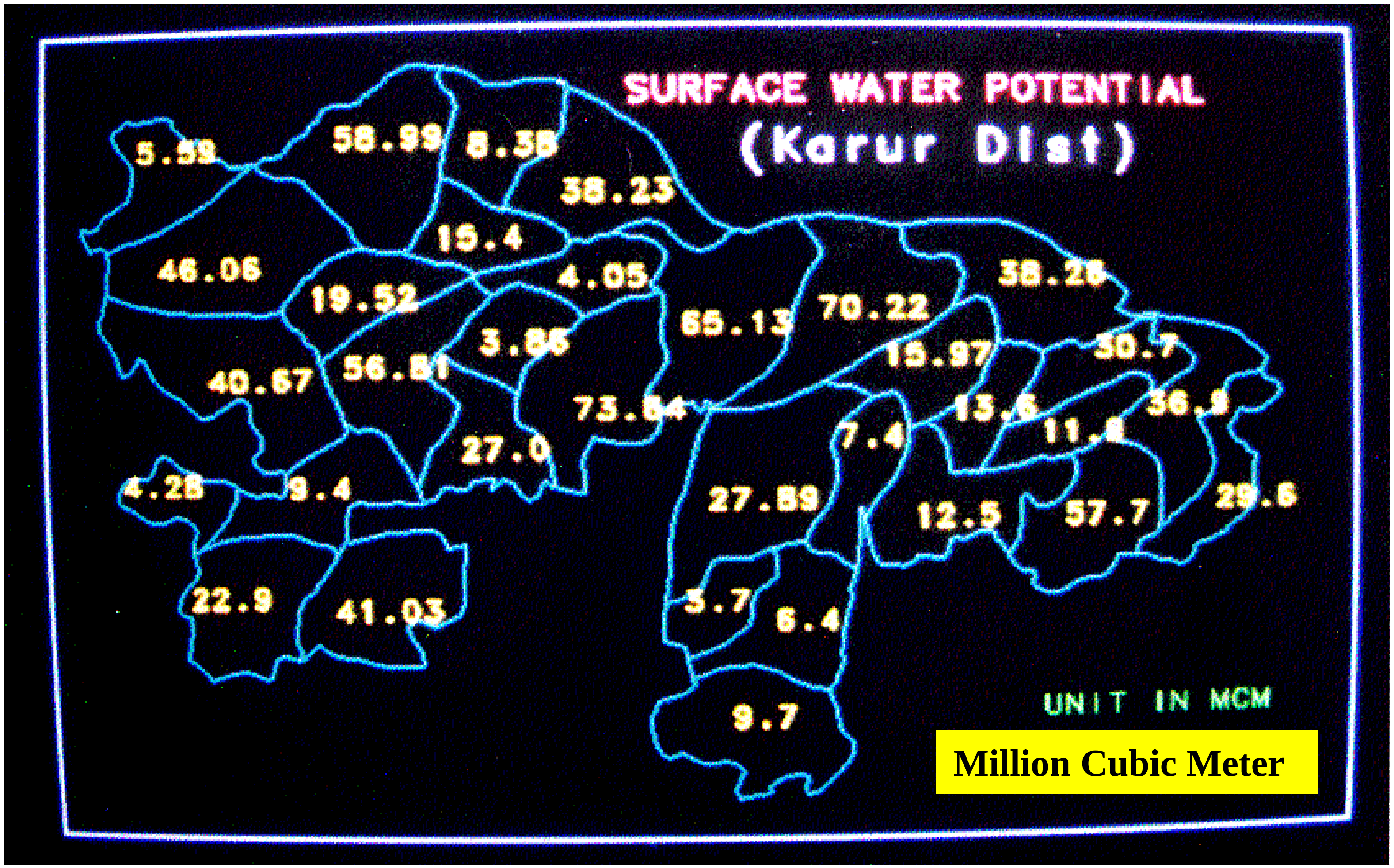
WATER SHEDWISE RUNOFF MODELING

- **INPUT DATA**
  - **Daily Rain Fall**
  - **Slope**
  - **Hydrological Soil Group**
  - **Land Use and Land Cover**
- **OUTPUT DATA**
  - Monthly **Run off**
  - **Annual Run Off**

ESTIMATION OF SURFACE WATER POTENTIAL / RUNOFF ESTIMATION




WATERSHED MAP
(Karur Dist.)
1
2
3
7
11
12
16
17
18
20
21
26
31
32
33


SURFACE WATER POTENTIAL
(Karur Dist)
58.99
38.23
15.4
46.06
19.52
4.05
65.13
70.22
40.67
15.97
30.7
27.0
7.4
9.4
27.89
12.5
57.7
22.9
41.03
6.4
9.7
UNIT IN MCM
Million Cubic Meter

STUDY - 2

TANK - RESERVOIR STORAGE FORE CASTING

- USING SATELLITE IR DATA

METHODOLOGY(in Brief)

Identification of 30 Surface Water Bodies each in Small, Medium and Major Categories

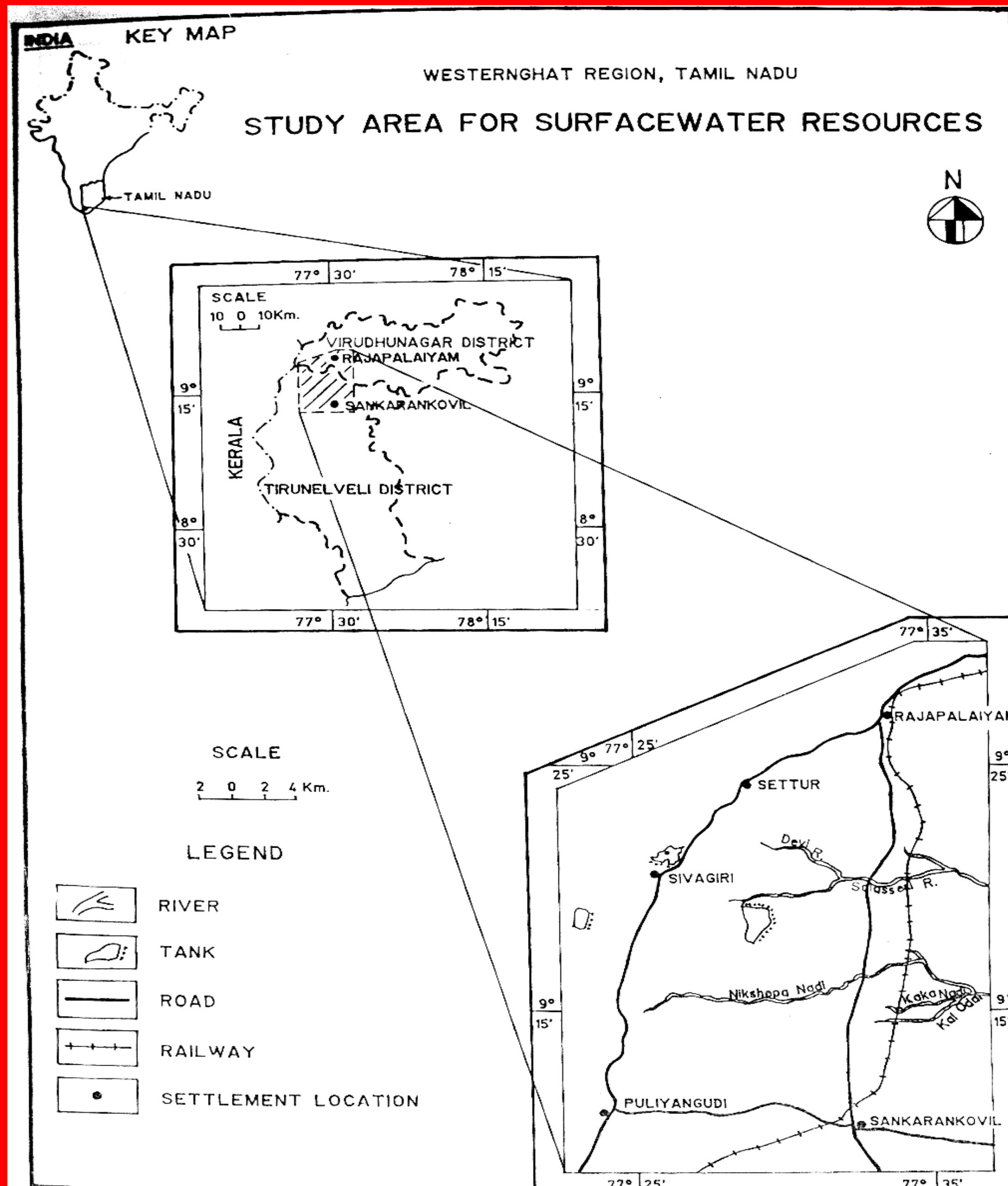
- Work out the Perimeter of Water Spread area from Satellite IR Data
- Work out Depth of Tanks
- Estimate Volume of Water in 30 Water bodies

- **Carry out Regression Analysis Between Water Volume Data of 30 tanks (Dependent Variable) and Perimeter of Water Spread area (Independent Variable) and Build up a Model**

> **Water Volume = Coefficient A+(Coefficient B X Water Spread Area**

- **Validate the model**

- **Feed the Perimeter data from future satellite data in the model and we can forecast the Water quantity**


INDIA
KEY MAP
TAMIL NADU
WESTERNGHAT REGION, TAMIL NADU
STUDY AREA FOR SURFACEWATER RESOURCES
N
SCALE
10 0 10Km.
VIRUDHUNAGAR DISTRICT
RAJAPALAIYAM
SANKARANKOVIL
KERALA
TIRUNELVELI DISTRICT
77° 30'
78° 15'
9° 15'
8° 30'
SCALE
2 0 2 4 Km.
LEGEND
RIVER
TANK
ROAD
RAILWAY
SETTLEMENT LOCATION
RAJAPALAIYAM
SETTUR
SIVAGIRI
Devi R.
Sarasseni R.
Nikshopa Nadi
Koka Nadi
Kal Odai
PULIYANGUDI
SANKARANKOVIL
77° 25'
77° 35'
9° 25'
9° 15'

SURFACEWATER QUANTIFICATION

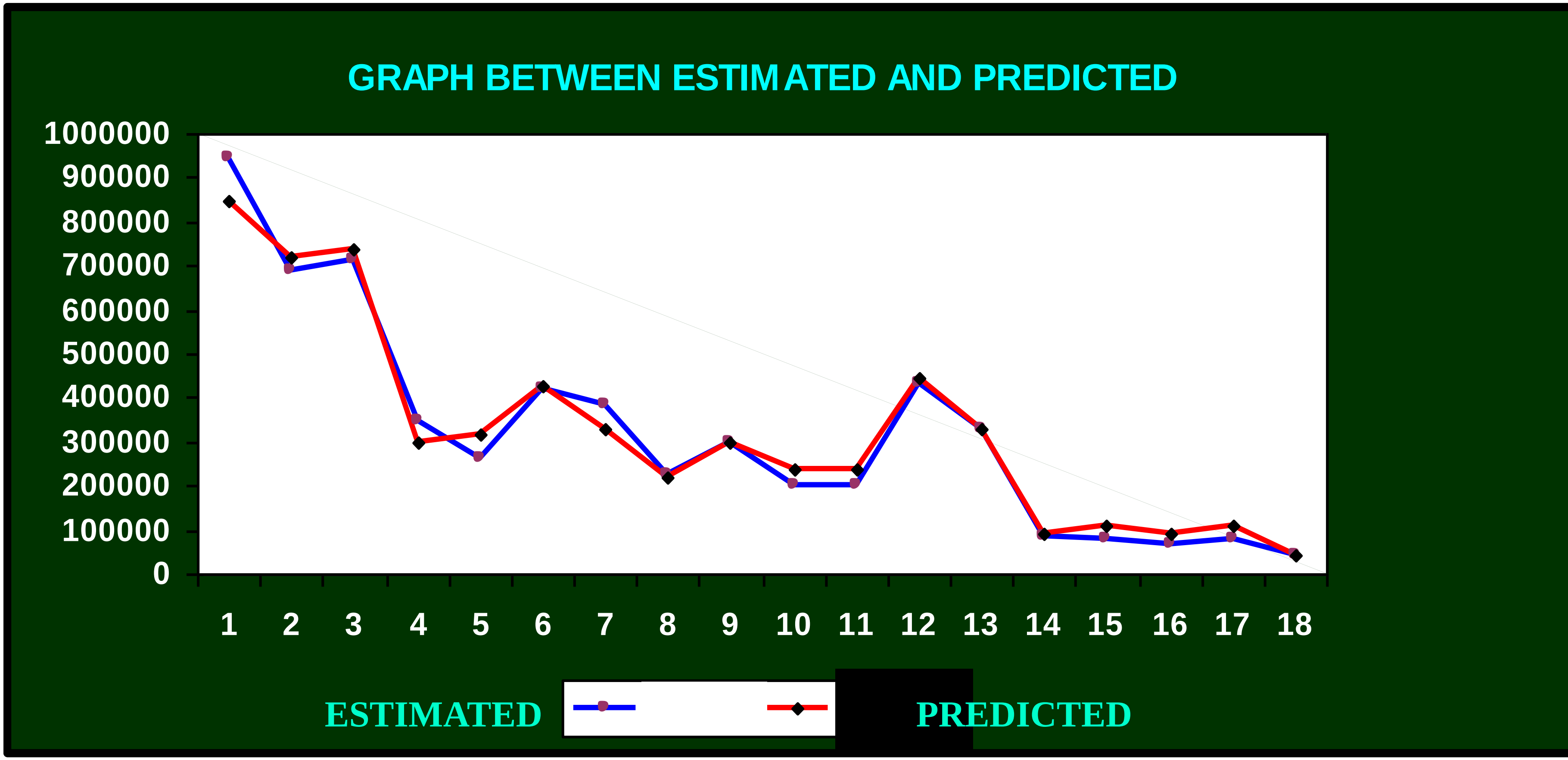
Sl.No.	Tank No.	Water Spread Area (in sq.mts)	Average Depth (in mts)	Water Volume (in cubic mts)
1	M-1	700000	1.50	1050000
2	M-2	640000	0.75	480000
3	M-3	700000	1.50	1050000
4	M-4	560000	2.50	1400000
5	M-5	470000	1.50	705000
6	M-6	420000	2.00	840000
7	M-7	480000	1.50	720000
8	M-8	200000	2.50	500000
9	M-9	140000	1.50	210000
10	M-10	100000	1.25	125000
11	I-1	160000	1.25	200000
12	I-2	60000	0.75	45000
13	I-3	150000	1.50	225000
14	I-4	250000	1.50	375000
15	I-5	120000	1.00	120000
16	I-6	250000	3.50	875000
17	I-7	280000	3.00	840000
18	I-8	180000	2.00	360000
19	I-9	150000	2.50	375000
20	I-10	100000	2.50	250000
21	I-11	130000	1.50	195000
22	I-12	150000	2.50	375000
23	I-13	170000	2.00	340000
24	I-14	180000	2.00	360000
25	I-15	260000	3.00	780000
26	I-16	80000	1.50	120000
27	I-17	120000	1.00	120000
28	I-18	100000	1.00	100000
29	I-19	80000	1.00	80000
30	I-20	230000	1.50	345000

M - Major Tank; I - Intermediate Tank; m - Minor Tanks

SURFACEWATER - PERIODICAL ASSESSMENT MODEL VALIDATION

Sl.No. (1)	Tank No. (2)	Water Spread Area (WSA) (in sq.mts) (3)	Water Volume Calculated (in Cubic mts) (4)	Water Volume by model Coef.A+(Coef.BxWSA) (in Cubic mts) (5)
1	VM-1	540000	945000	847466
2	VM-2	460000	690000	718666
3	VM-3	475000	712500	738066
4	VI-1	200000	350000	300066
5	VI-2	210000	262500	316166
6	VI-3	280000	420000	428866
7	VI-4	220000	385000	332266
8	VI-5	150000	225000	219566
9	VI-6	200000	300000	300066
10	VI-7	160000	200000	235666
11	VI-8	160000	200000	235666
12	VI-9	290000	435000	444966
13	Vm-1	220000	330000	332266
14	Vm-2	70000	87500	90766
15	Vm-3	80000	80000	106866
16	Vm-4	70000	70000	90766
17	Vm-5	80000	80000	106866
18	Vm-6	40000	40001	42466

VM - Validation Tank - Major
VI - Validation Tank - Intermediate
Vm - Validation Tank - Minor

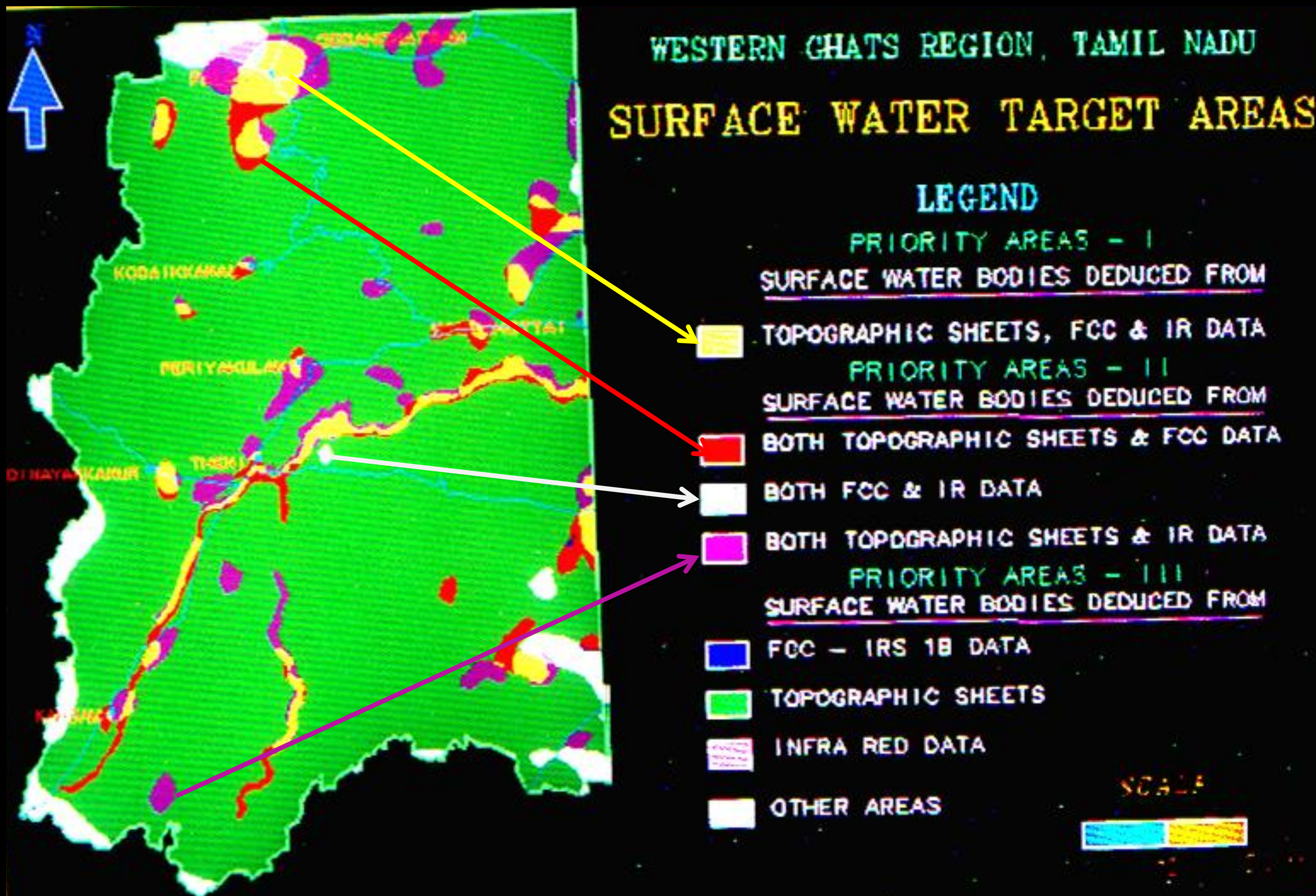

GRAPH BETWEEN ESTIMATED AND PREDICTED
1000000
900000
800000
700000
600000
500000
400000
300000
200000
100000
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
ESTIMATED
PREDICTED

STUDY - 3

SURFACE WATER TARGETTING - A SPATIAL DESIGN

METHODOLOGY IN BRIEF

- GIS Image Creation Showing Water Bodies Deduced from
  - Topo Sheets
  - Satellite FCC Data
  - Satellite IR Data
  - GIS Integration & Detection of Target Areas


WESTERN GHATS REGION, TAMIL NADU
SURFACE WATER TARGET AREAS
LEGEND
PRIORITY AREAS - I
SURFACE WATER BODIES DEDUCED FROM
TOPOGRAPHIC SHEETS, FCC & IR DATA
PRIORITY AREAS - II
SURFACE WATER BODIES DEDUCED FROM
BOTH TOPOGRAPHIC SHEETS & FCC DATA
BOTH FCC & IR DATA
BOTH TOPOGRAPHIC SHEETS & IR DATA
PRIORITY AREAS - III
SURFACE WATER BODIES DEDUCED FROM
FCC - IRS 1B DATA
TOPOGRAPHIC SHEETS
INFRA RED DATA
OTHER AREAS
SCALE
KODAIKKANAL
PERIYAKULAM

STUDY 4

SURFACE WATER QUALITY FROM SATELLITE DATA

- A Model from Cauvery River

METHODOLOGY IN BRIEF

- Spectro Radio metric Survey in Six Pollution Points in Cauvery for 5 Days
- Thus Generation of 30 Data Bases on TM 4bands, IRS 4bands and SPOT 3bands (11)
- Water Sample Collection and Quality Analysis of 30 Samples on Temperature, Turbidity, B.O.D, C.O.D, Total Hardness, Nitrate, pH, Silica, Fluoride, etc
- Carry out Graphical Correlation
- Carry out Bivariate Regression Analysis
- Generate Pollution Monitoring Model Directly from Satellite Data

Physico - Chemical Parametes	*TM bands*				*Chinthamani IRS bands*				*Spot bands*		
	1	2	3	4	1	2	3	4	1	2	3
Temperature	F	N	N	N	N	N	N	N	N	N	N
Turbidity	–	–	–	–	–	–	–	–	–	–	–
Biological Oxygen Demand	F	⊕	F	F	F	⊖	N	⊕	N	⊕	⊖
Chemical Oxygen Demand	F	⊕	F	F	F	⊕	N	⊕	N	⊕	⊕
Total Hardness	F	⊕	F	F	F	⊕	N	⊕	N	⊕	⊕
Nitrate	N	⊕	N	F	F	⊖	N	⊕	N	⊕	N
pH	–	–	–	–	–	–	–	–	–	–	–
Silica	N	N	N	N	N	⊕	F	N	N	N	N
Flouride	–	–	–	–	–	–	–	–	–	–	–

+ **Positive correlation**

F **Fair correlation**

- **Negative correlation**

N **No correlation**

Physico - Chemical Parameters	*Sarkarpalayam*										
	TM bands				*IRS bands*				*Spot bands*		
	1	2	3	4	1	2	3	4	1	2	3
Temperature	F	F	F	F	F	⊕	⊕	F	⊕	F	F
Turbidity	–	–	–	–	–	–	–	–	–	–	–
Biological Oxygen Demand	F	⊕	F	F	F	F	F	F	F	F	F
Chemical Oxygen Demand	F	F	⊕	F	F	F	F	F	F	F	F
Total Hardness	F	F	⊕	F	F	F	F	F	F	F	F
Nitrate	F	⊕	⊕	F	F	⊕	F	⊕	F	F	F
pH	–	–	–	–	–	–	–	–	–	–	–
Silica	F	⊕	⊕	F	F	⊕	F	⊕	F	F	F
Flouride	F	⊕	⊕	F	F	⊕	F	⊕	F	F	F

+ Positive correlation | **F Fair correlation**

- Negative correlation | **N No correlation**

STUDY - 5

SOIL EROSION - RESERVOIR SILTATION
AND
REMEDIAL MEASURES

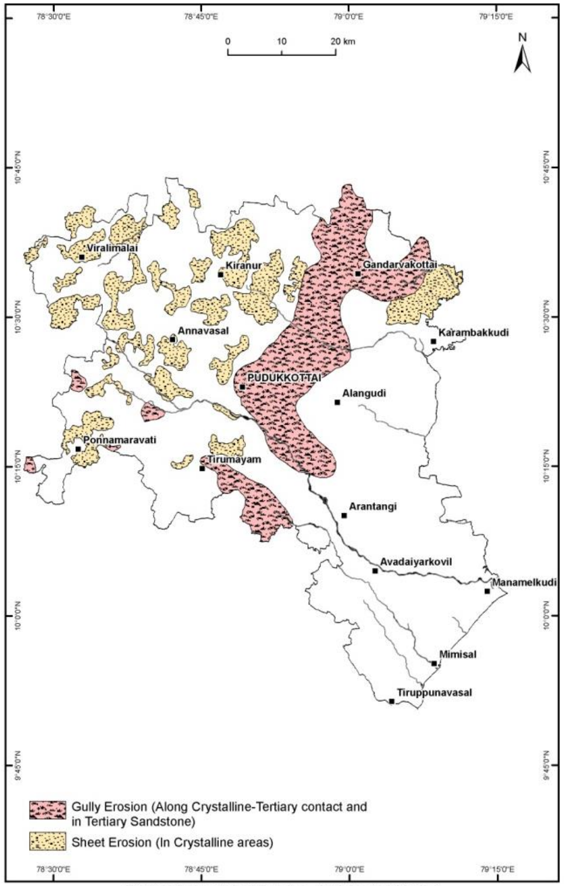


Fig.6.16 Areas of Soil Erosion - Pudukkottai District

SOIL RESOURCES

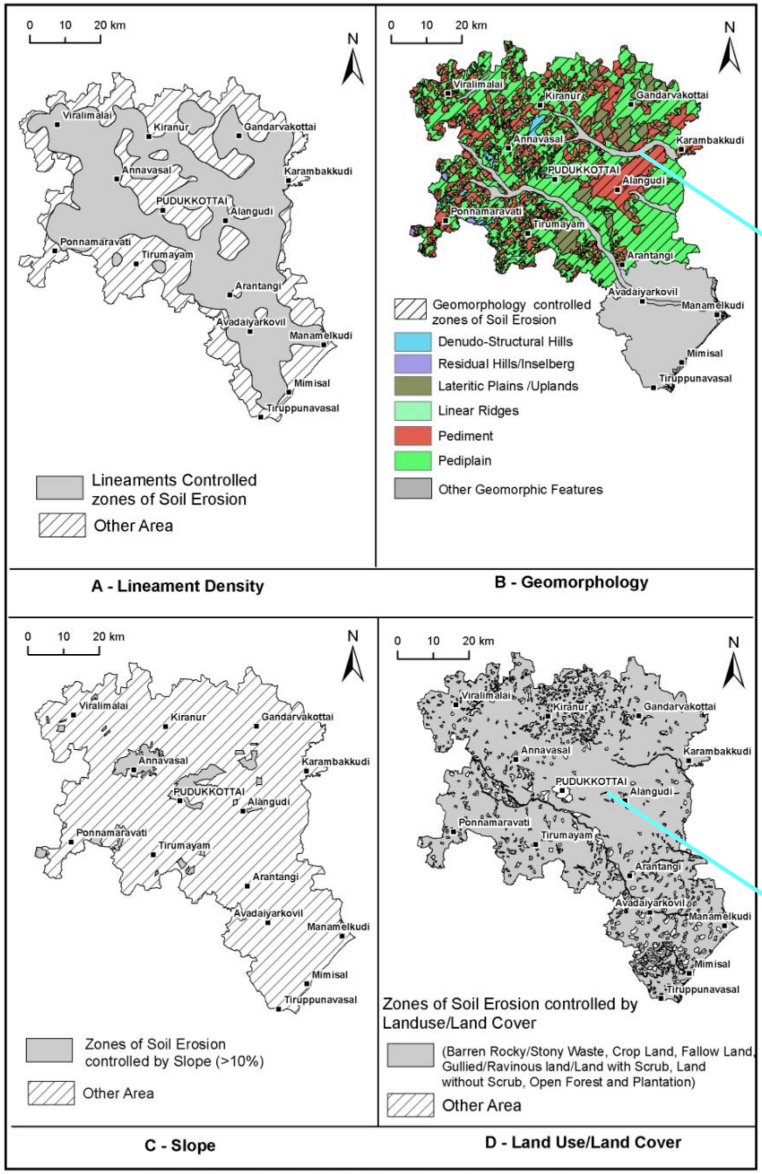


Fig.6.17 Soil Erosion Controlling Geosystem Parameters

Soil erosion prone Geomorphic features

Soil erosion prone LU/LC

Soil Erosion Functional Model

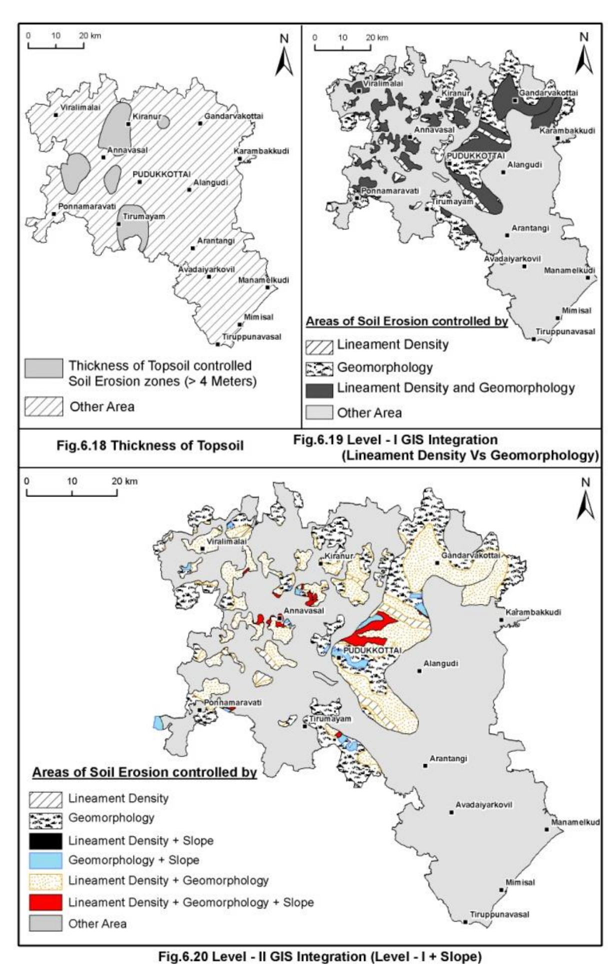


Fig.6.18 Thickness of Topsoil

Fig.6.19 Level - I GIS Integration (Lineament Density Vs Geomorphology)

Fig.6.20 Level - II GIS Integration (Level - I + Slope)

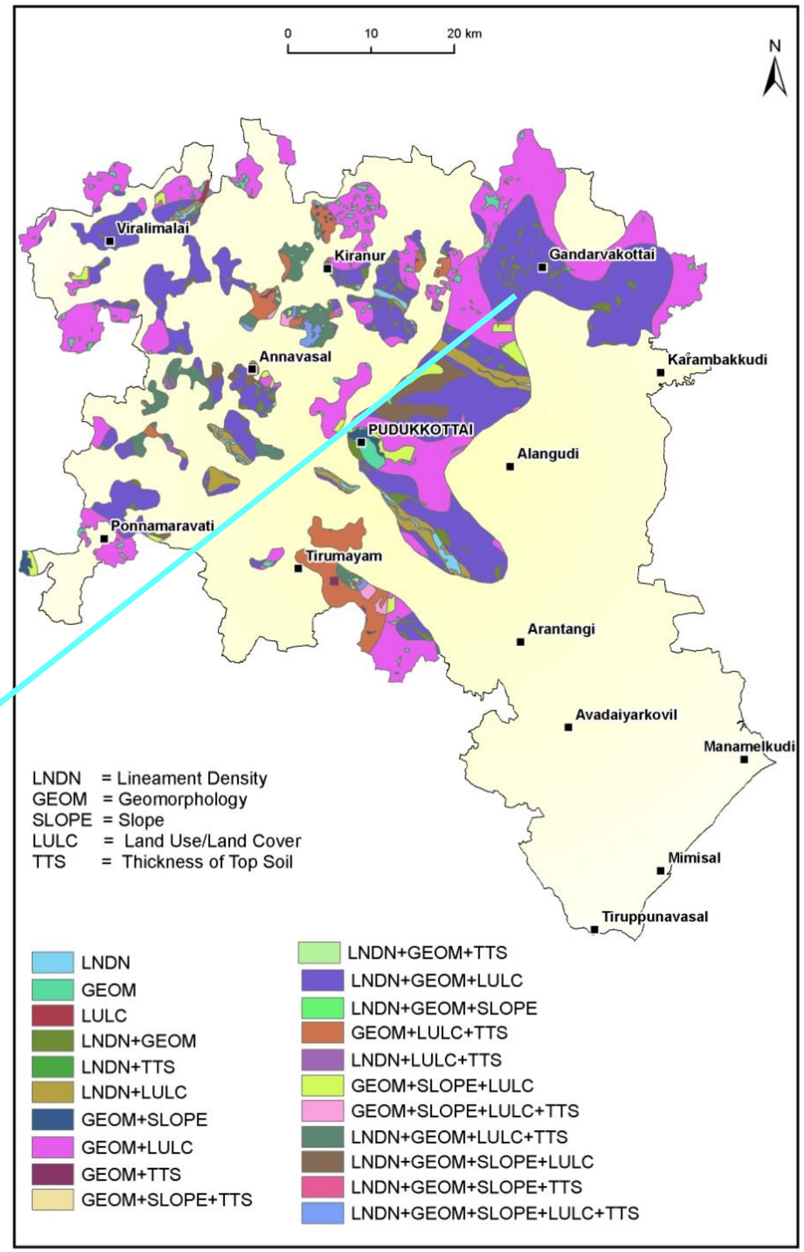


Fig.6.21 Soil Erosion Functional Model - Pudukkottai District

Soil erosion Controlled by LNDN + GEOM + LU/LC

Sl. No.	Controlling Geo-system Parameters	Remedial Measures
1	Lineament Density	Gully Plugging, Gully Filled Vegetation
2	<u>Erosion prone Geomorphology</u> 2.1 Residual hills/Inselberg, Denudo-Structural hills	Afforestation, Contour bounding
	2.2 Lateritic Plains/Uplands	Plantations, Dry land Irrigation, Horticulture
	2.3 Pediment/Pediplains	Agriculture, Horticulture, Mixed Plantation, etc
3	Slope	Contour bounding, Bench Cultivation, Check Dam, Silt trapping
4	<u>Landuse/Land Cover</u> 4.1 Barren Rocky/Stony Waste	Afforestation, Horticulture
	4.2 Fallow Land	Cultivation, Deep penetrating rooted Plants
	4.3 Gullied land/Ravenous land	Gully Plugging, Gully filed Vegetation
	4.4 Open Forest and Plantation	Intensive Afforestation
5	Thickness of Topsoil	Afforestation,Geotextiling, Irrigation

Silted Water Bodies

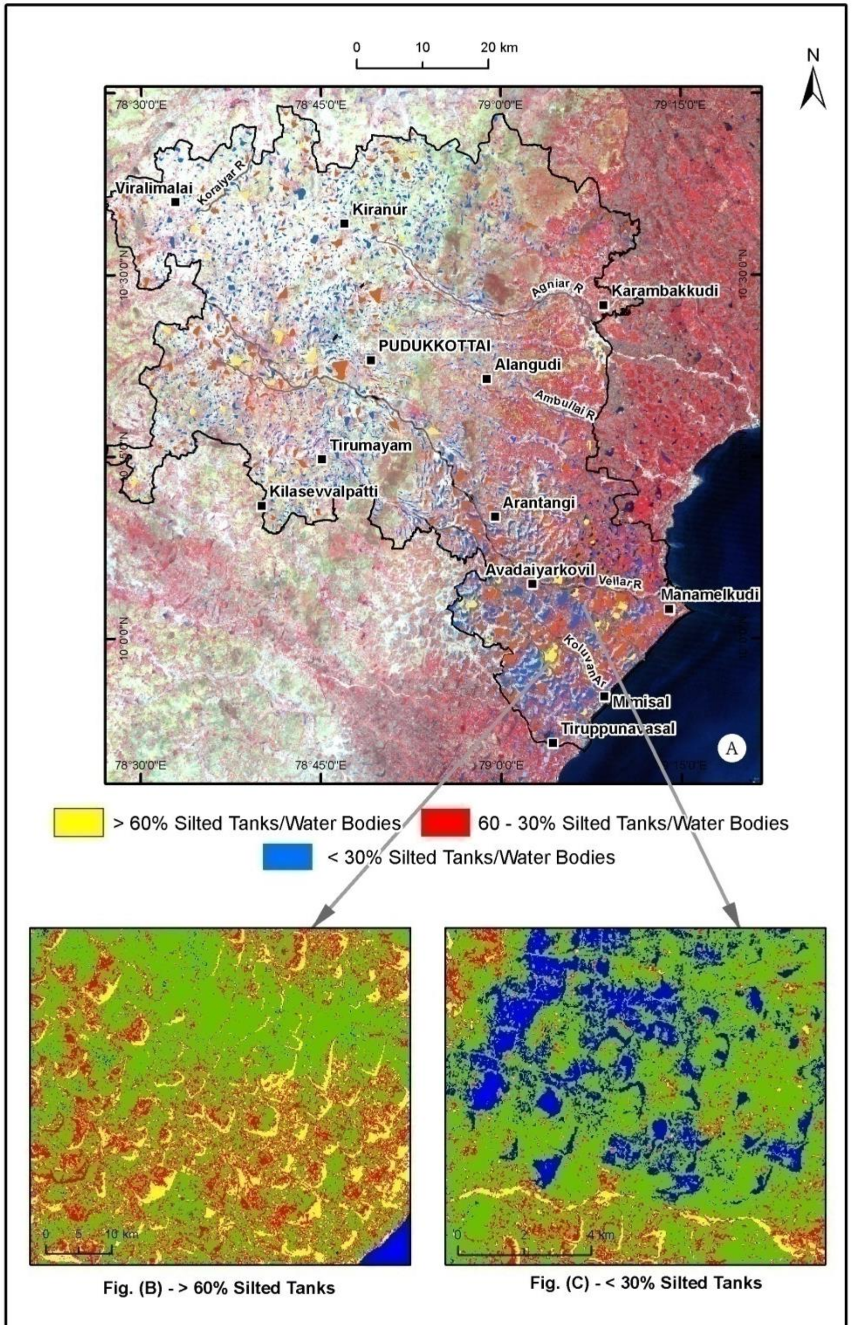


Fig. (B) - > 60% Silted Tanks

Fig. (C) - < 30% Silted Tanks

Fig. 5.2 IRS FCC (A) and Density Sliced (B and C) Images showing Silted Water Bodies

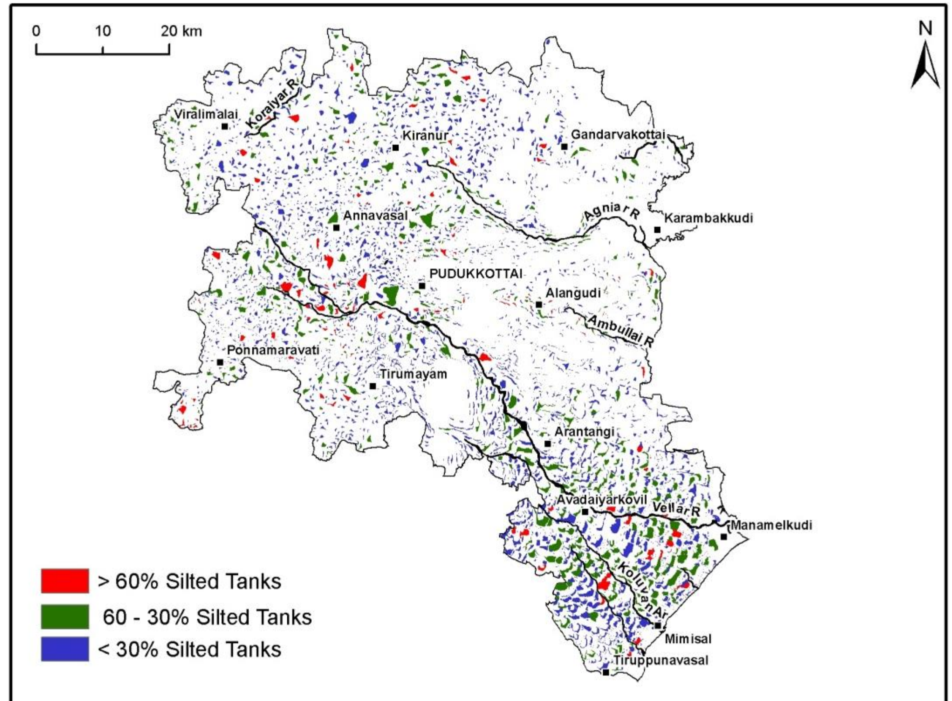


Fig. 6.22 Silted Tanks/Water Bodies

REMOTE SENSING AND GIS BASED SOIL EROSION VULNERABLE AREA MAPPING AND MITIGATION MODELLING FOR MADURAI, THENI AND DINDIGUL DISTRICTS, TAMIL NADU, INDIA

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[1]Centre for Remote Sensing, Bharathidasan University, Tiruchirappalli

[2]Gandhigram Rural Institute-Deemed University, Dindigul, Tamil Nadu

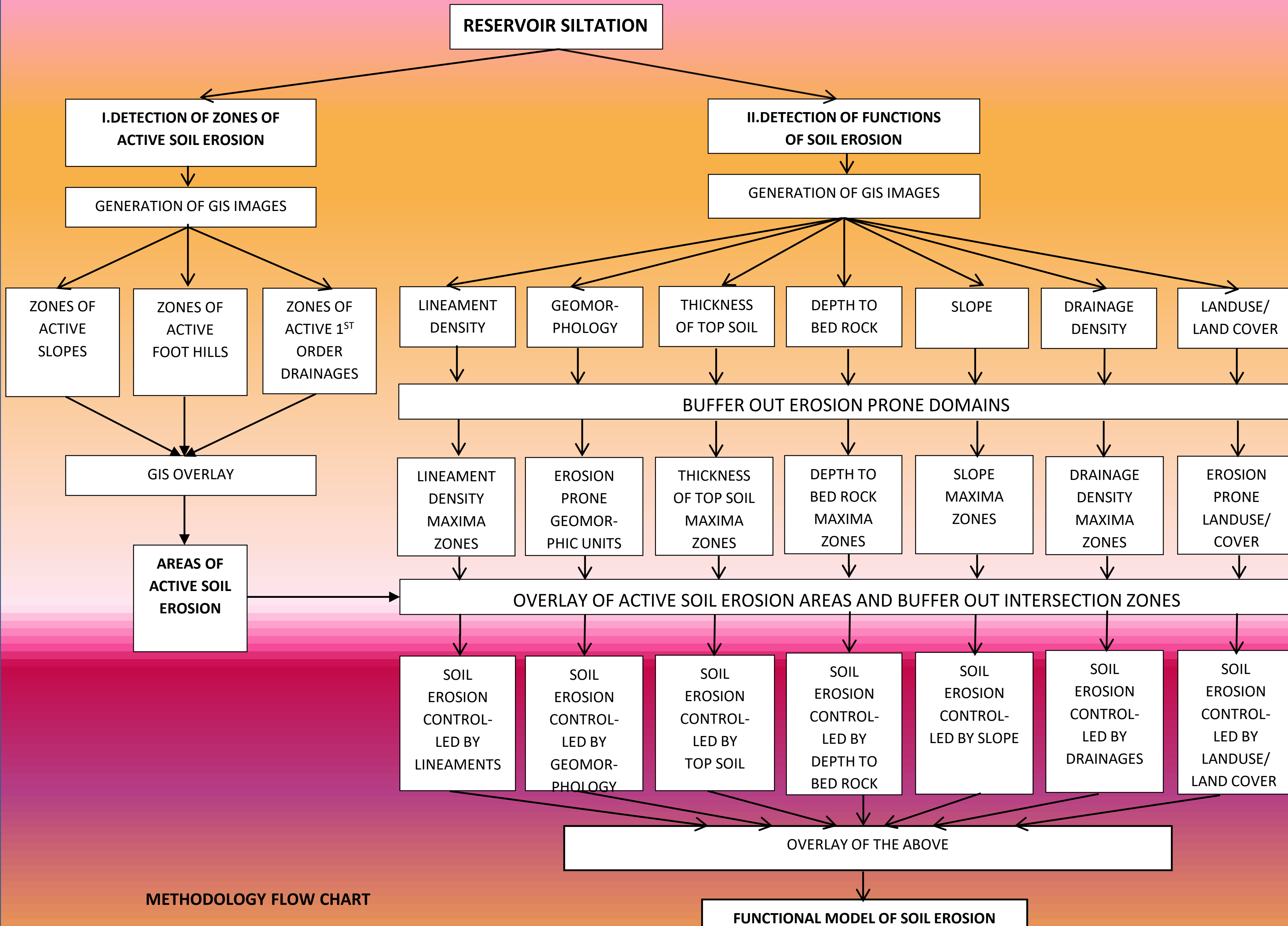
Email: kkpvl@yahoo.co.in

About the study area

- Soil is one among the very important natural and non-renewable resources for the existence of life
- All the water bodies in the study area, i.e., Madurai, Theni and Dindigul districts, are heavily silted due to the sand, silt and clay soil brought from the upper catchments due to erosion.
- The study area consists of more than 10m of thickness of fertile top soil to a maximum of 45m, developed from weathered charnockite rock, covers most part.

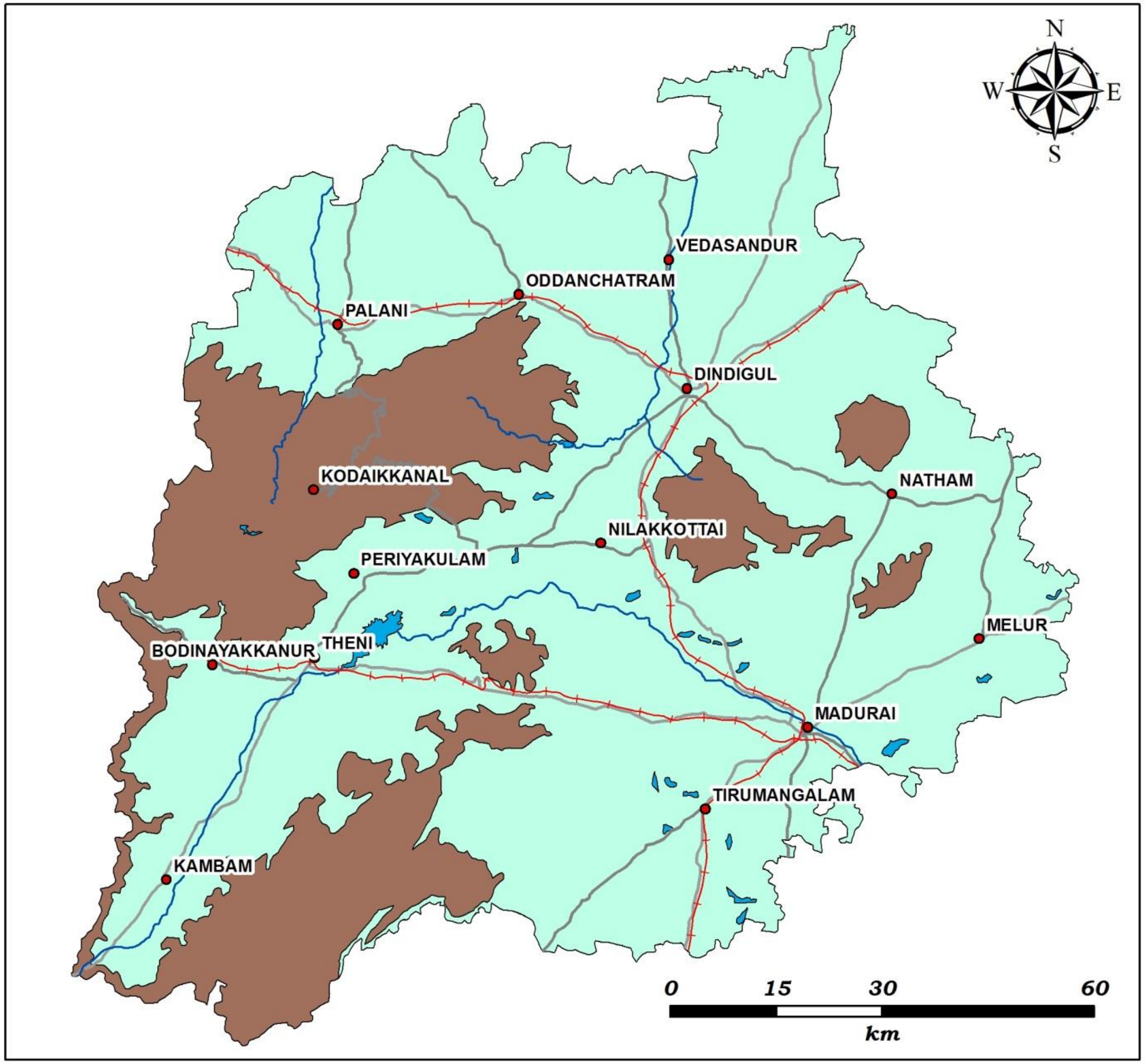
Aims & Objectives

- Generation of digital database on the geosystem parameters
- Identification of zones vulnerable for soil erosion
- Understanding the combinations of inducing parameters of soil erosion
- Suggestion of remedial measures based on the functions of soil erosion.



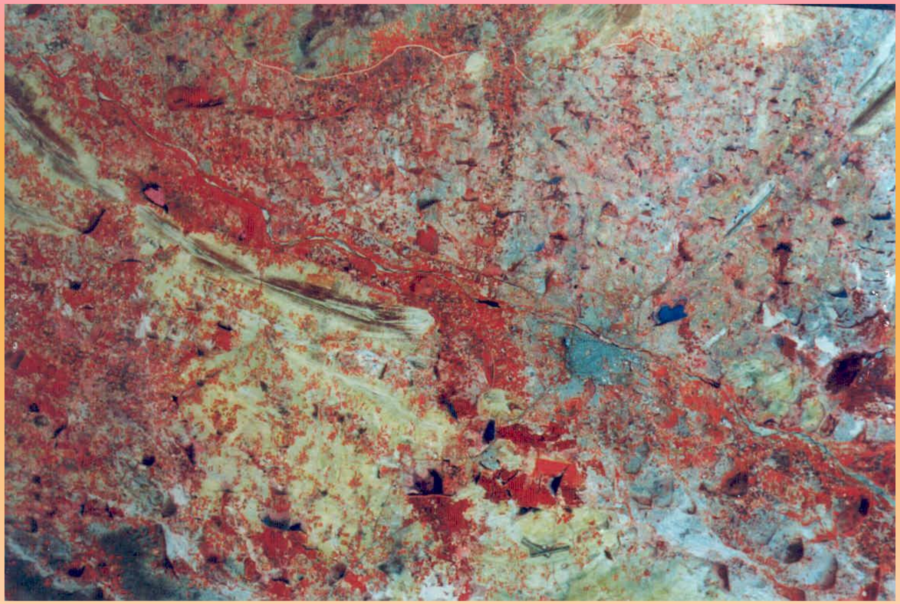
METHODOLOGY FLOW CHART

BASE MAP
Parts of Western Ghats, Tamil Nadu

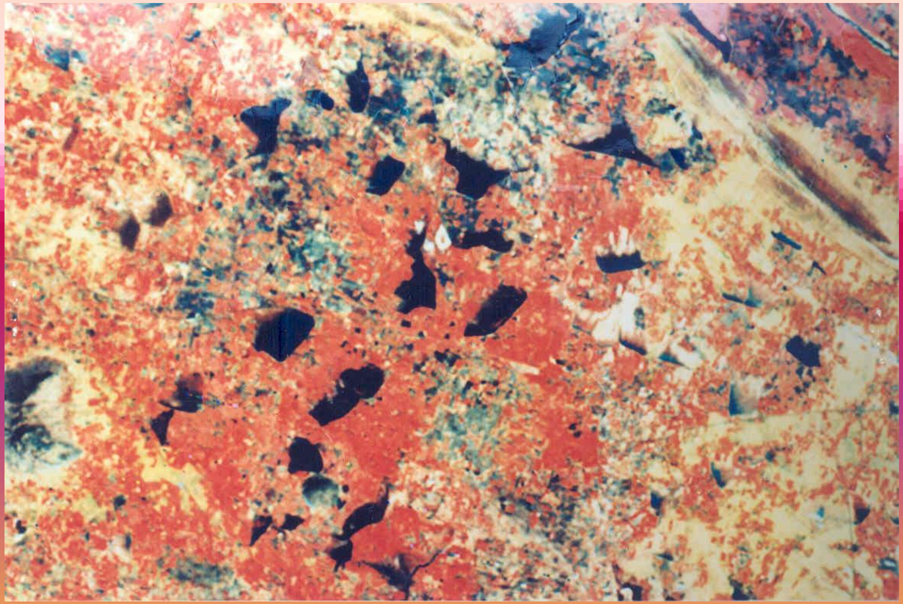


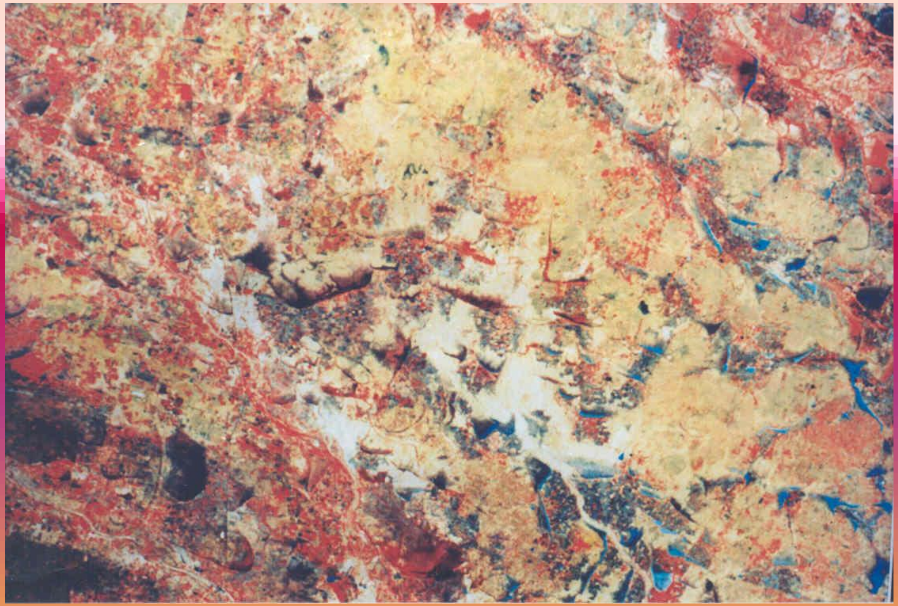
Legend

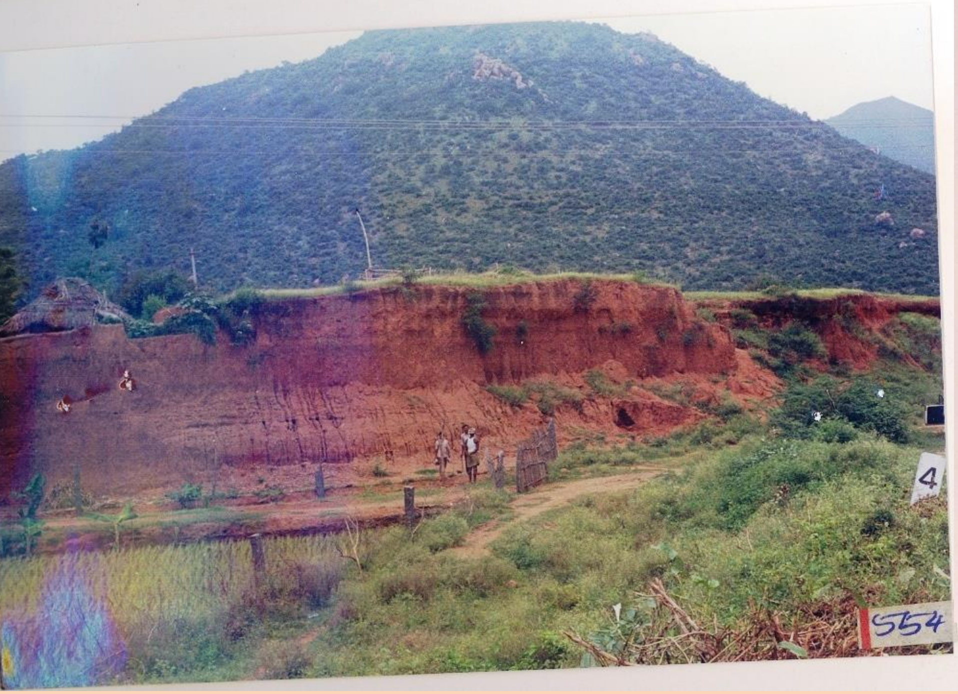
- Major Settlements
- Rail Network
- Major Road Network
- River
- Reservoirs / Major Tanks
- Major Hills
- Plain



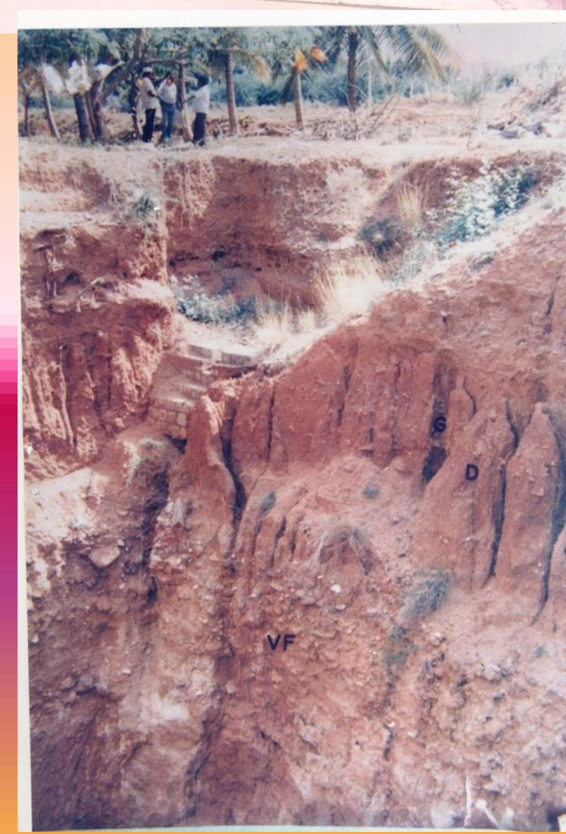
IRS satellite FCC images showing areas of soil erosion and silted water bodies






4
554

611

612

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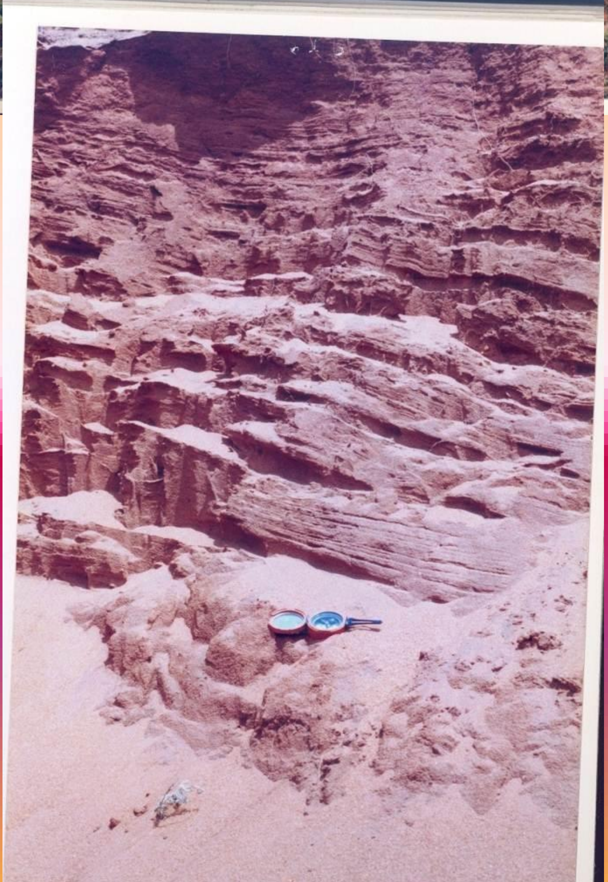
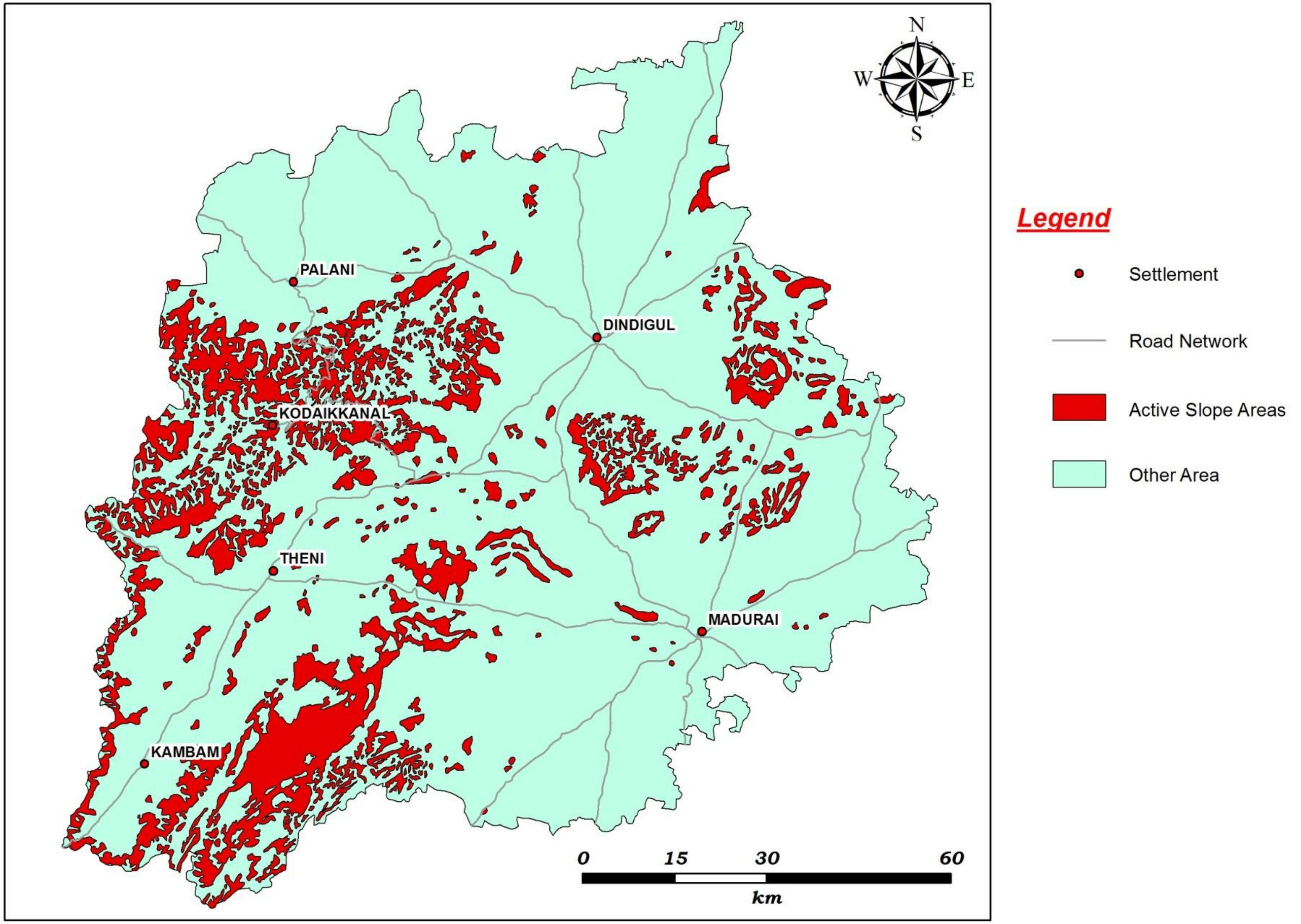
VF

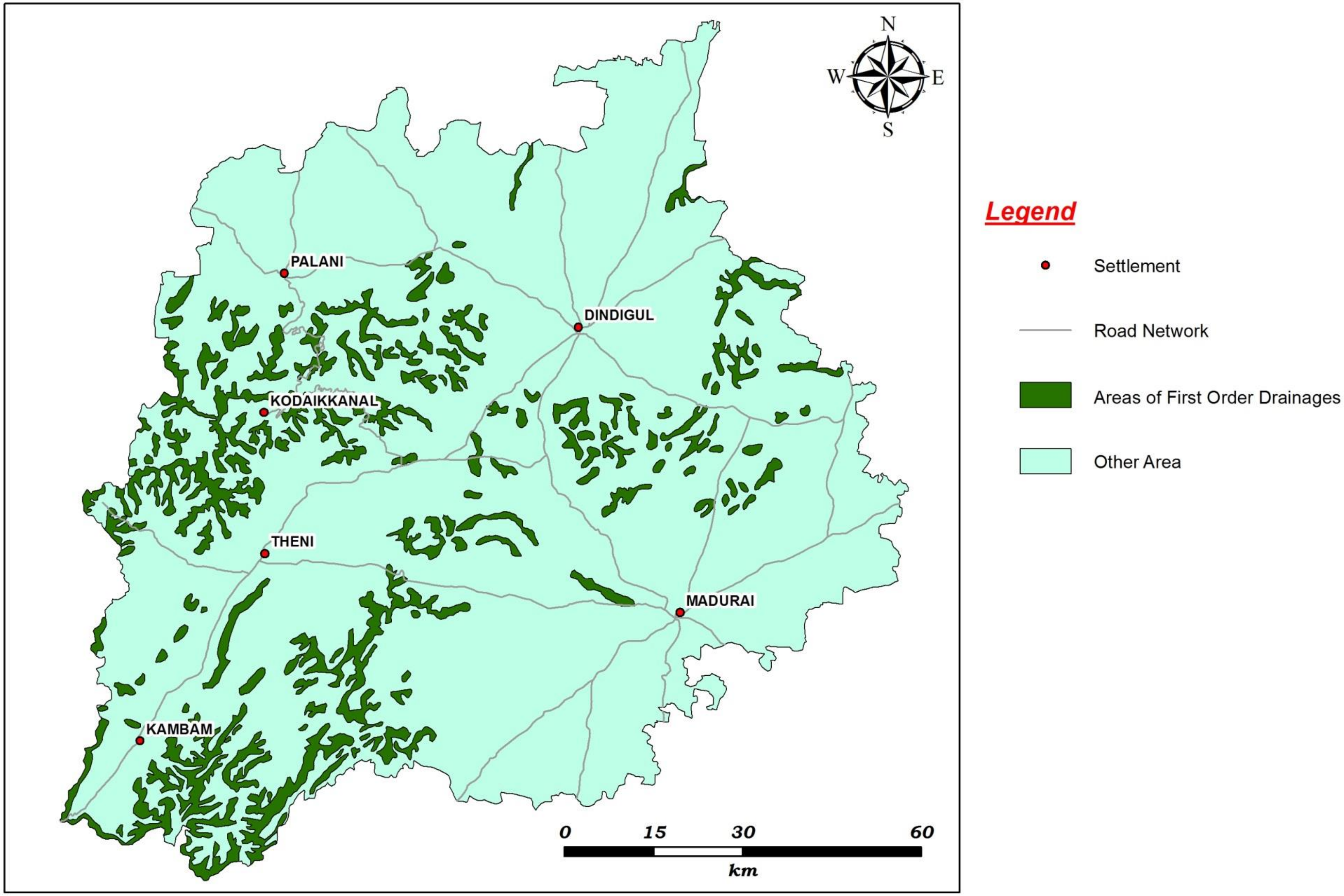


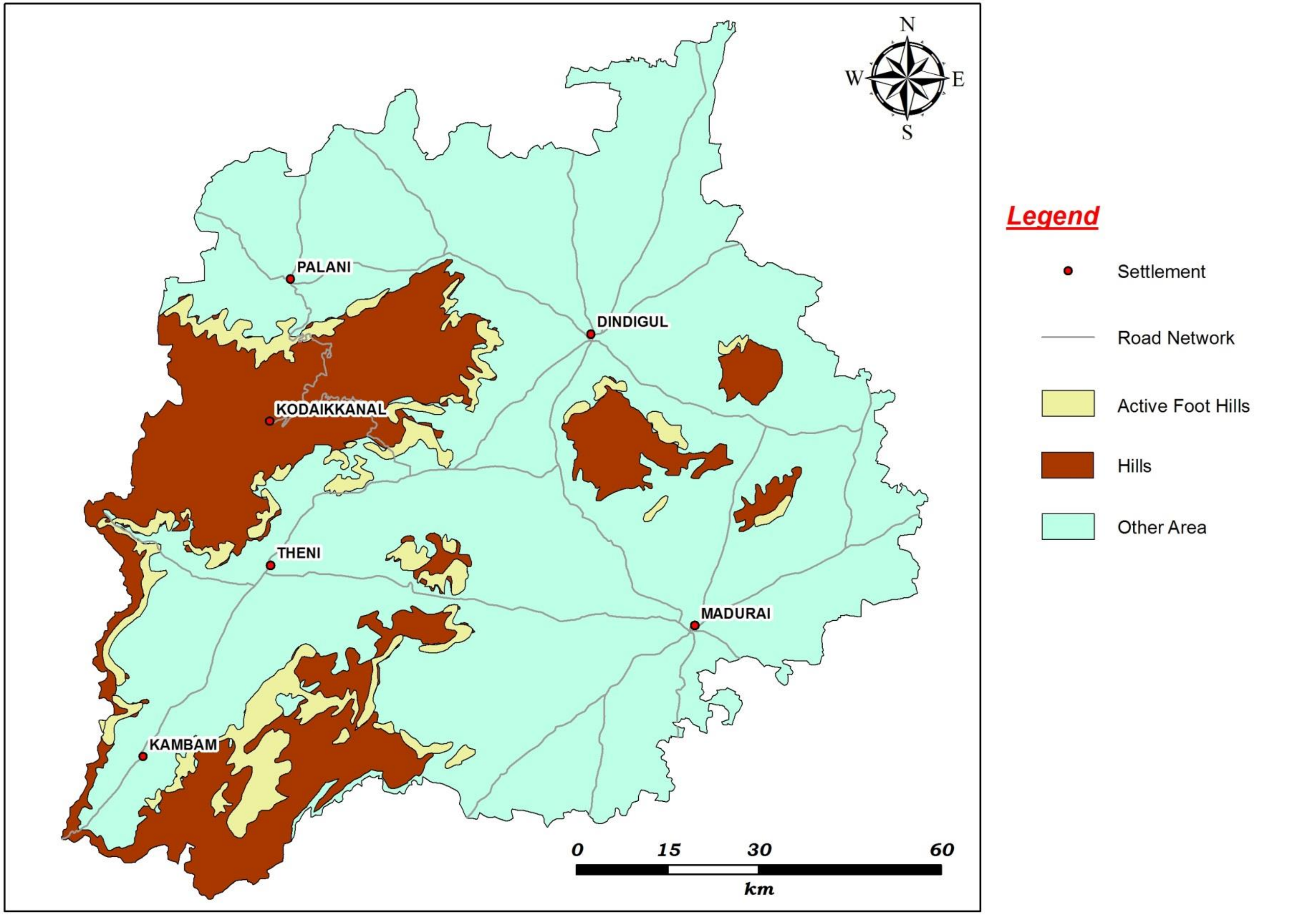
ACTIVE SLOPE AREAS



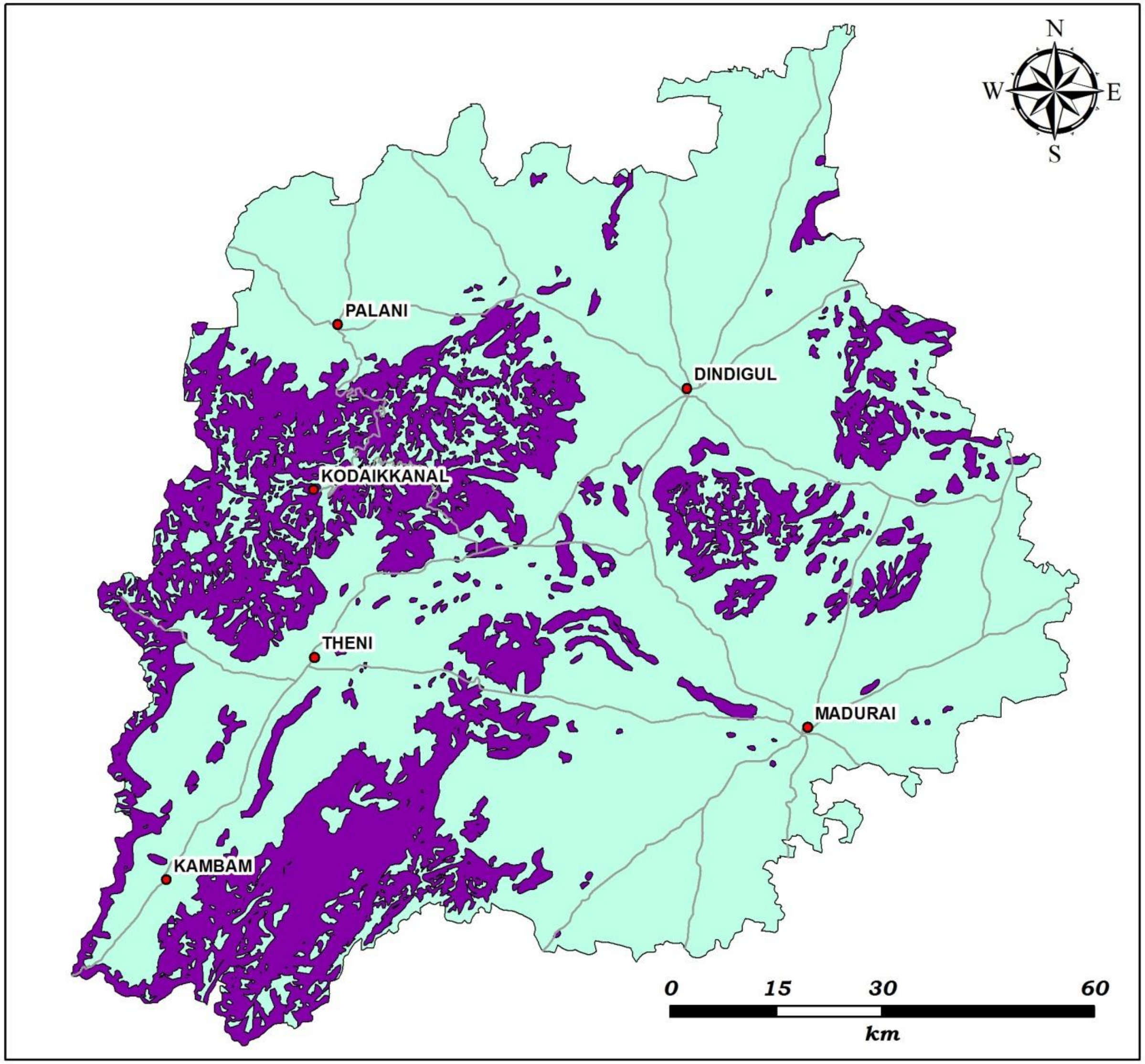
AREAS OF FIRST ORDER DRAINAGES



ACTIVE FOOT HILLS



AREAS OF ACTIVE SOIL EROSION



Legend

Settlement

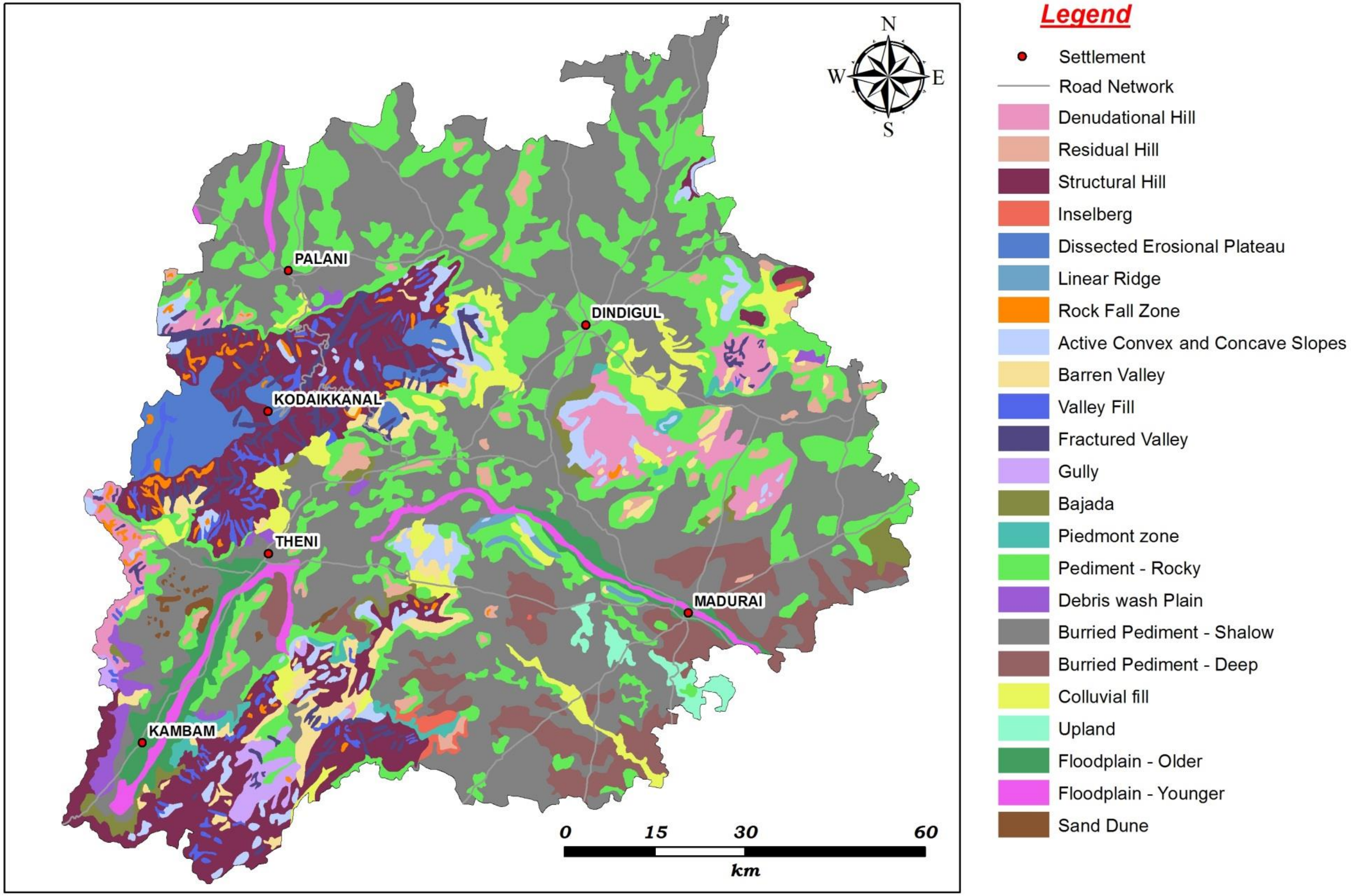
Road Network

Areas of Active Soil Erosion

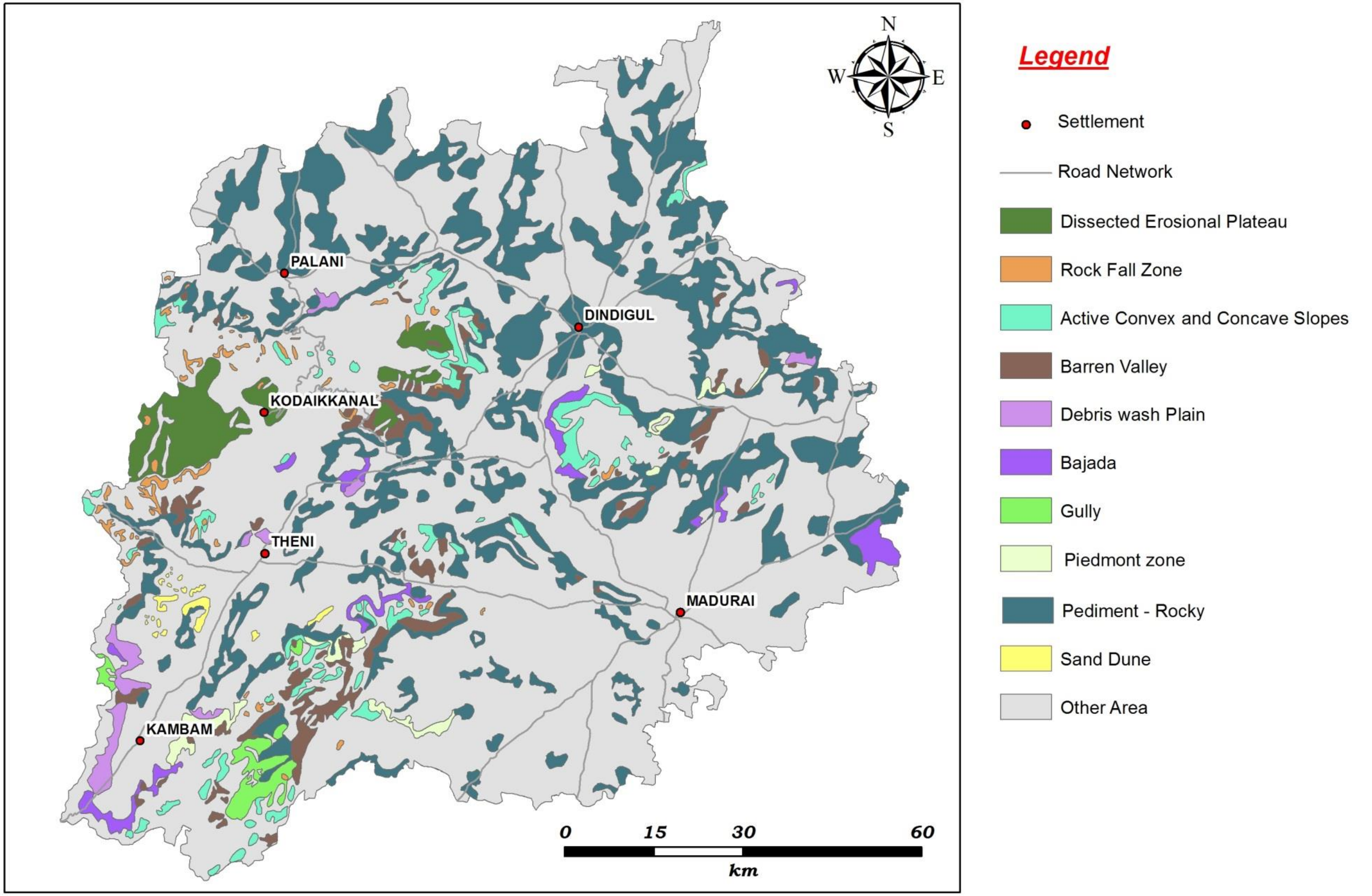
Other Area

(Combined Image of zones of
- Active Slopes
- Active Foot Hills and
- First Order Drainages)

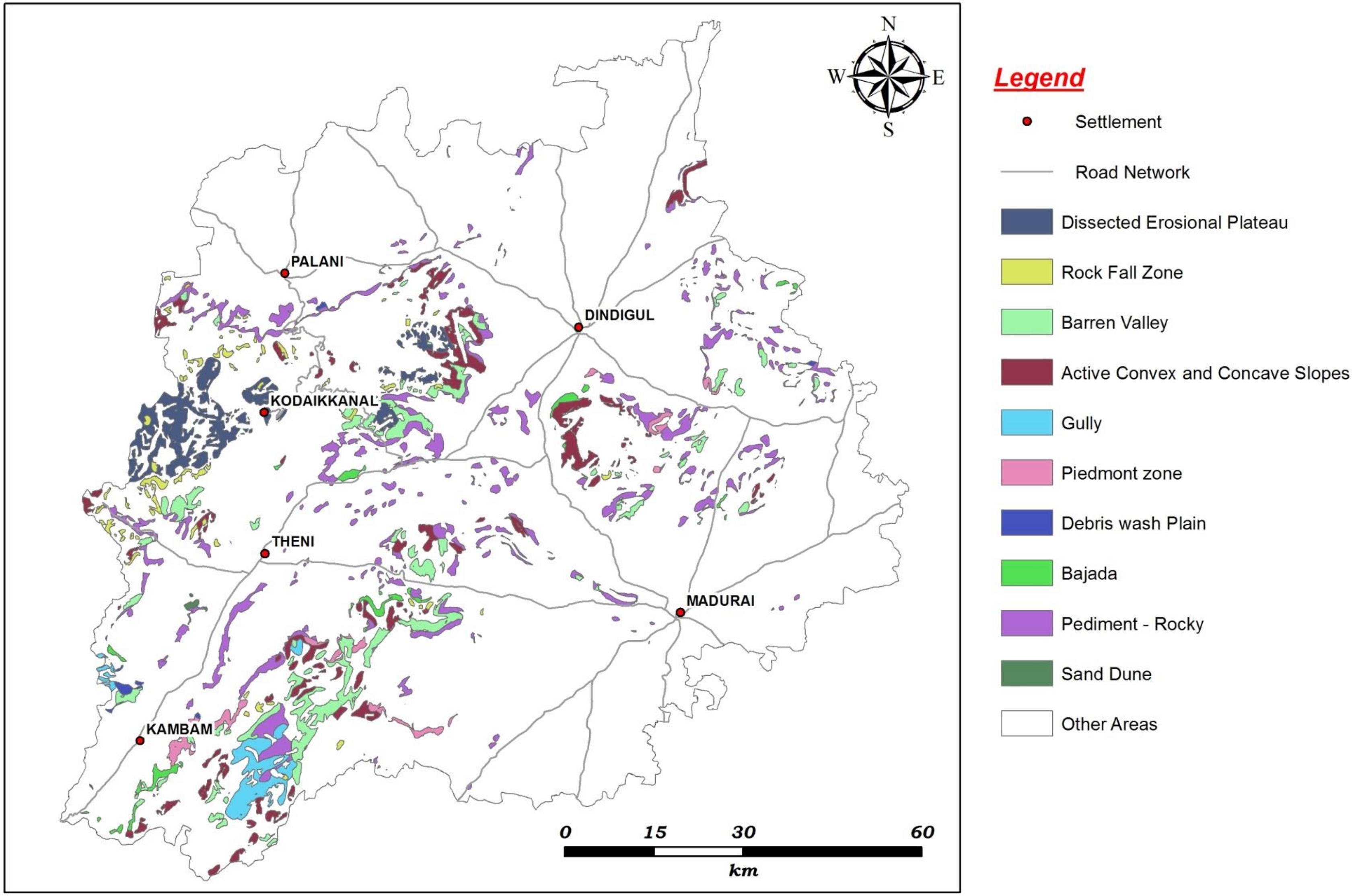
GEOMORPHOLOGY



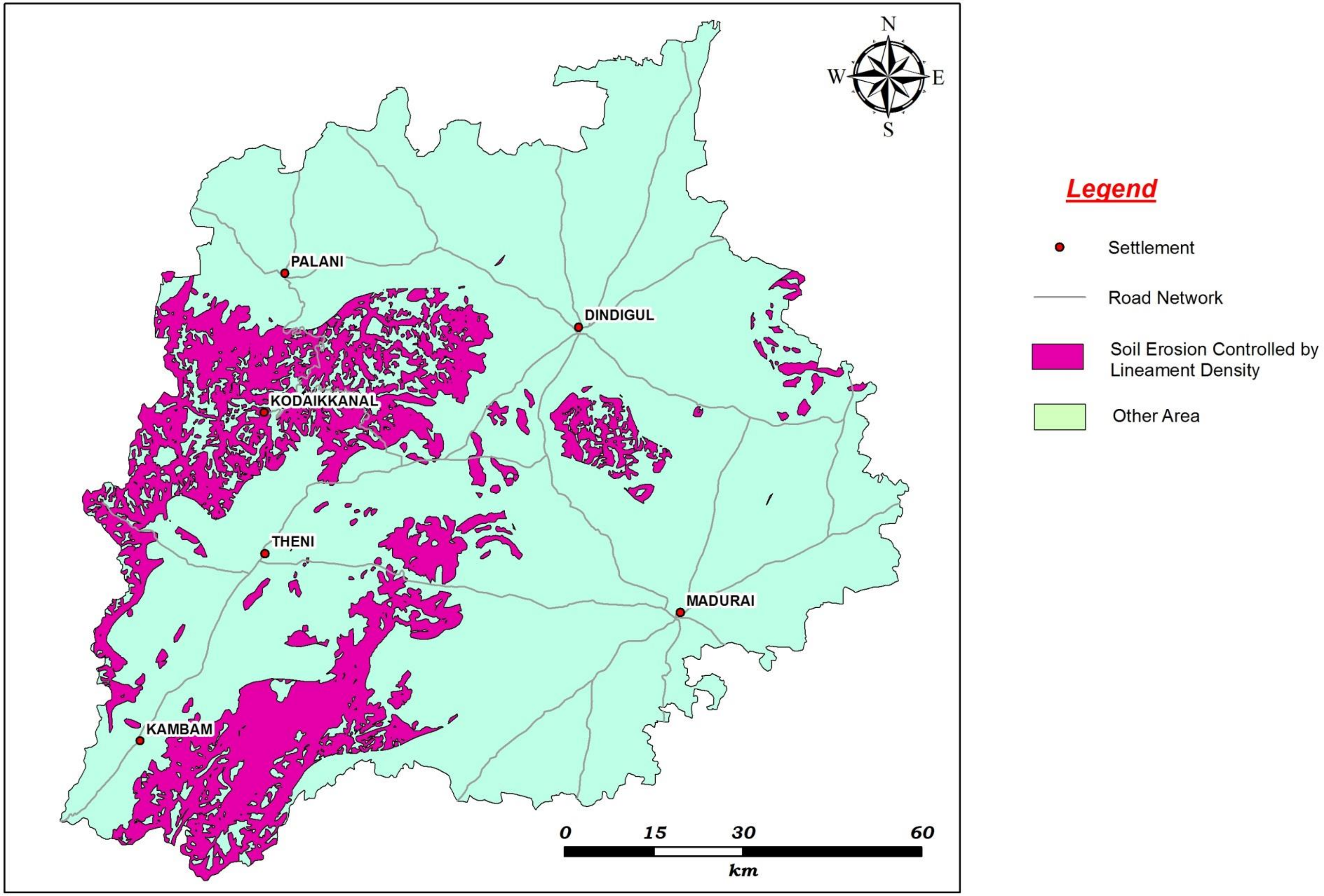
GEOMORPHOLOGY - EROSION PRONE



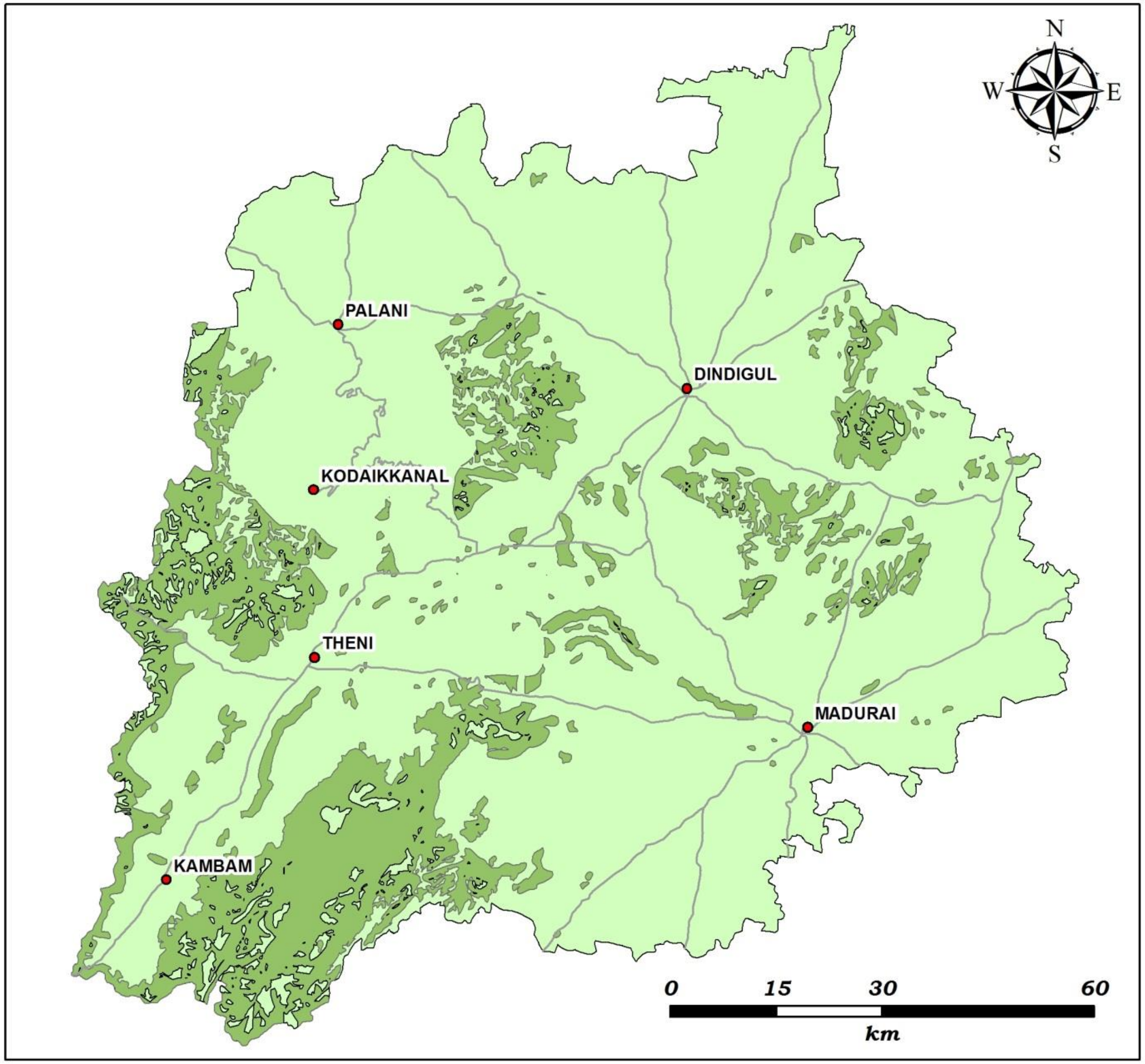
SOIL EROSION CONTROLLED BY GEOMORPHOLOGY



SOIL EROSION CONTROLLED BY LINEAMENT DENSITY



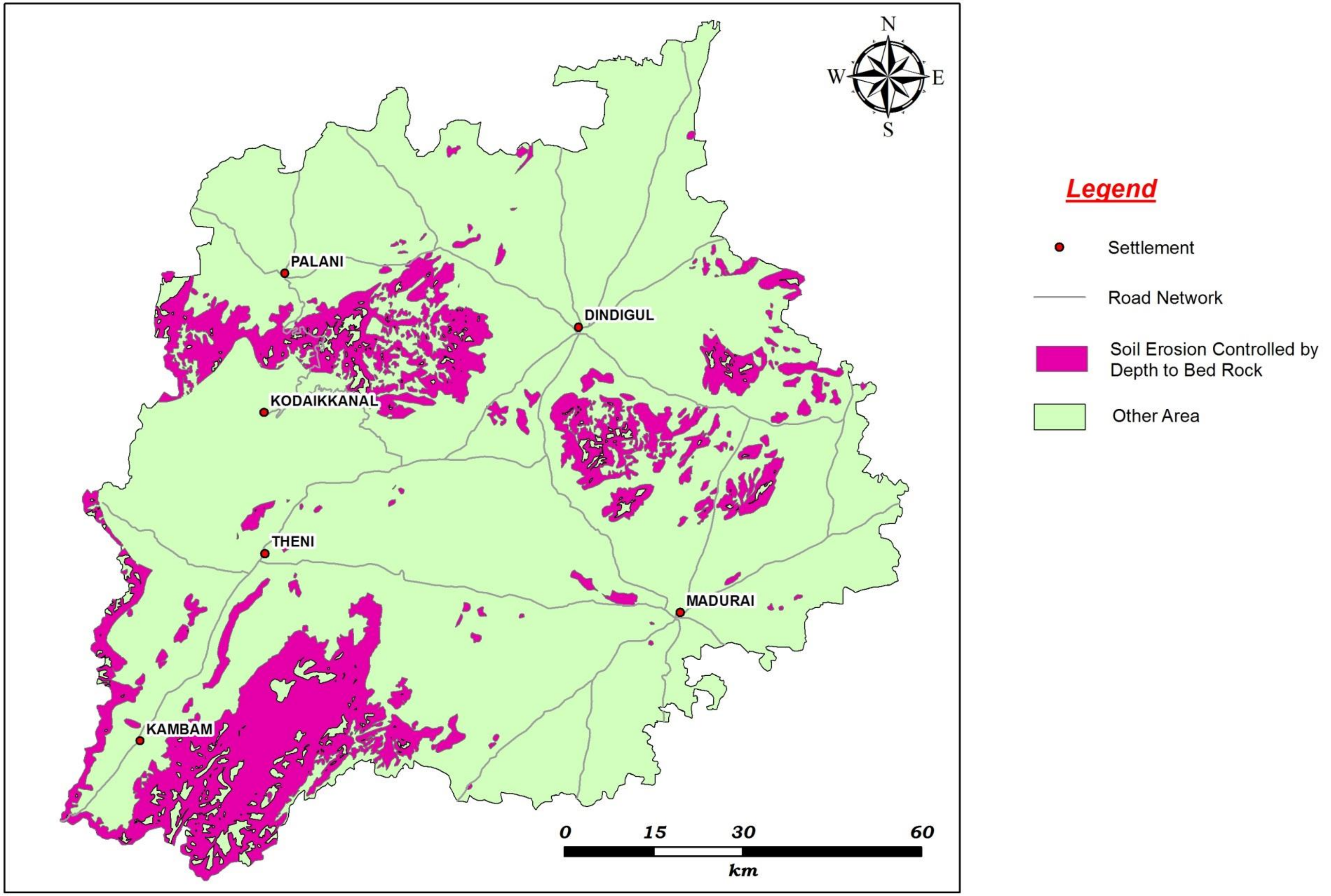
SOIL EROSION CONTROLLED BY THICKNESS OF TOP SOIL



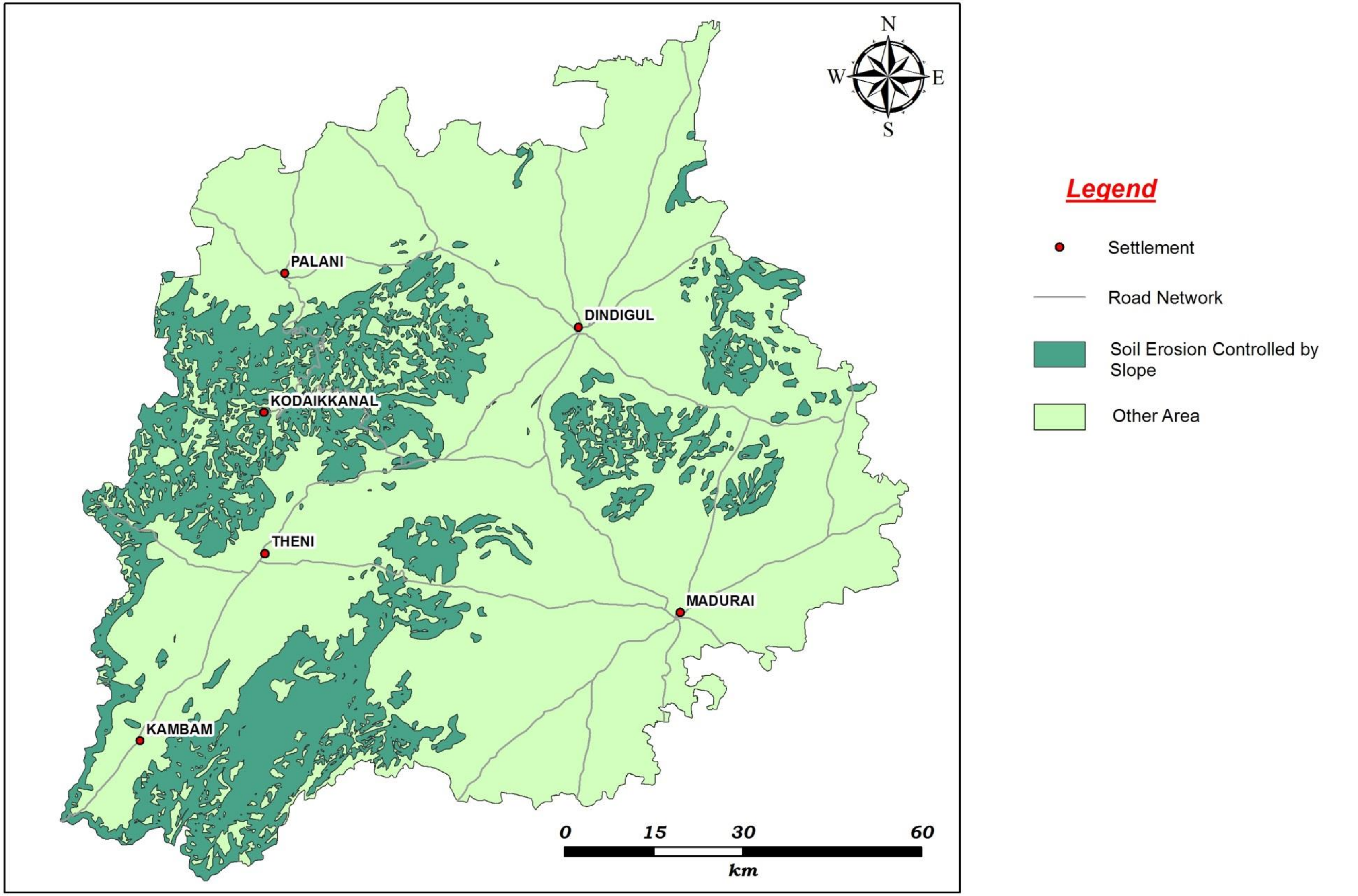
Legend

- Settlement
- Road Network
- Soil Erosion Controlled by Thickness of Top Soil
- Other Area

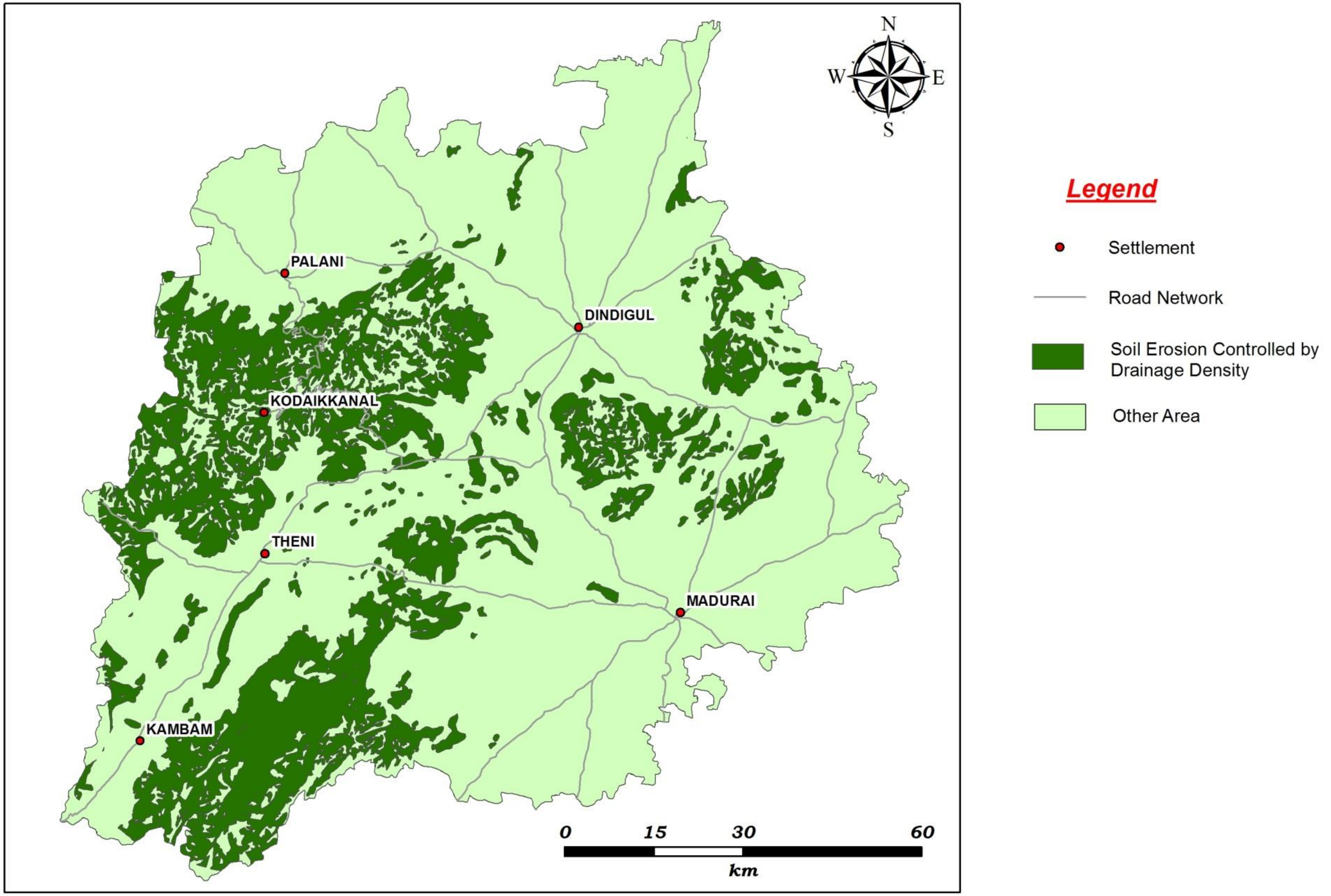
SOIL EROSION CONTROLLED BY DEPTH TO BED ROCK



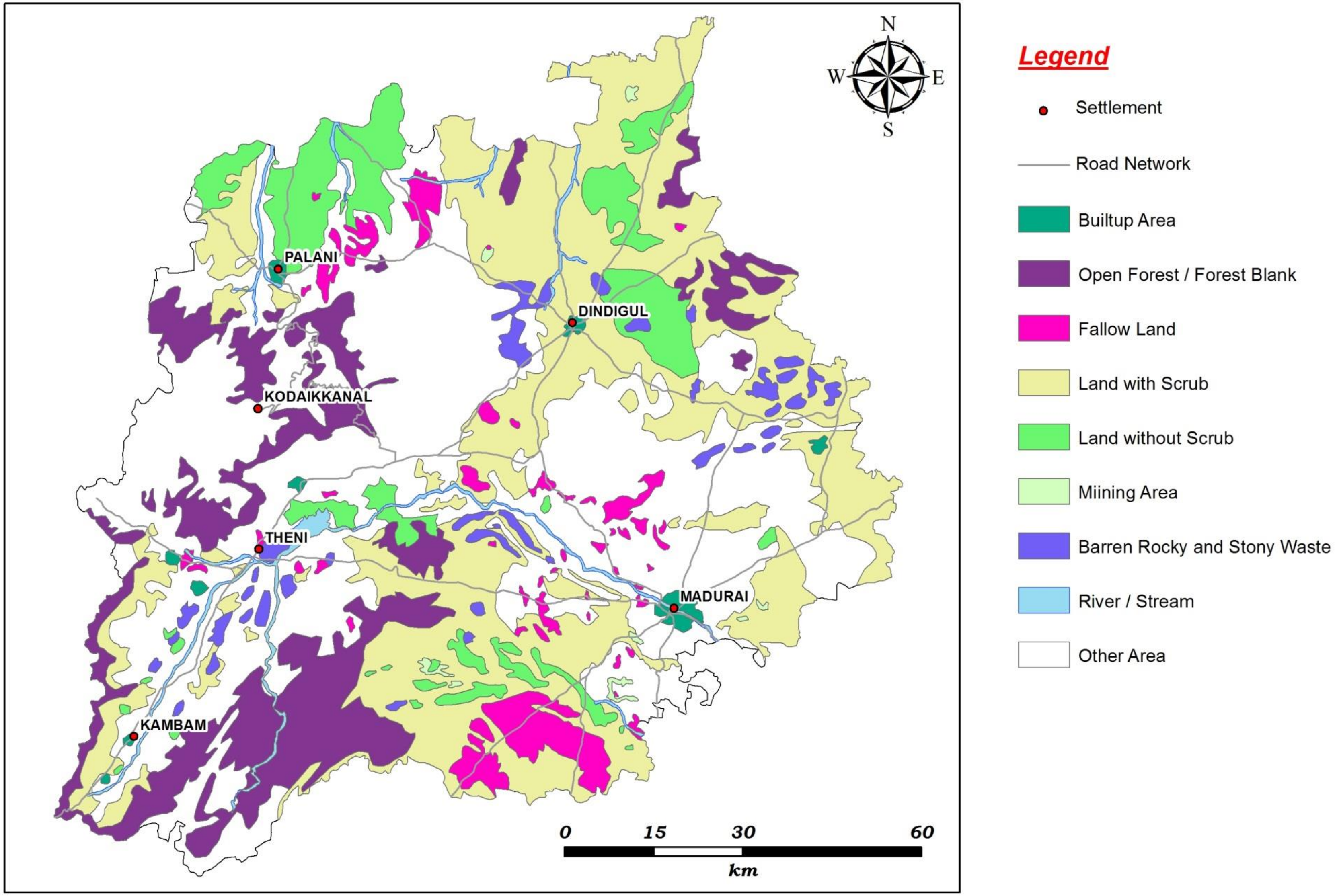
SOIL EROSION CONTROLLED BY SLOPE



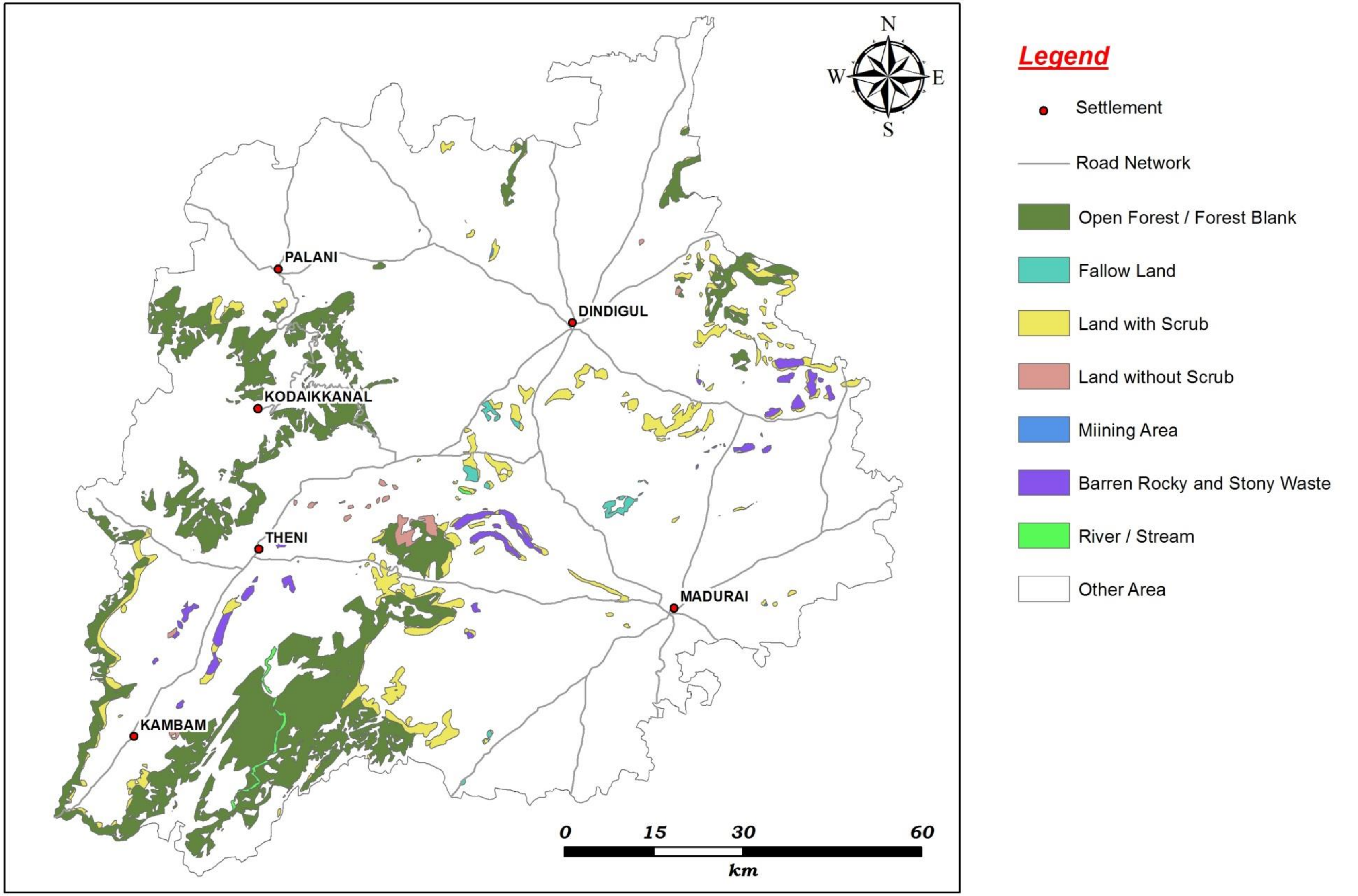
SOIL EROSION CONTROLLED BY DRAINAGE DENSITY



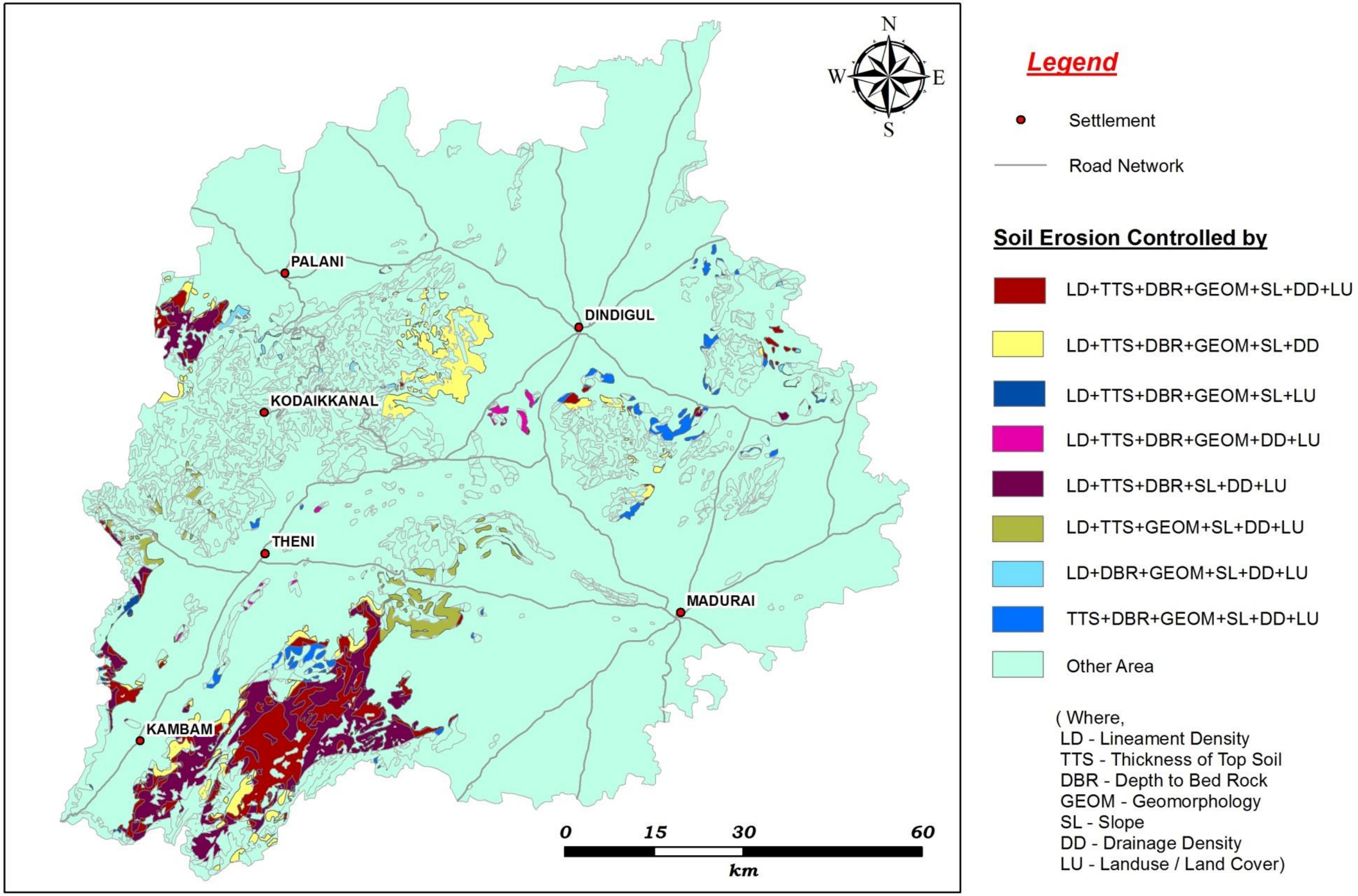
LANDUSE / LAND COVER - EROSION PRONE



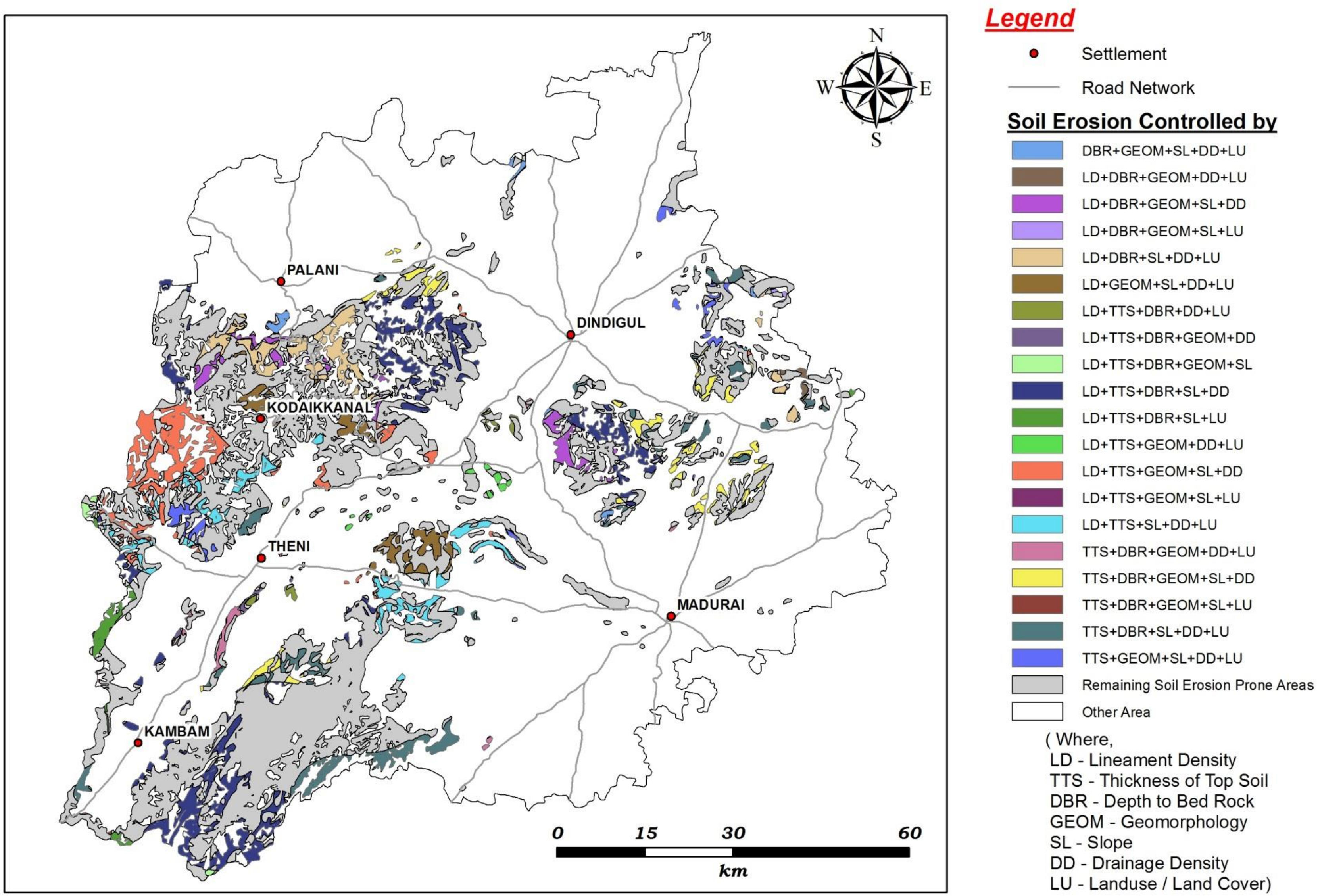
SOIL EROSION CONTROLLED BY LANDUSE / LAND COVER



FUNCTIONS OF SOIL EROSION (6 & 7 Parameters)



FUNCTIONS OF SOIL EROSION (5 PARAMETERS)



Remedial Measures

Areas of soil erosion controlled by	Controlling Parameter based Remedial Measures
1) Lineament density	Gully Filled Vegetation
2) Geomorphology	Afforestation, Gully Plugging, Check Dams, Pasture development
3) Thickness of top soil	Afforestation, Geotextiling, Nailing
4) Depth to bed rock	Intensive Afforestation
5) Slope	Bench Cultivation
6) Drainage density	Gully Plucking, Check Dams
7) Landuse/land cover	Afforestation, etc.

Conclusions

- Vulnerable areas of soil erosion and the inducing parameters of soil erosion have been mapped easily using Remote Sensing, Field surveys and GIS.
- Based on the combination of soil erosion inducing parameters existing in each zones, proper remedial measures have been suggested to arrest the silt in the catchment itself.

RUNOFF AND SOIL EROSION ESTIMATION USING REMOTE SENSING AND GIS OF SOLANI WATERSHED – A CASE STUDY-YEAR 2008

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WATER RESOURCES DIVISION
INDIAN INSTITUTE OF REMOTE SENSING
DEHRADUN

Aims

AIMS

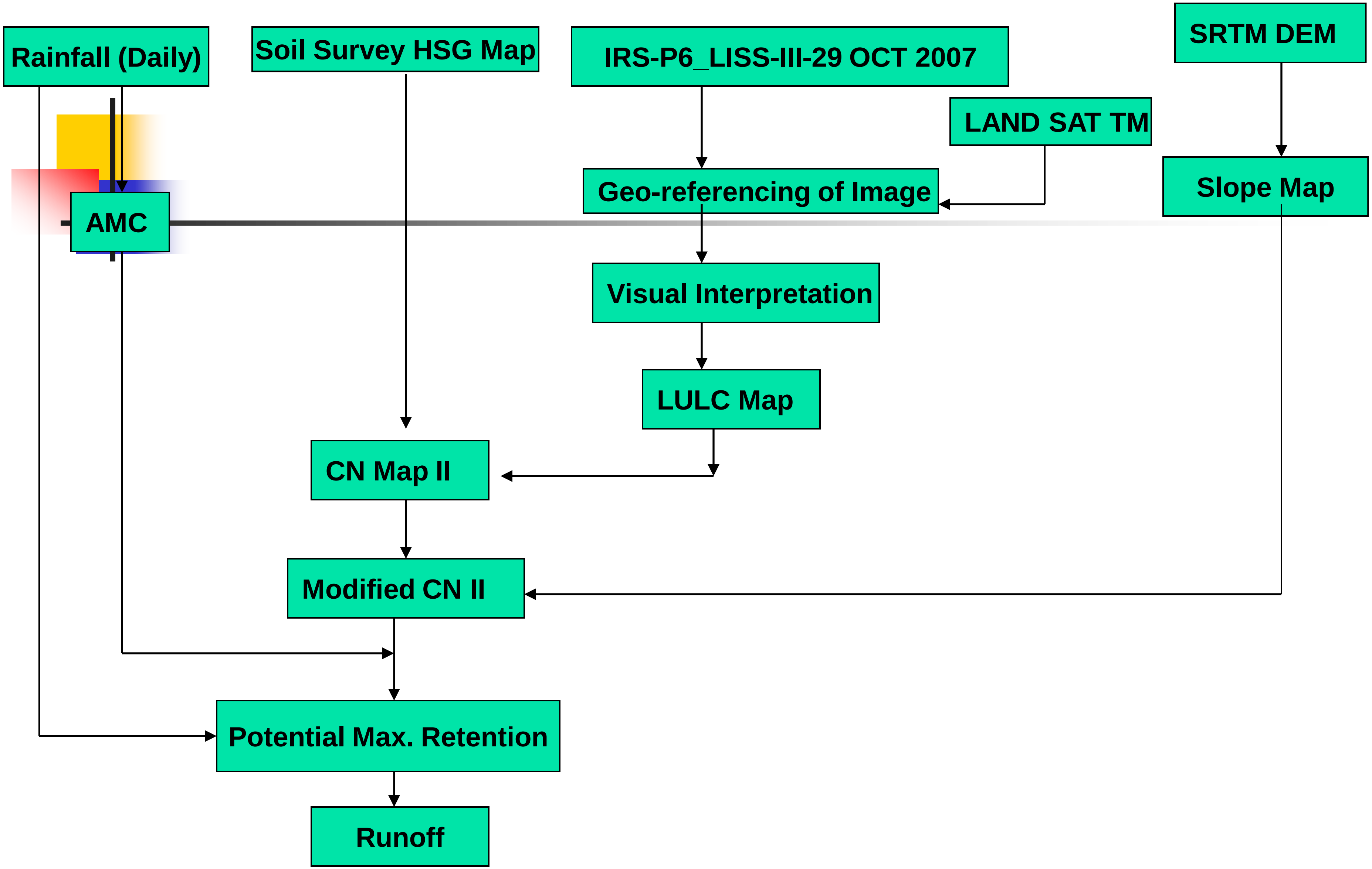
Aims of this present study is to Estimate,

- Runoff
- Soil erosion and
- Sediment yield
- using Remote Sensing and GIS for Solani watershed.

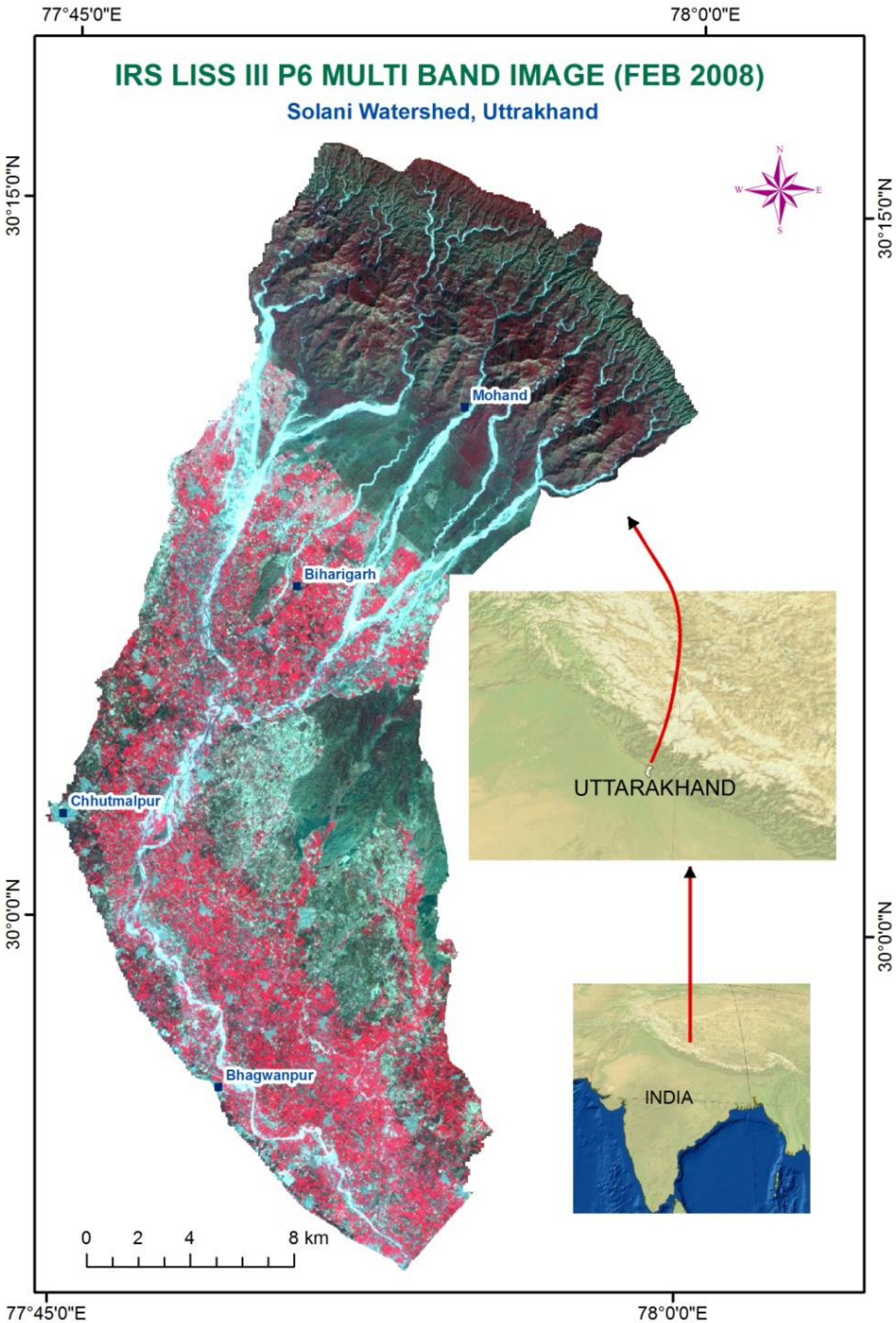
OBJECTIVES

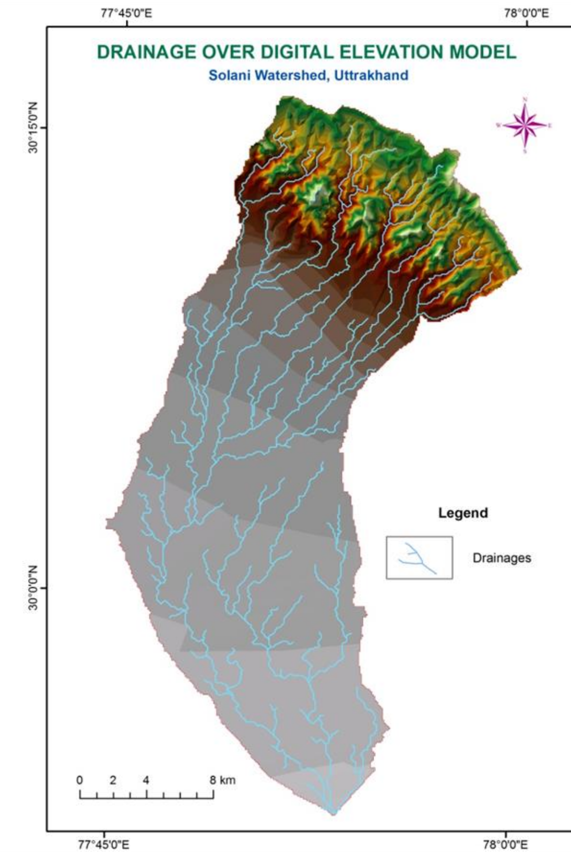
- Estimation of runoff for Solani watershed through Curve Number method using Remote sensing data and GIS for the year 2008 and
- Estimation of soil erosion and sediment yield for Solani watershed using RUSLE, Remote sensing data and GIS for the year 2008.

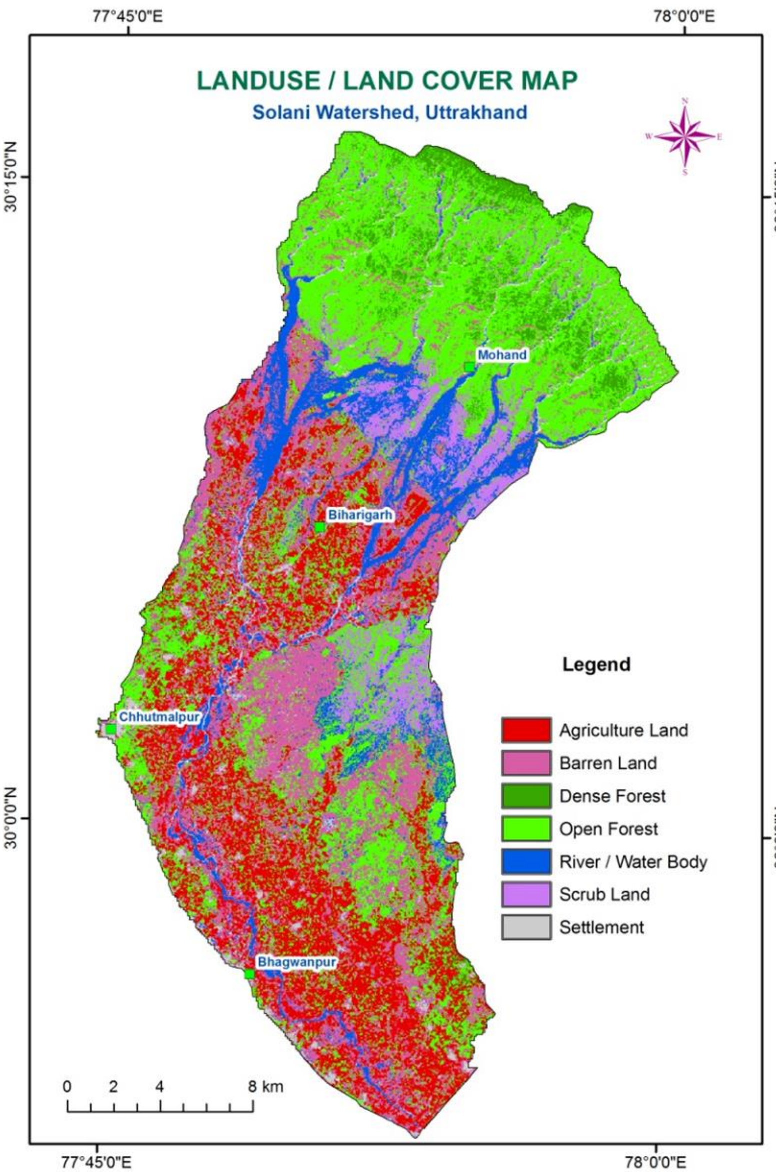
1. RUNOFF ESTIMATION



Flow Chart for Runoff Estimation

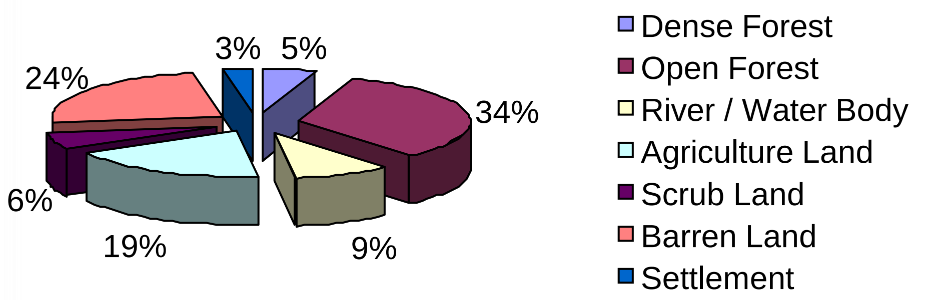

IRS LISS III P6 MULTI BAND IMAGE (FEB 2008)
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
UTTARAKHAND
INDIA
0 2 4 8 km

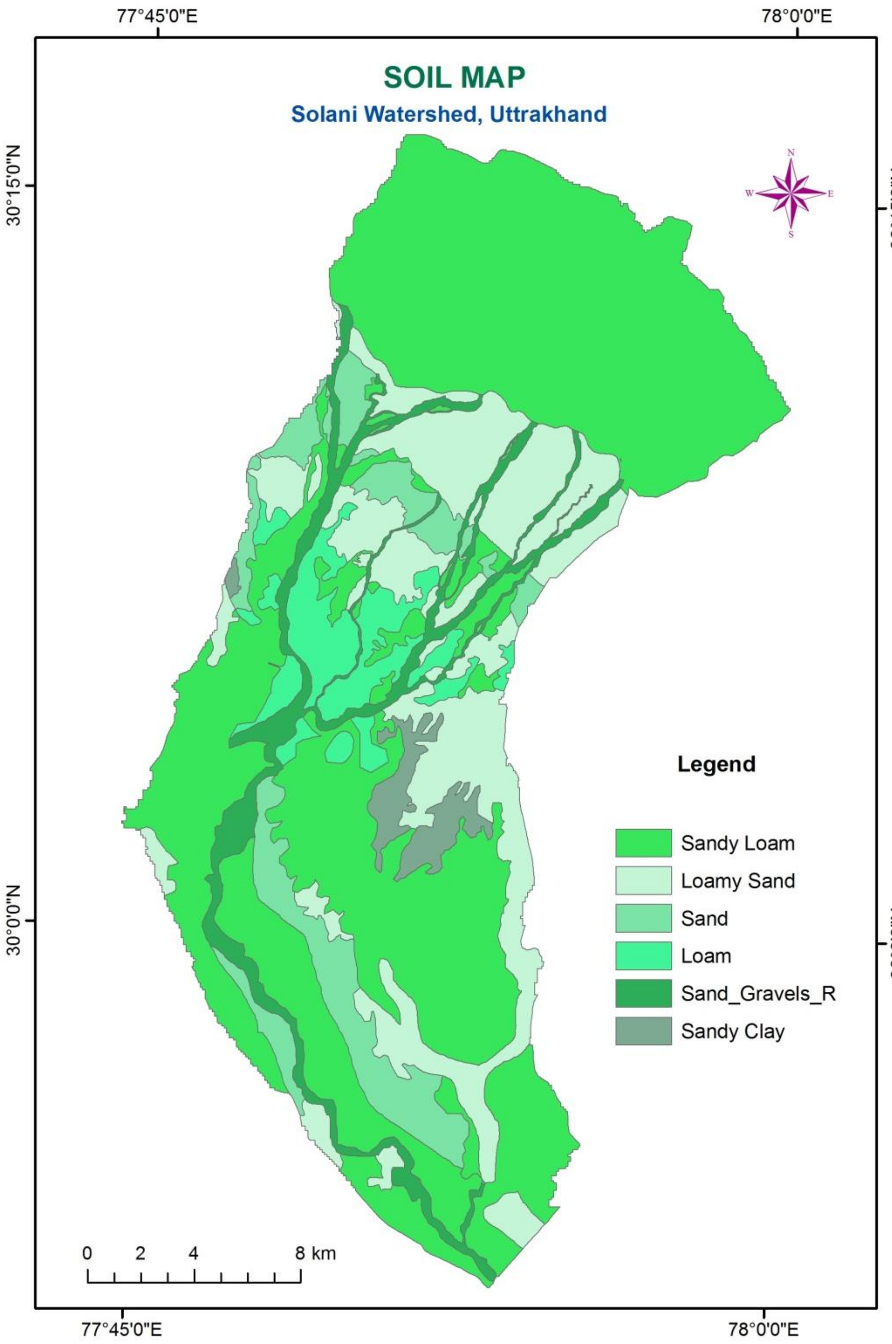

DRAINAGE OVER DIGITAL ELEVATION MODEL
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Legend
Drainages
0 2 4 8 km

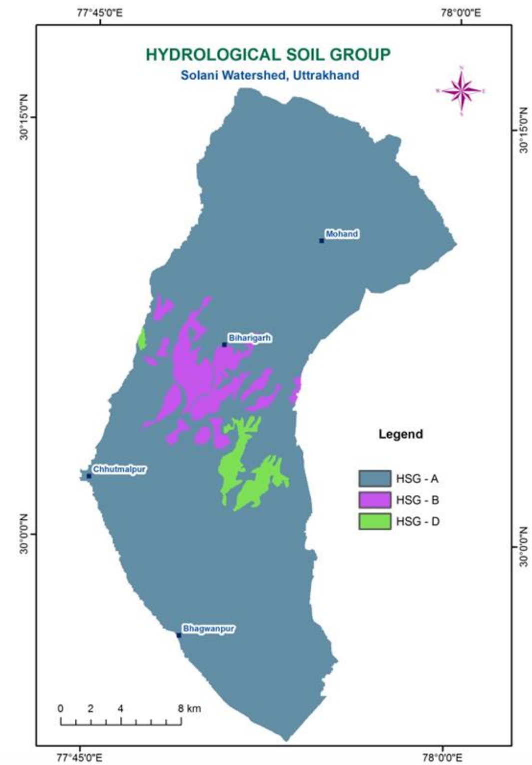


Sl. No.	Landuse / Land cover Categories	Area (sq.km)	Area in %
1	Dense Forest	25.92	5
2	Open Forest	181.33	34
3	River / Water Body	48.38	9
4	Agriculture Land	101.02	19
5	Scrub Land	31.56	6
6	Barren Land	128.18	24
7	Settlement	14.86	3

Landuse / Land cover – Percentage share in Solani Watershed




SOIL MAP
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
N
S
E
W
Legend
Sandy Loam
Loamy Sand
Sand
Loam
Sand_Gravels_R
Sandy Clay
0 2 4 8 km


HYDROLOGICAL SOIL GROUP
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
HSG - A
HSG - B
HSG - D
0 2 4 8 km

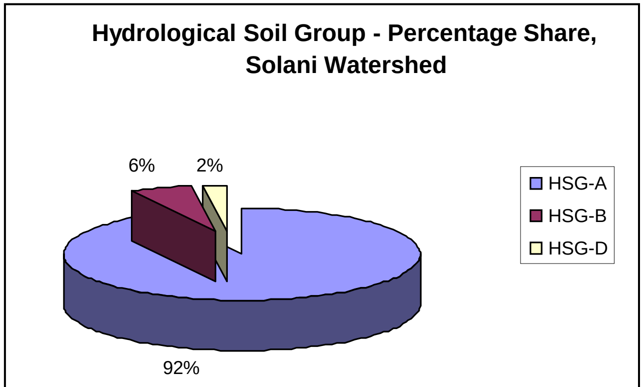
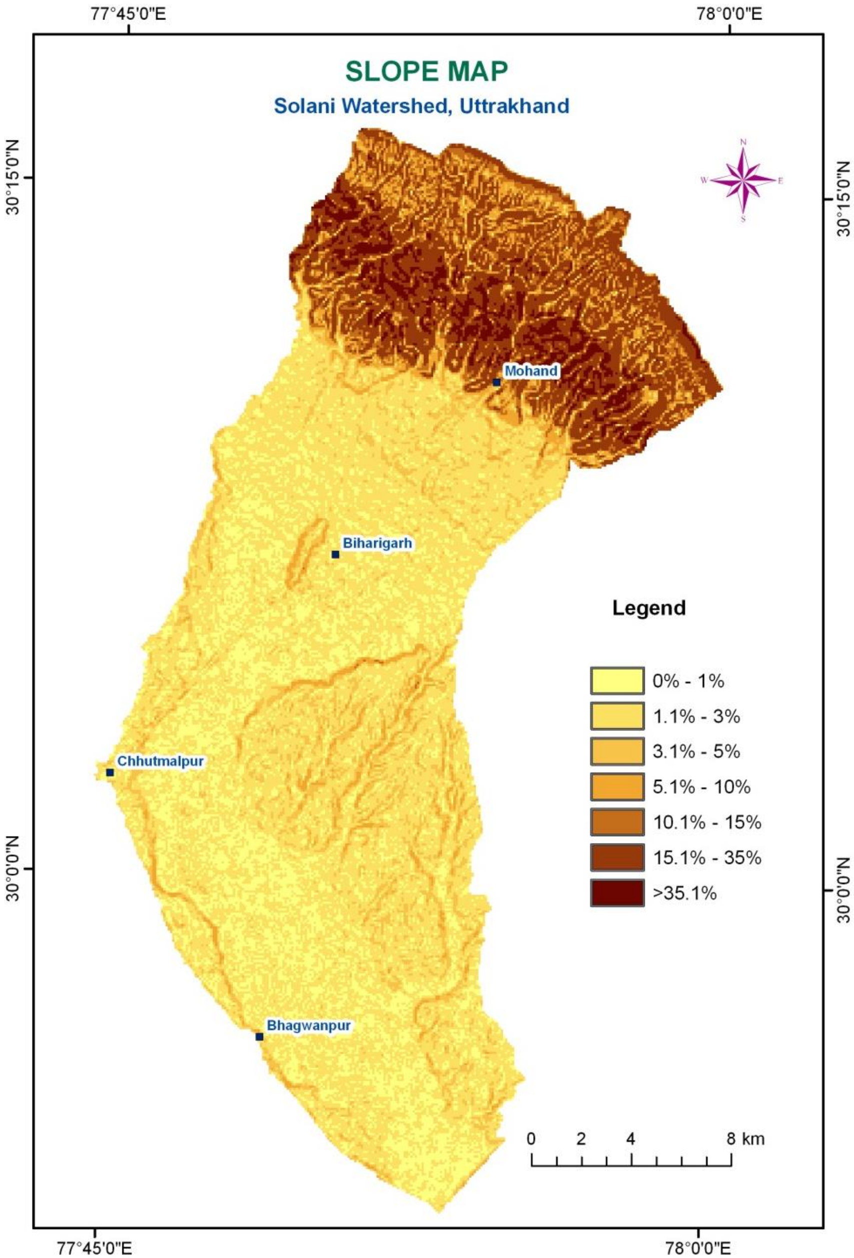
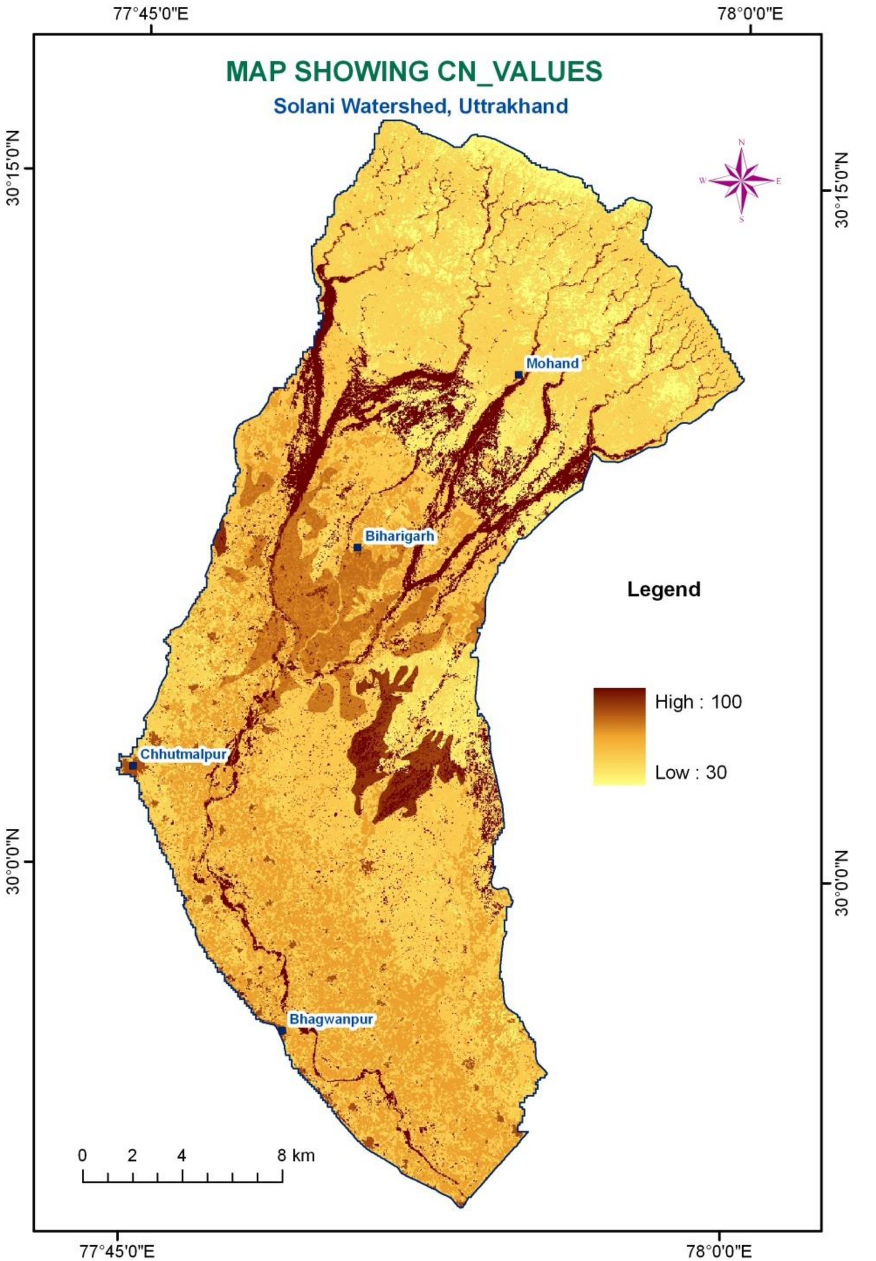
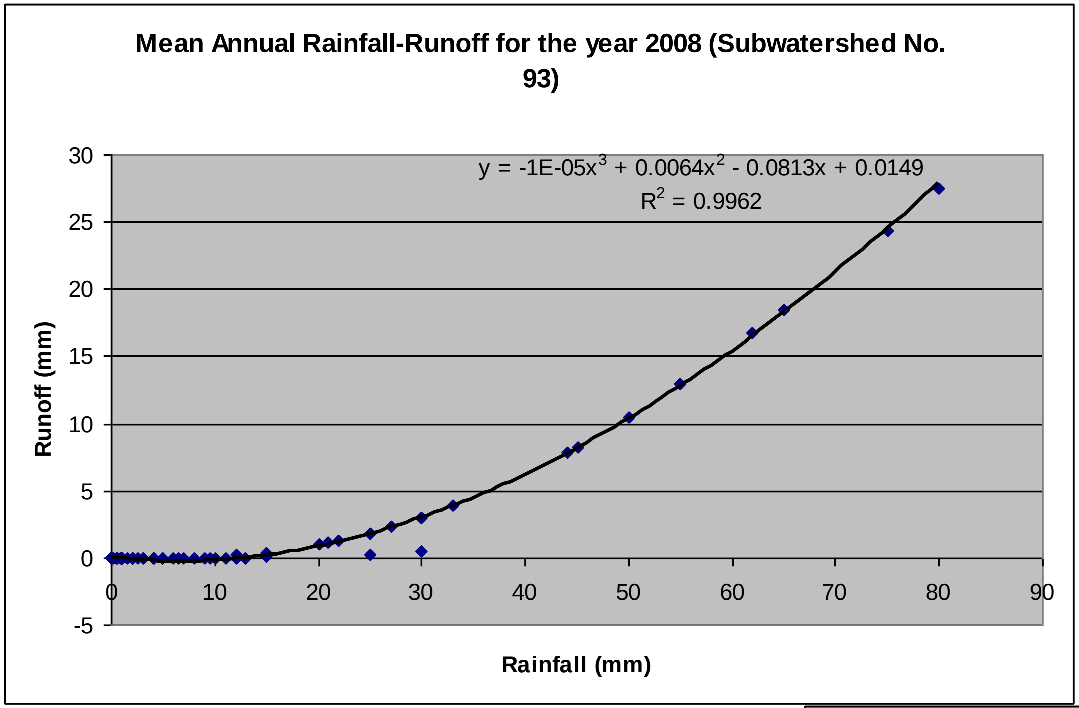
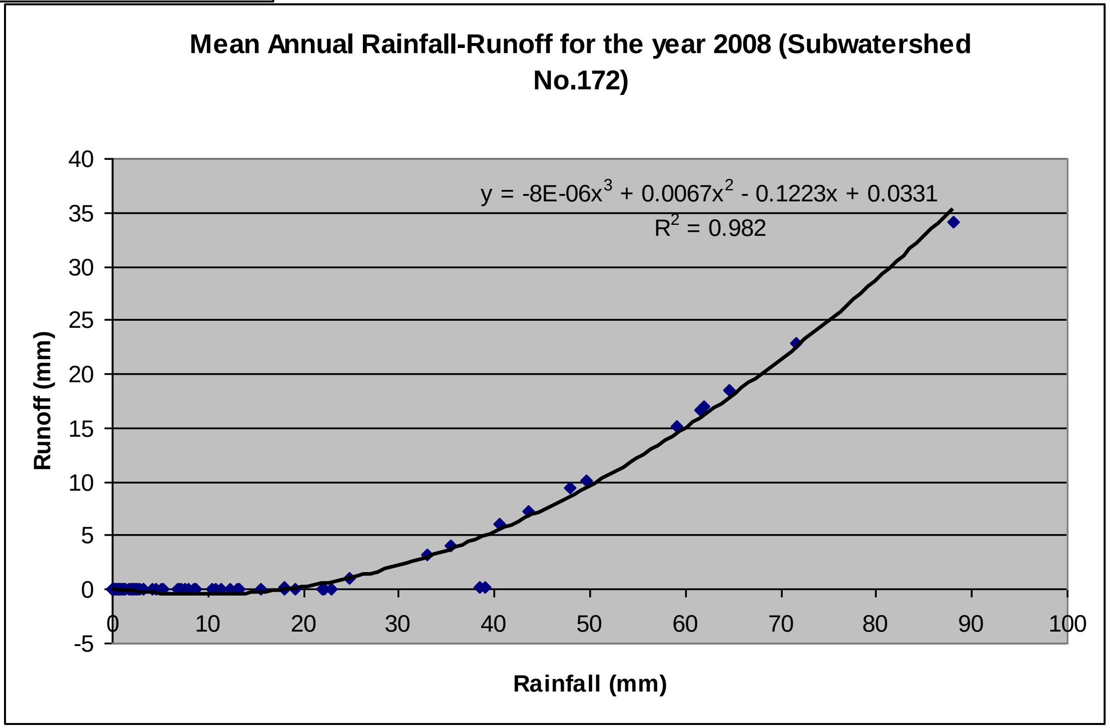

Hydrological Soil Group - Percentage Share,
Solani Watershed
6%
2%
92%
HSG-A
HSG-B
HSG-D

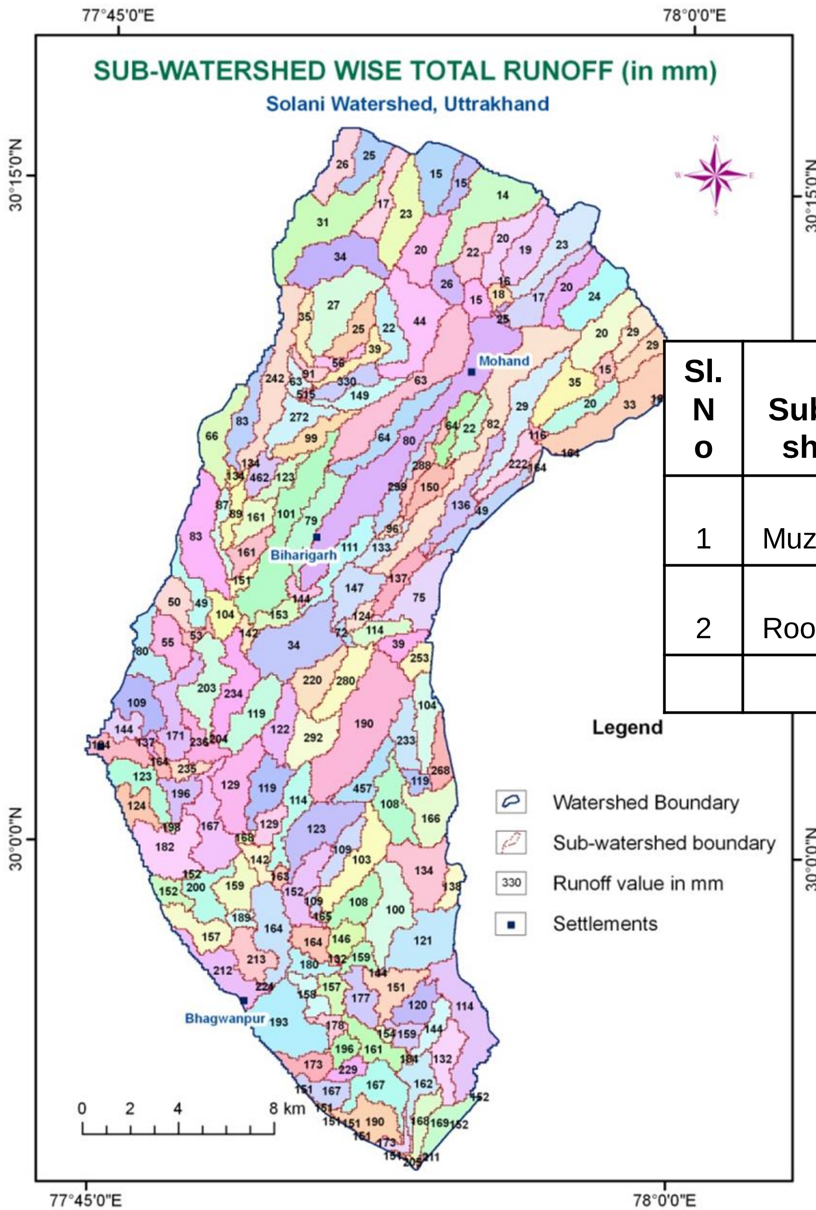
Fig. 8


SLOPE MAP
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
0% - 1%
1.1% - 3%
3.1% - 5%
5.1% - 10%
10.1% - 15%
15.1% - 35%
>35.1%
0 2 4 8 km


MAP SHOWING CN_VALUES
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
High : 100
Low : 30
0 2 4 8 km


Mean Annual Rainfall-Runoff for the year 2008 (Subwatershed No. 93)
y = -1E-05x3 + 0.0064x2 - 0.0813x + 0.0149
R2 = 0.9962
Runoff (mm)
Rainfall (mm)
30
25
20
15
10
5
0
-5
0
10
20
30
40
50
60
70
80
90


Mean Annual Rainfall-Runoff for the year 2008 (Subwatershed No.172)
y = -8E-06x3 + 0.0067x2 - 0.1223x + 0.0331
R2 = 0.982
Runoff (mm)
Rainfall (mm)
40
35
30
25
20
15
10
5
0
-5
0
10
20
30
40
50
60
70
80
90
100

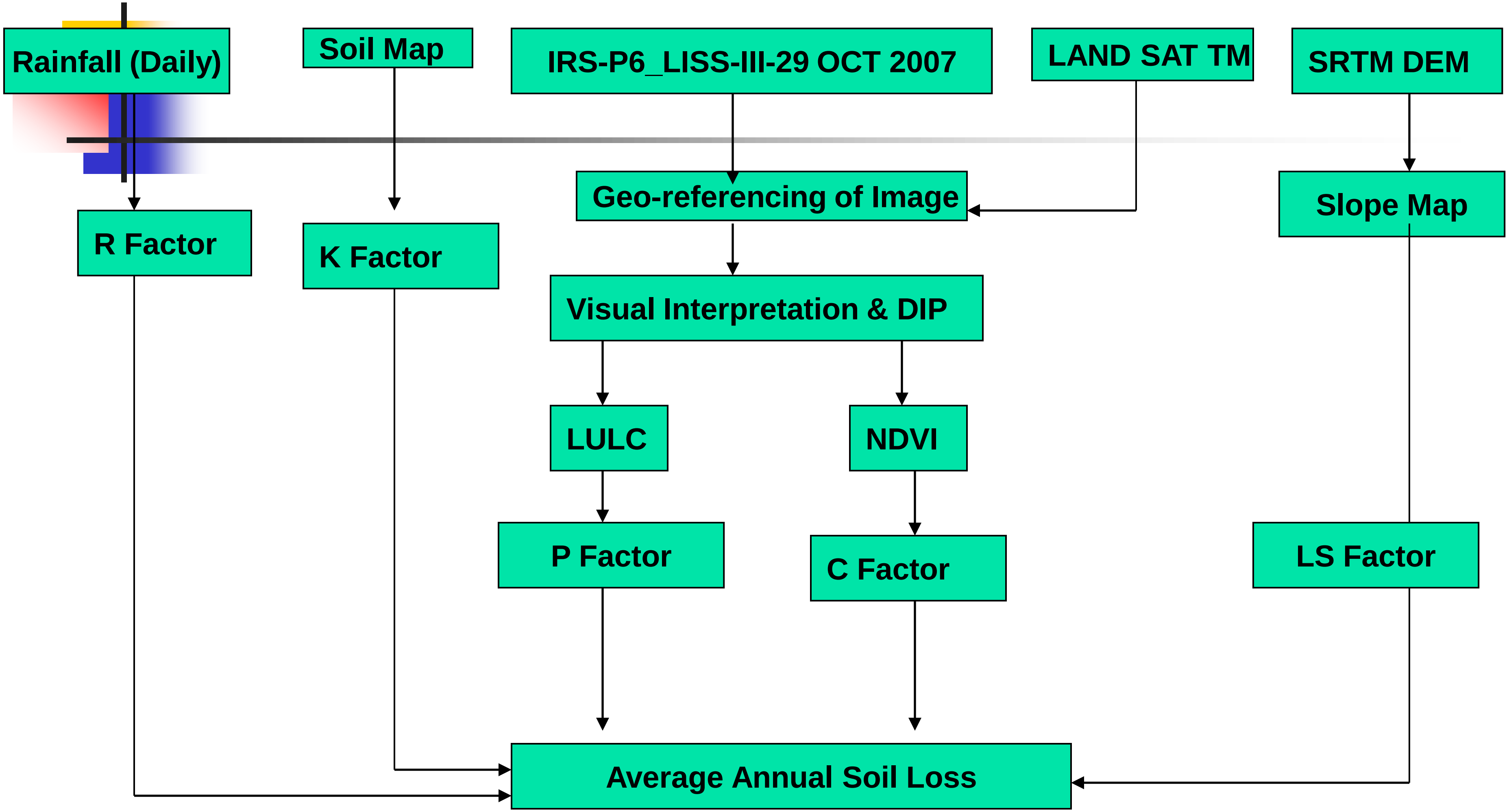


Sl. No	SubWater-sheds of	No. of Rainy Days	Rainfall (mm)	Runoff (mm)	Area(sq. m)	Volume (m^3)
1	Muzafferpur	72	1126.00	16089.0	289.8×10^6	4662.8×10^6
2	Roorkee	86	1105.85	15811.4	233.3×10^6	3689.1×10^6
				Total	523.1×10^6	8351.9×10^6

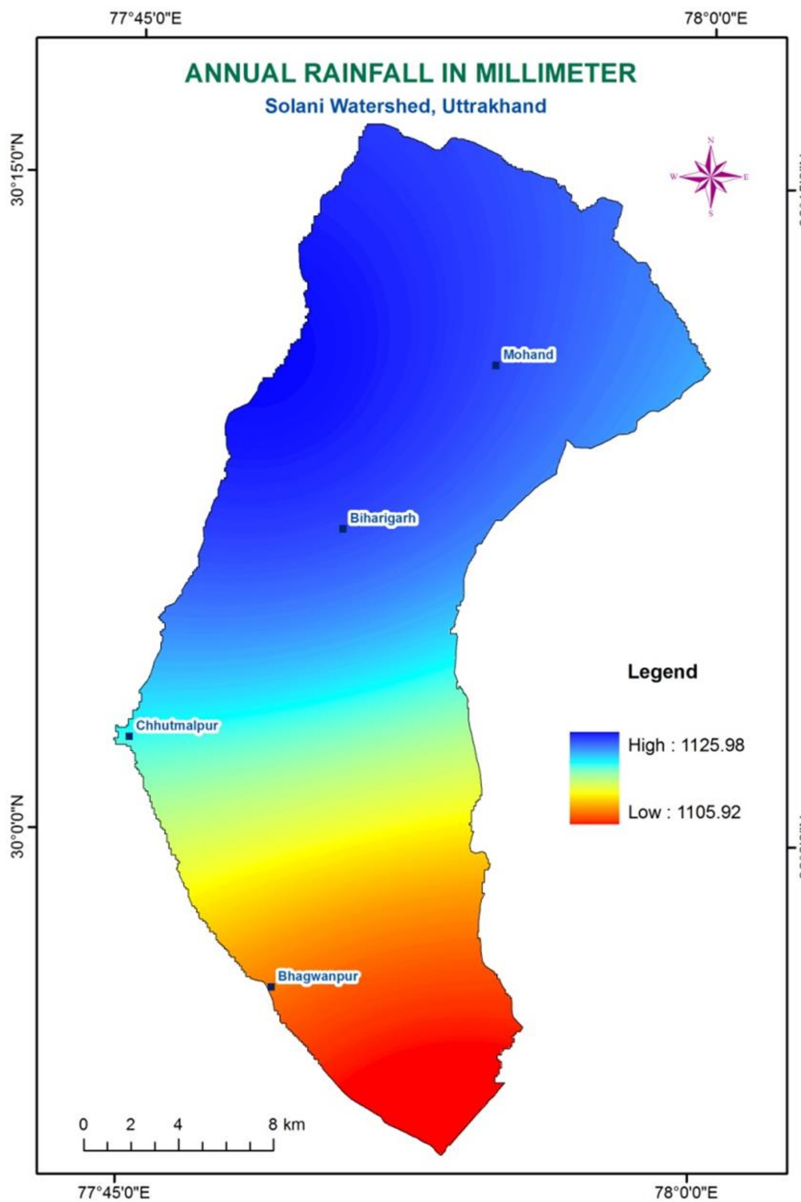
CONCLUSIONS

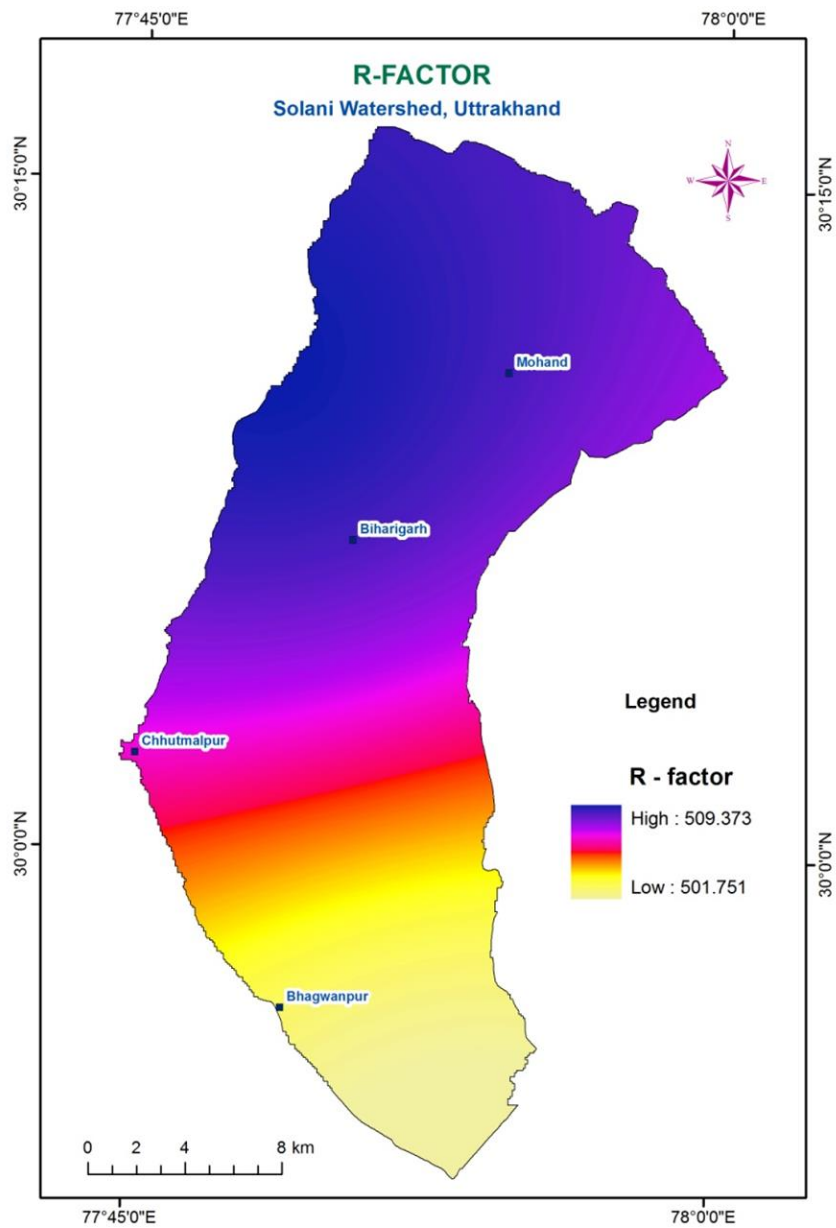
- The average annual runoff is 170.7 mm against the average rainfall of 1116mm for the year 2008 in Solani watershed.
- The use of Remote Sensing data with collateral data and the efficiency of GIS platform has been well documented for runoff estimation.
- This approach could be applied easily for other watersheds for efficient and effective planning and implementation.

2. SOIL LOSS ESTIMATION



Flow Chart for Estimation of Annual Soil Loss





R-Factor = 81.5 + (0.380 * [rain.img])

$$LS = (As/22.13)^n \ X \ (\sin \beta/0.0896)^m$$

Where,

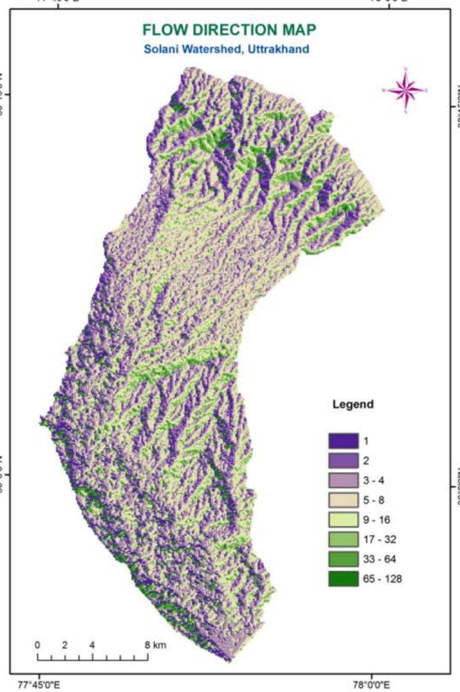
As = specific area *(=A/b),* defined as the upslope contributing area for an overland cell (A) per unit width normal to the flow direction *(b);*

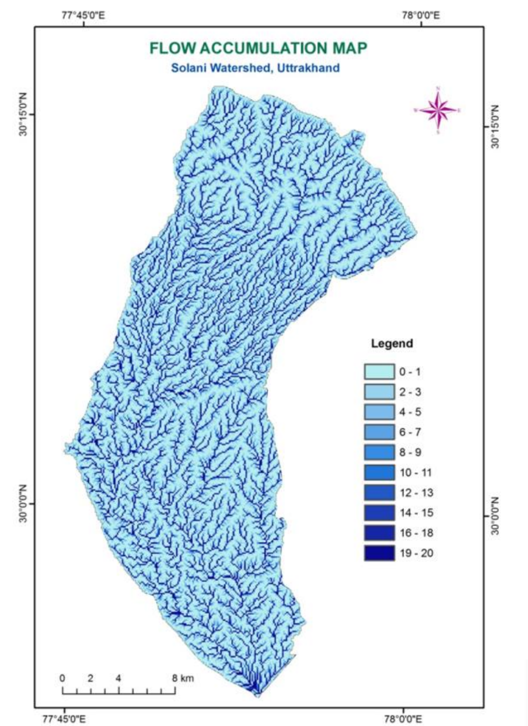
β = the slope gradient in degrees;

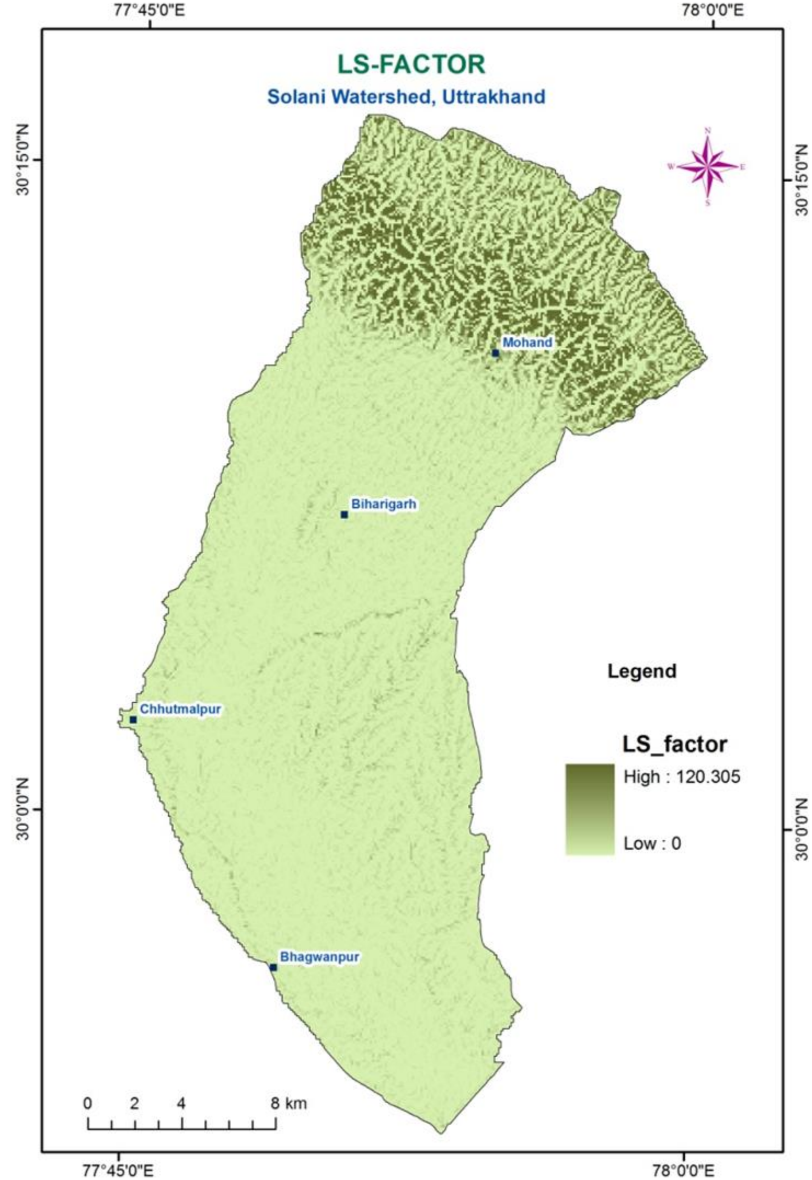
n = 0.4; and *m* = 1.3.

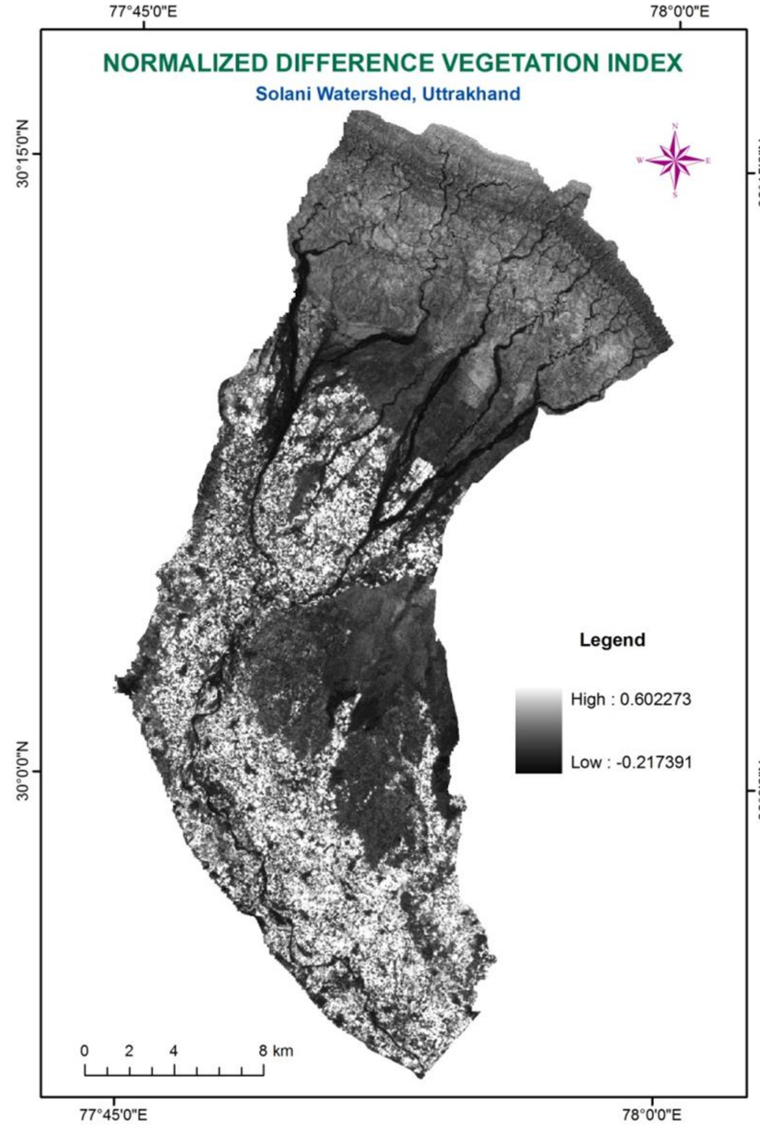
The slope steepness factor S, is evaluated from developed by McCool et al. (1987, 1993),

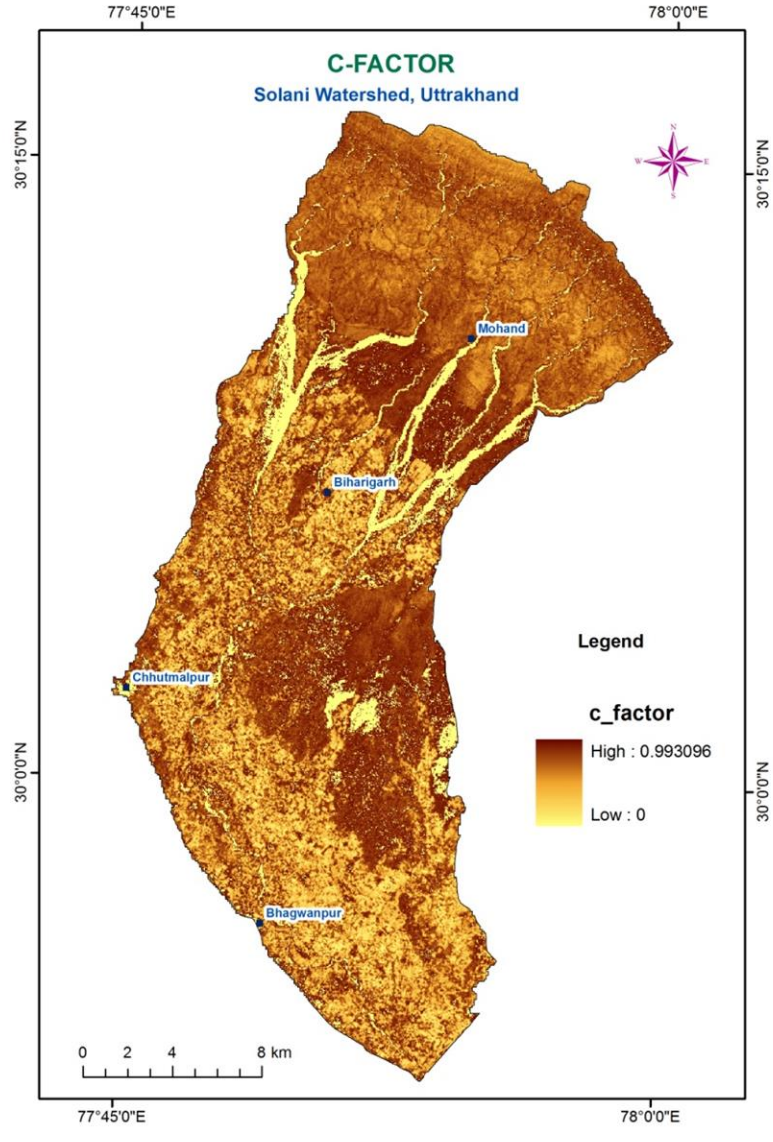
$$S = 10.8 \sin\theta + 0.03, \quad S < 9\ \% \ (\text{i.e. } \tan\theta < 0.09)$$


FLOW DIRECTION MAP
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Legend
1
2
3 - 4
5 - 8
9 - 16
17 - 32
33 - 64
65 - 128
0 2 4 8 km


FLOW ACCUMULATION MAP
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Legend
0 - 1
2 - 3
4 - 5
6 - 7
8 - 9
10 - 11
12 - 13
14 - 15
16 - 18
19 - 20
0 2 4 8 km


LS-FACTOR
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
LS_factor
High : 120.305
Low : 0
0 2 4 8 km


77°45'0"E
78°0'0"E
NORMALIZED DIFFERENCE VEGETATION INDEX
Solani Watershed, Uttrakhand
30°15'0"N
30°0'0"N
Legend
High : 0.602273
Low : -0.217391
0 2 4 8 km


77°45'0"E
78°0'0"E
C-FACTOR
Solani Watershed, Uttrakhand
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
c_factor
High : 0.993096
Low : 0
0 2 4 8 km

$$K = \frac{2.1 \times 10^{-4} (12-OM)M^{1.14} + 3.25(s-2) + 2.5(p-3)}{759.4}$$

Where,

K = soil erodibility (tons-yr/MJ-mm,

OM= Per cent organic matter,

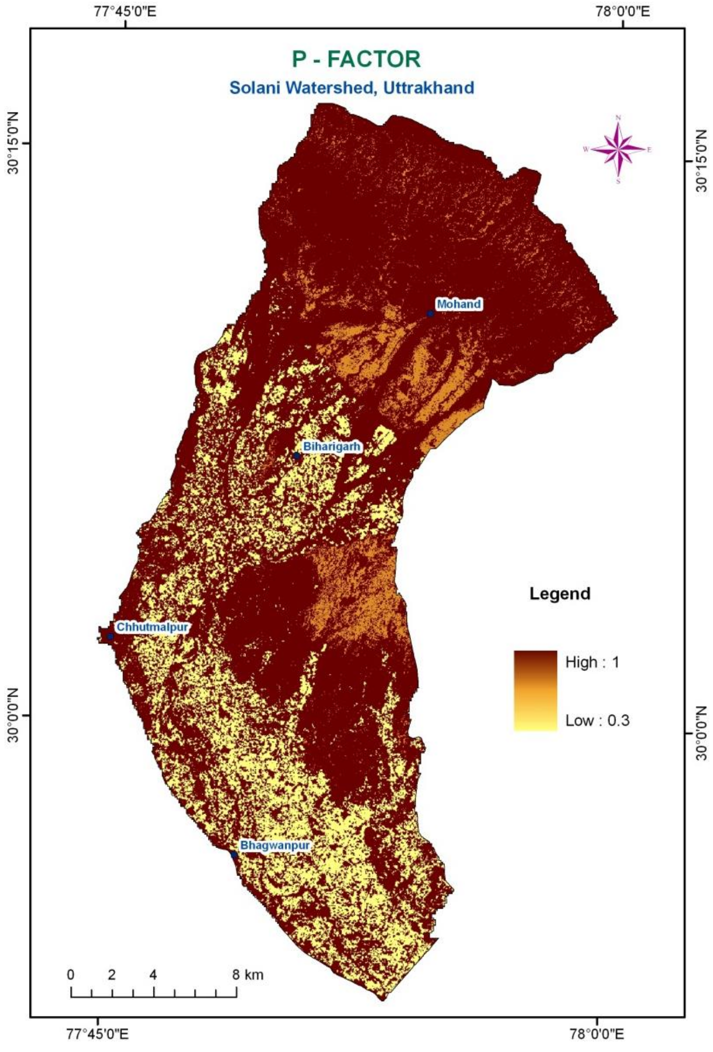
p = permeability code,

s = soil structure code,

M = a function of the primary partical size function given by

M = (% silt+% very fine sand) X (100-% clay)

For this case study the value of K is assumed as 0.05.



Soil Erodibility Factor (K) is considered here as 0.05

$$Tc = Ktc\ .K.R.As^{1.44}.S^{1.14}$$

Where,

Tc = Transport capacity, kg/sq.m/yr

S = Slope gradient, m/m

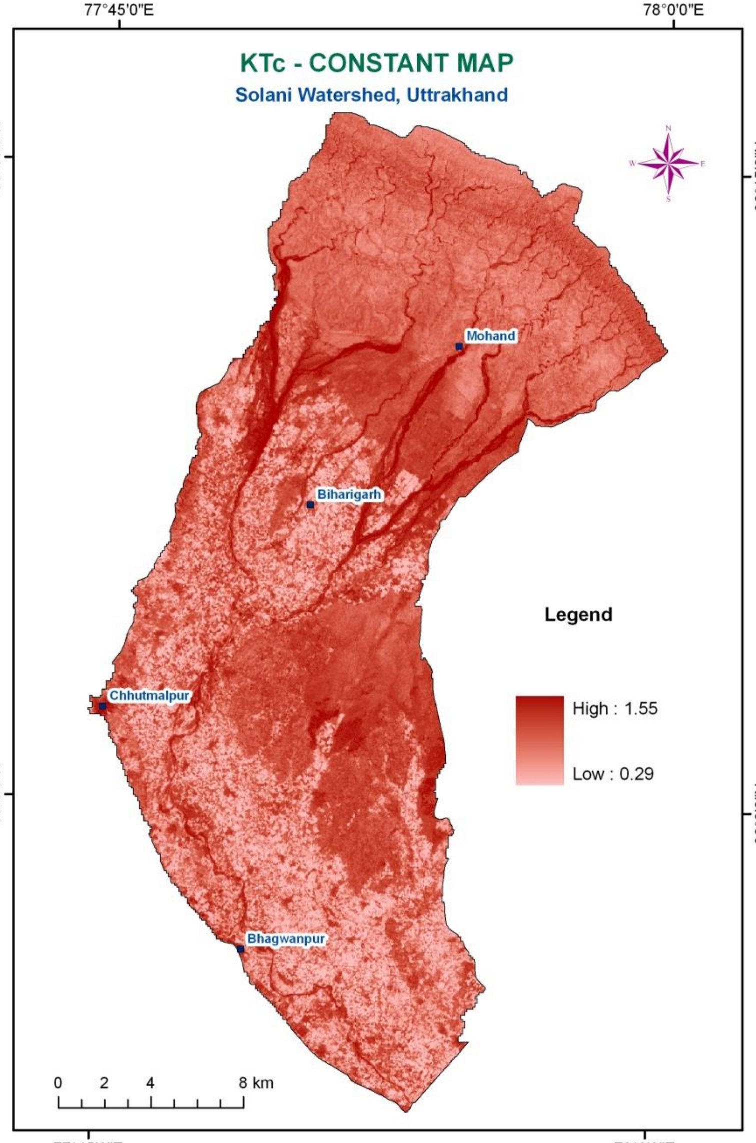
As = Specific area, sq.m

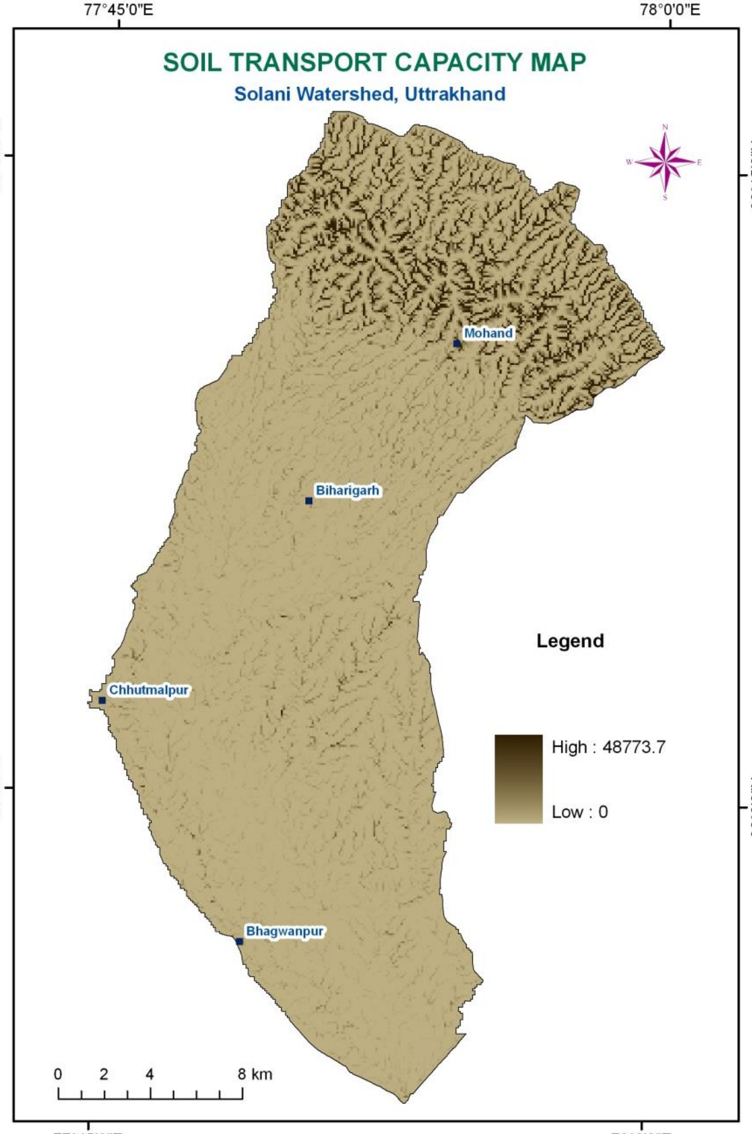
R = Rainfall factor

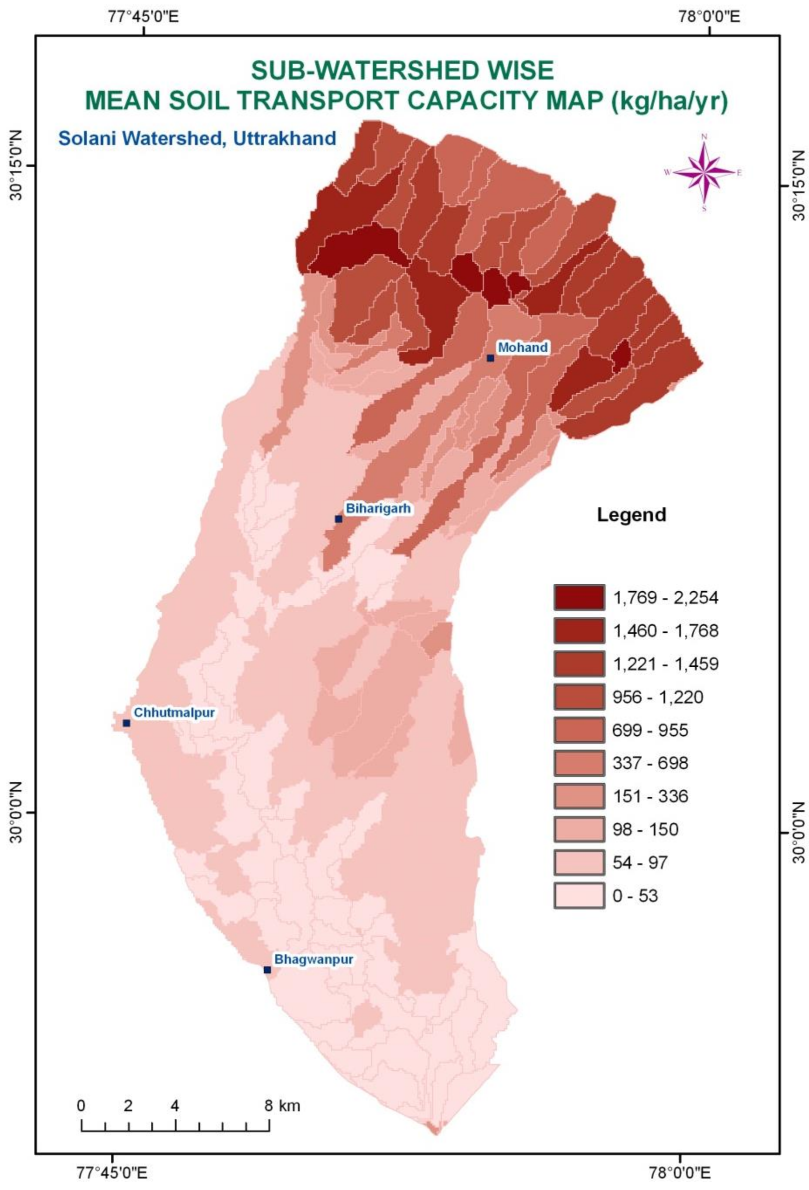
K = Soil Erodability factor

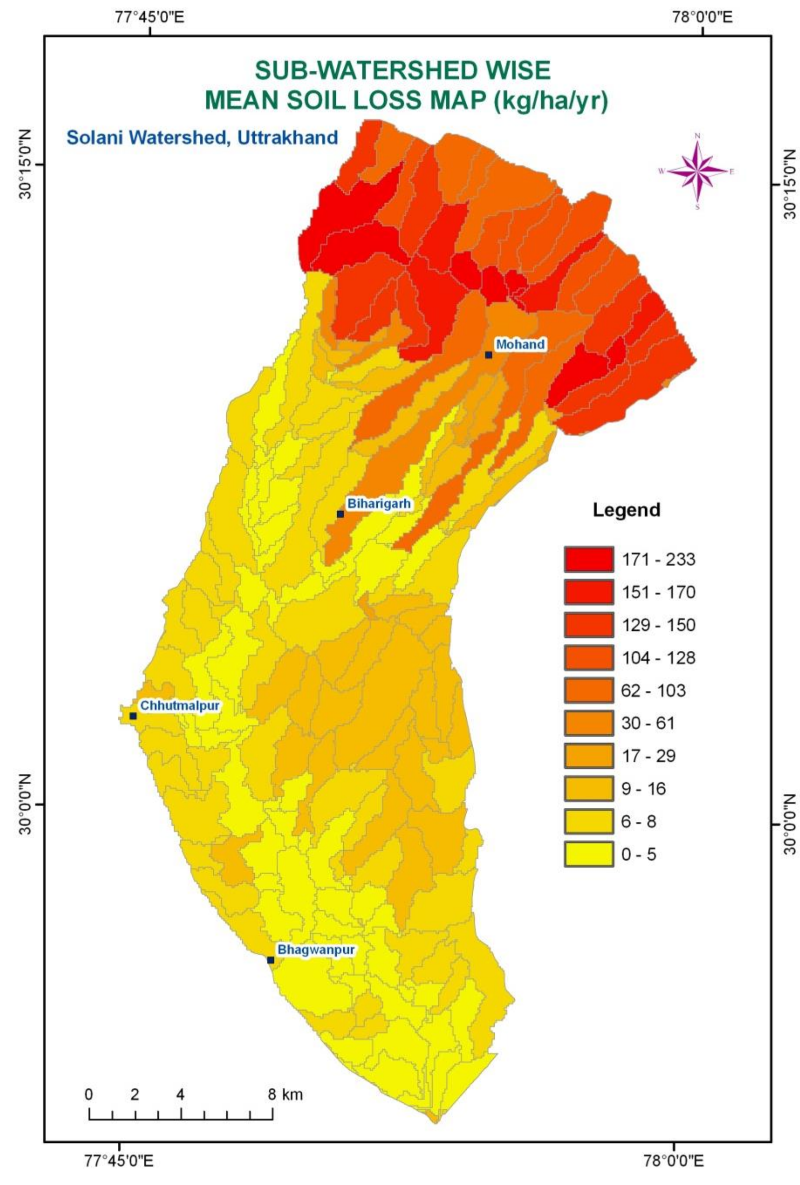
Ktc = β. EXP (-NDVI/1-NDVI) (Ktc map is shown as Fig. 20)

β = 0.1-1.5, here the value of beta is taken as 1.


KTc - CONSTANT MAP
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
High : 1.55
Low : 0.29
0 2 4 8 km


SOIL TRANSPORT CAPACITY MAP
Solani Watershed, Uttrakhand
77°45'0"E
78°0'0"E
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
High : 48773.7
Low : 0
0 2 4 8 km


77°45'0"E
78°0'0"E
SUB-WATERSHED WISE
MEAN SOIL TRANSPORT CAPACITY MAP (kg/ha/yr)
Solani Watershed, Uttrakhand
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
1,769 - 2,254
1,460 - 1,768
1,221 - 1,459
956 - 1,220
699 - 955
337 - 698
151 - 336
98 - 150
54 - 97
0 - 53
0 2 4 8 km


77°45'0"E
78°0'0"E
SUB-WATERSHED WISE
MEAN SOIL LOSS MAP (kg/ha/yr)
Solani Watershed, Uttrakhand
30°15'0"N
30°0'0"N
Mohand
Biharigarh
Chhutmalpur
Bhagwanpur
Legend
171 - 233
151 - 170
129 - 150
104 - 128
62 - 103
30 - 61
17 - 29
9 - 16
6 - 8
0 - 5
0 2 4 8 km

CONCLUSIONS

- The integration of remote sensing and GIS techniques was successfully employed in this study to find out the erosion and sediment transport capacity of the Solani watershed.
- The results of this study has depicted that the amount of soil loss in the Solani watershed is ranging from 0 to 2385 kg/ha/yr. The soil transport capacity and soil loss are having a direct relationship.
- This approach could be applied easily for other watersheds for efficient and effective planning and implementation for various conservation measures.


Thank You