SOIL EROSION & RESERVOIR SILTATION

Unit 10

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SOIL EROSION & RESERVOIR SILTATION

Erosion is the process of detachment and transport of soil particles by erosive agents (Ellison, 1944)

Erosion is a natural geologic process

SOIL EROSION: A process of detachment and transportation of soil materials by erosion agents. e.g. water – rainfall and runoff.

RESERVOIR SILTATION: Deposition of transported sand, silt & clay materials in the reservoirs due to reduction in velocity of flowing water.

SOIL ERODABILITY: The natural susceptibility of a soil to erosion i.e., both detachment and transport.

SEDIMENT YIELD: The total sediment outflow from a watershed or drainage basin measurable at a point of reference and in a specified period of time.

REMOTE SENSING: Identification of soil erosion areas using satellite imageries makes the problems solvable very easily and possible to arrest the silt in the catchment itself so as to avoid siltation of reservoirs in downstream sides and protect the soil in the catchment area.

GEOINFORMATICS (GIS): Identification of controlling factors of soil erosion using recently emerging GIS technology reduces the time and cost ratio and enable to adopt suitable remedial measures to control soil erosion in the catchment itself.

IMPACTS OF SOIL EROSION AND RESERVOIR SILTATION

- ➔ Excessive sediment accumulation reduces reservoir storage capacity and more frequent sediment removal is required.
- ➔ Erosion severely diminishes the ability of the soil to support plant growth; and the sand advance to the fertile lands. Thus, the loss in agricultural productivity.
- ➔ Damages the engineering structures such as abrasion in hydel dams and canals.
- ➔ Suspended nutrients trigger algal blooms that reduce water clarity, deplete oxygen, lead to fish kills and create odors.
- ➔ Erosion of stream banks and adjacent areas destroys stream side vegetation
- ➔ Excessive deposition of sediments in streams, blankets the bottom fauna, ‘paves’ stream bottoms and destroys fish pawning areas.
- ➔ Turbidity from sediment reduces in – stream photosynthesis which leads to reduced food supply and habitat.

Soil erosion is broadly classified into two groups, one is geologic and the other one is accelerated. The normal geologic soil erosion is compensated by the formation of new soil cover by weathering process. While the anthropogenic activity intervene these normal processes, then it changes as accelerated soil erosion.

The process of soil erosion is controlled by various factors such as,

- Rainfall
- Slope of the land
- Forest cover removal
- Nature of soil i.e. texture, structure and organic matter
- Water table
- Barren surface
- Continuous dry weather
- Wind velocity

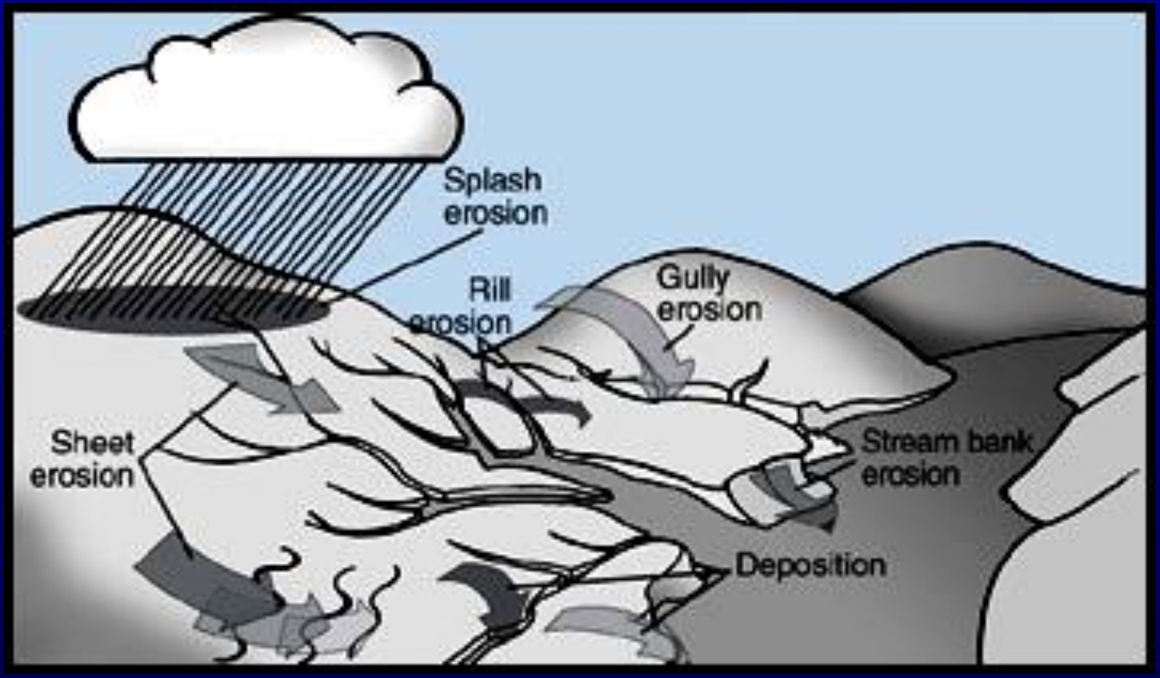
TYPES OF SOIL EROSION

1. SOIL EROSION BY WATER
2. SOIL EROSION BY WIND
3. SOIL EROSION BY GLACIER

Different types of Soil erosion

Types of Soil erosion	Erosion by Water	Rain splash erosion
		Sheet wash erosion
		Rill erosion
		Gulley erosion
		Shore erosion
		Slip erosion
		Stream-bank erosion
	Erosion by Wind	Saltation
		Suspension
		Surface creep
	Erosion by Ice	Plucking
		Abrasion
		Freeze thaw / Frost shattering

TYPES OF SOIL EROSION



Splash erosion

Sheet erosion

Rill erosion

Inter rill erosion

Gully erosion

Channel erosion and

Rain splash erosion: Falling raindrops splash soil. Raindrops fall at a speed of about 20 miles per hour. The raindrop splash beats the bare soil into flowing mud. A single raindrop may splash-wet soil as much as two feet high give feet away.

Sheet erosion: Soil is removed uniformly in thin layer from the entire surface area. Movement of soil by splash erosion is the primary cause of sheet erosion.

Rill erosion: When, run-off water laden with soil flowing along the slopes forming small finger-like channels, rill erosion is formed. Rill erosion is an intermediary stage between sheet erosion and gulley erosion.

Gulley erosion: As the volume of concentrated run-off increases and attains more velocity on slopes, it enlarges the rill into gullies. Gullies often starts along bullock car tracks or burrows of animals. At an advanced stage, gullies result into ravines, which are sometimes 50 to 100 feet deep.

Slip erosion: Landslides cause slope erosion, big masses of soil and rock body slip down damaging the field. The effects of slip erosion are site specific.

Stream-bank erosion: Streams and rivers change their course by cutting one bank and depositing silt loads on the others. During flash floods, the damage is very much accelerated.

Shore erosion: Seashore erosion commonly known as coastal erosion is caused by the striking action of the waves.

Saltation: In saltation, soil particles of medium size (0.10-0.15 mm diameter) are carried by wind in a series of short bounces. The direct pressure of the wind on soil particles causes these bounces.

Surface creeps: Saltation also encourages soil creep (rolling or sliding) along the surface of the large particles (0.5-1.0 mm diameter). The bouncing particles carried by saltation strike the large aggregates and speed up their movement along the surface.

Suspension: When the particles of soil are very small (less than 0.1 mm) they are carried over long distances. Finer suspended particles are moved parallel to the ground surface and upward.

The problems of the soil erosion vary from place to place in our country. For example in northern states, particularly in Assam, shifting cultivation (called ‘Jhum’ cultivation, and ‘chaparies’), is responsible for soil erosion.

Whereas in Rajasthan, wind erosion is the dominant phenomenon. In Punjab, soil erosion is caused by ‘chos’ – sand torrent in the Siwalik foothills.

In the state of Maharastra, the problem of soil erosion is in the form of moisture loss.

In southern states, particularly Tamil Nadu and Kerala, the cause for soil erosion is misuse of land in the form of removal of natural forest cover to plantation purposes such as tea, coffee, cinchona and eucalyptus. In Andhra Pradesh and Karnataka, sheet erosion is common in the low rainfall areas.

CONTROLLING FACTORS OF SOIL EROSION

Erosive potential of an area depends on,

- Climate – rain drop size, intensity, distribution, fall velocities, total mass of impact and temperate.
- Characteristics of soil – texture, structure, permeability, compactness and infiltration capacity
- Vegetal cover – types of vegetation, density, root systems
- Topography – slope, slope length, slope configuration and surfacial features
- Human activities – landuse, construction practices, agricultural operations, landuse conversion to rocky wastes, deforestation, industrial waste disposals, mining and mine waste gushing.

Soil Erosion Controlled by Geoscientific parameters such as

- ➔ Geology
- ➔ Structure of the area
- ➔ Geomorphology
- ➔ Subsurface geology
- ➔ Drainage Density
- ➔ Water level / table
- ➔ Slope
- ➔ Land use / Land cover
- ➔ Climate

PRINCIPLES OF SOIL EROSION AND SEDIMENT CONTROL

- Retain existing vegetation wherever feasible
- Vegetate in denuded areas
- Divert runoff away from denuded areas
- Minimise length and steepness of slopes
- Keep runoff velocities low
- Prepare drainage ways and outlets to handle concentrated or increased runoff
- Trap sediment on site
- Inspect and maintain control measures.

MEASUREMENT OF SOIL EROSION

The Universal Soil Loss Equation (USLE) – designed by two soil scientists namely, Wischmeier and Smith during the year 1978 is to predict the soil loss in the field.

$$A = R * K * LS * C * P$$

The Universal Soil Loss Equation (USLE) predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices

A = Soil loss in tons/ha/year

R = Rainfall and runoff factor

K = soil erodability factor

LS = Slope length-gradient factor

C = vegetative cover factor

P = conservation practice factor

R= rainfall factor. The value of this factor is determined by the amount and intensity of rainfall determined by location in the country.

K = soil erosivity factor. The value of this factor depends upon soil texture (mineral composition) and structure (the proportion of air, organic matter and water that gives a soil its structure.)

LS = Length of slope factor. This factor accounts for the effects of the grade of a field and the shape of its slopes. It is important to realize that it does not take a steep slope to move a lot of soil. A gentle but long slope can results in high levels of erosion.

C = Cultural practices factor. This factor accounts for the impact of crop rotations (pasture, legumes, corn, etc.) that will provide varying degrees of soil cover. Also, this factor includes conservation tillage practices and other cultural practices can reduce or enhance substantially soil loss.

P= Supporting Practices factor. This factor accounts for management pratices such as construction of terraces or contour strips that keep water at about the same elevation in a field, and thus avoid direct downhill flow.

K Factor Data – Soil erodability factor (Organic Matter Content)

Textural Class	Average	Less than 2 %	More than 2 %
Clay	0.22	0.24	0.21
Clay Loam	0.30	0.33	0.28
Coarse Sandy Loam	0.07	--	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.30	0.34	0.26
Loamy Fine Sand	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.20	-	0.20
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silty Clay	0.26	0.27	0.26
Silty Clay Loam	0.32	0.35	0.30
Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

Table 3A. LS Factor Calculation

Slope Length ft (m)	Slope (%)	LS Factor
	10	1.3800
	8	0.9964
	6	0.6742
	5	0.5362
100 ft (31 m)	4	0.4004
	3	0.2965
	2	0.2008
	1	0.1290
	0	0.0693

Table 4A. Crop Type Factor

Crop Type	Factor
Grain Corn	0.40
Silage Corn, Beans & Canola	0.50
Cereals (Spring & Winter)	0.35
Seasonal Horticultural Crops	0.50
Fruit Trees	0.10
Hay and Pasture	0.02

Soil Loss Tolerance Rates

Soil Erosion Class	Potential Soil Loss (tons/acre/year)
Very Low (tolerable)	<3
Low	3 - 5
Moderate	5 - 10
High	10 - 15
Severe	>15

Table 7. Management Strategies to Reduce Soil Losses

Factor	**Management Strategies**	**Example**
R	The R Factor for a field cannot be altered.	--
K	The K Factor for a field cannot be altered.	--
LS	Terraces may be constructed to reduce the slope length resulting in lower soil losses.	Terracing requires additional investment and will cause some inconvenience in farming. Investigate other soil conservation practices first.
C	The selection of crop types and tillage methods that result in the lowest possible C factor will result in less soil erosion.	Consider cropping systems that will provide maximum protection for the soil. Use minimum tillage systems where possible.
P	The selection of a support practice that has the lowest possible factor associated with it will result in lower soil losses.	Use support practices such as cross slope farming that will cause deposition of sediment to occur close to the source.

VEGETATIVE METHODS OF SOIL STABILIZATION

Vegetal cover reduces erosion by,

- Absorbing the impact of raindrops
- Reducing the velocity of runoff
- Reducing runoff volumes by increasing water percolation in to the soil
- Binding soil with roots
- Protecting soil from wind

This method needs

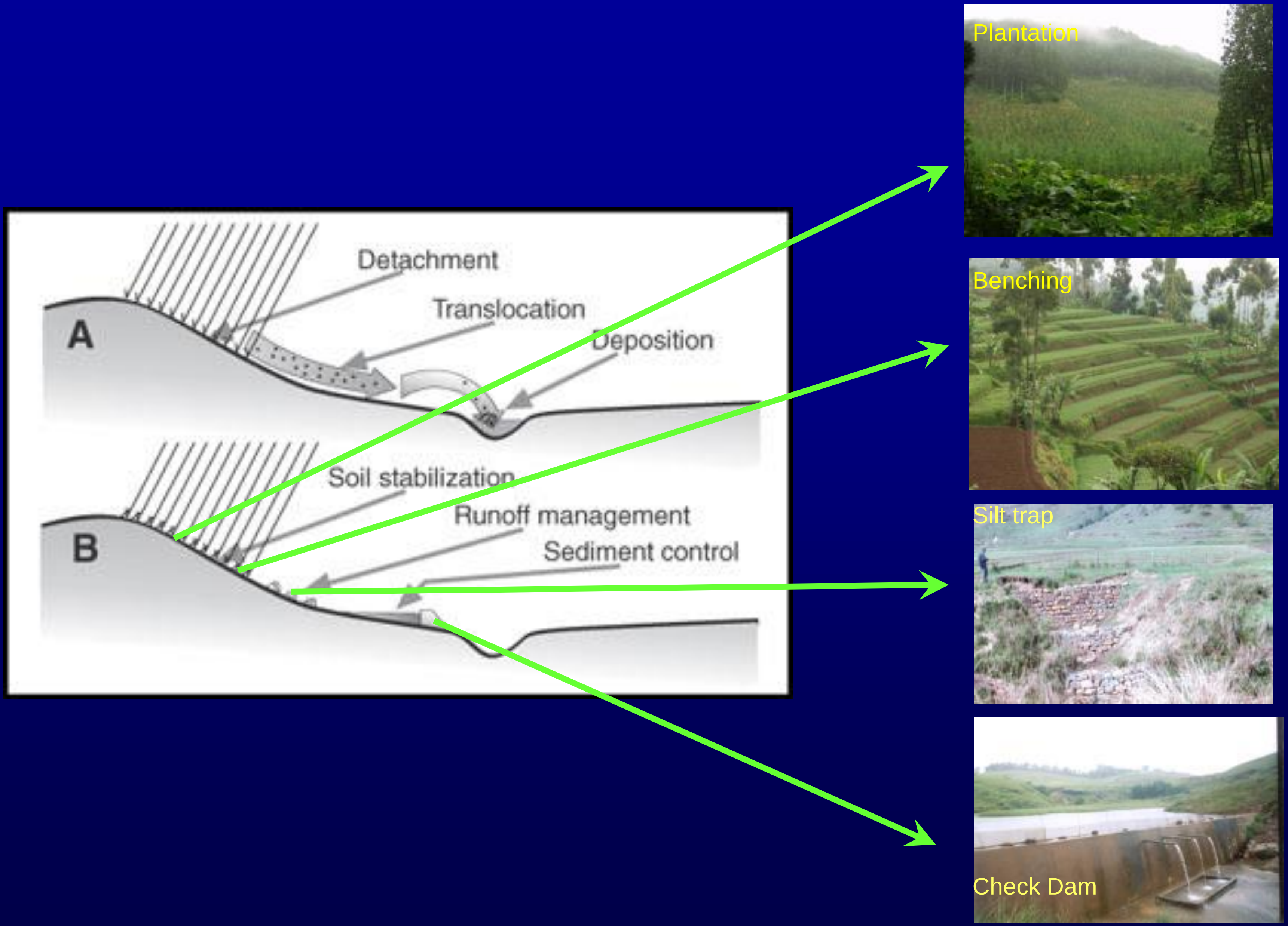
- Careful selection of plants
- Site preparation, seeding
- Fertilizing and
- Mulching

MECHANICAL METHODS OF SOIL EROSION CONTROL

Contouring / Contour cultivation, Contour strip cropping, Contour bunds Terracing, Terrace cultivation

Water conveyance structures

- Grassed water ways
- Check dams
- Dikes and swales
- Pipe slope drains and paved chutes
- Permanent water ways,
- Channel linings
  - Gravel lined swale
  - Rock lined water ways
  - Plastic lined ditches
- Wind breaks
- Changing soil humus levels and tillage practices
- Geotextiles

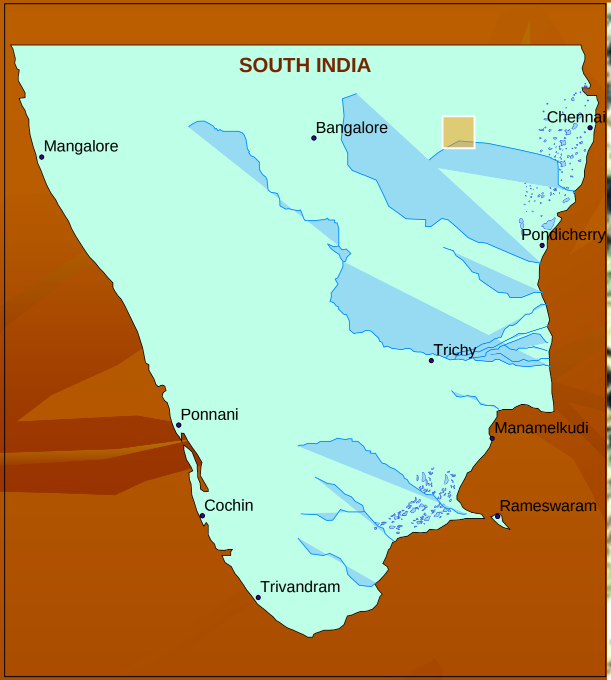

A
Detachment
Translocation
Deposition
B
Soil stabilization
Runoff management
Sediment control
Plantation
Benching
Silt trap
Check Dam

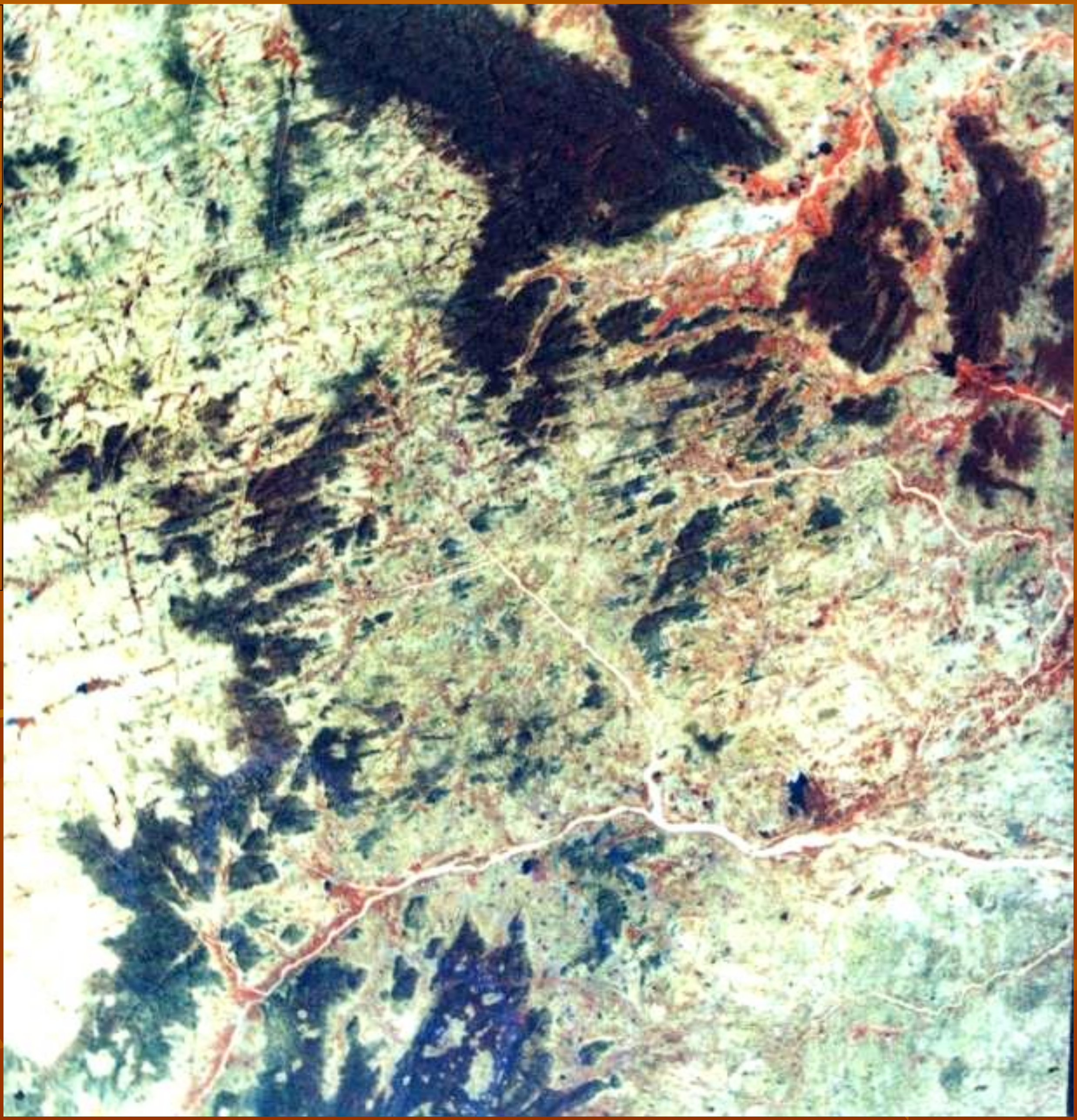
Identification of Soil Erosion Prone Areas,

Soil Erosion Functional Model

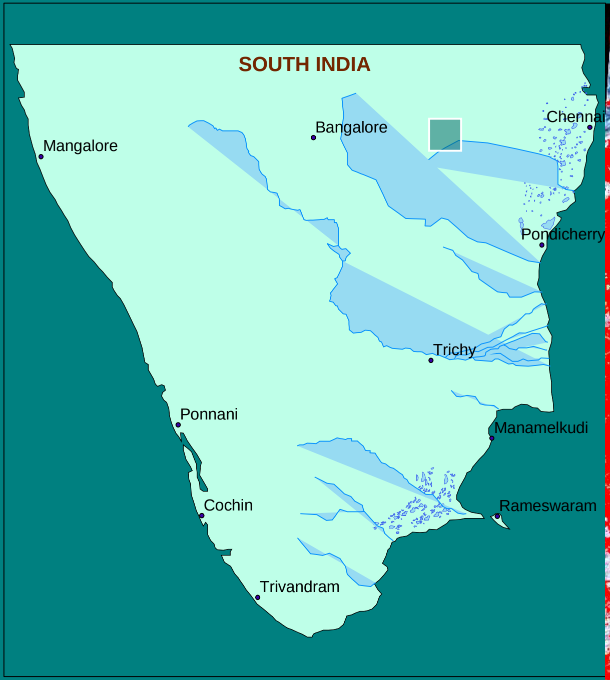
Conservation Measures

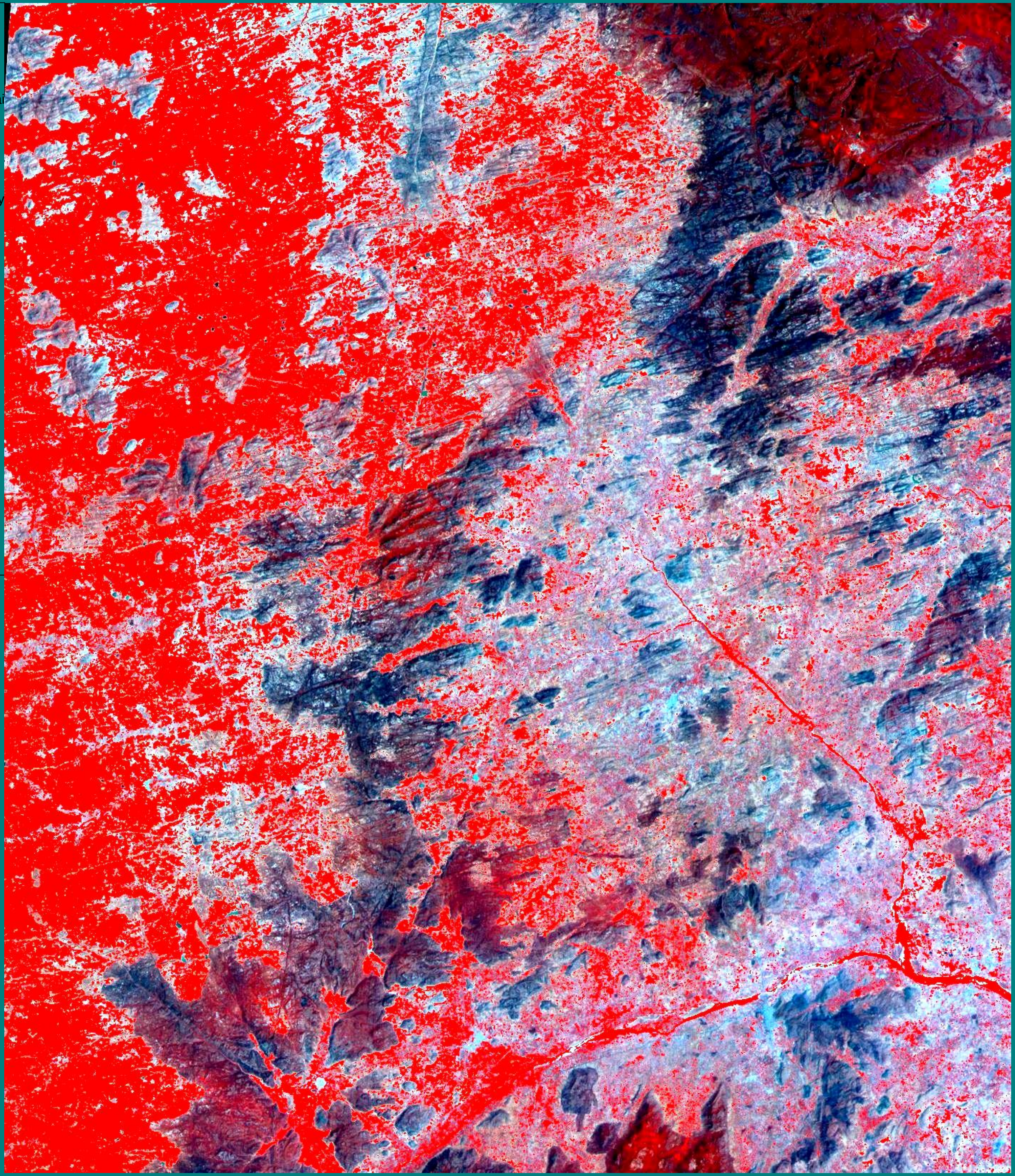
Using Remote Sensing and GIS



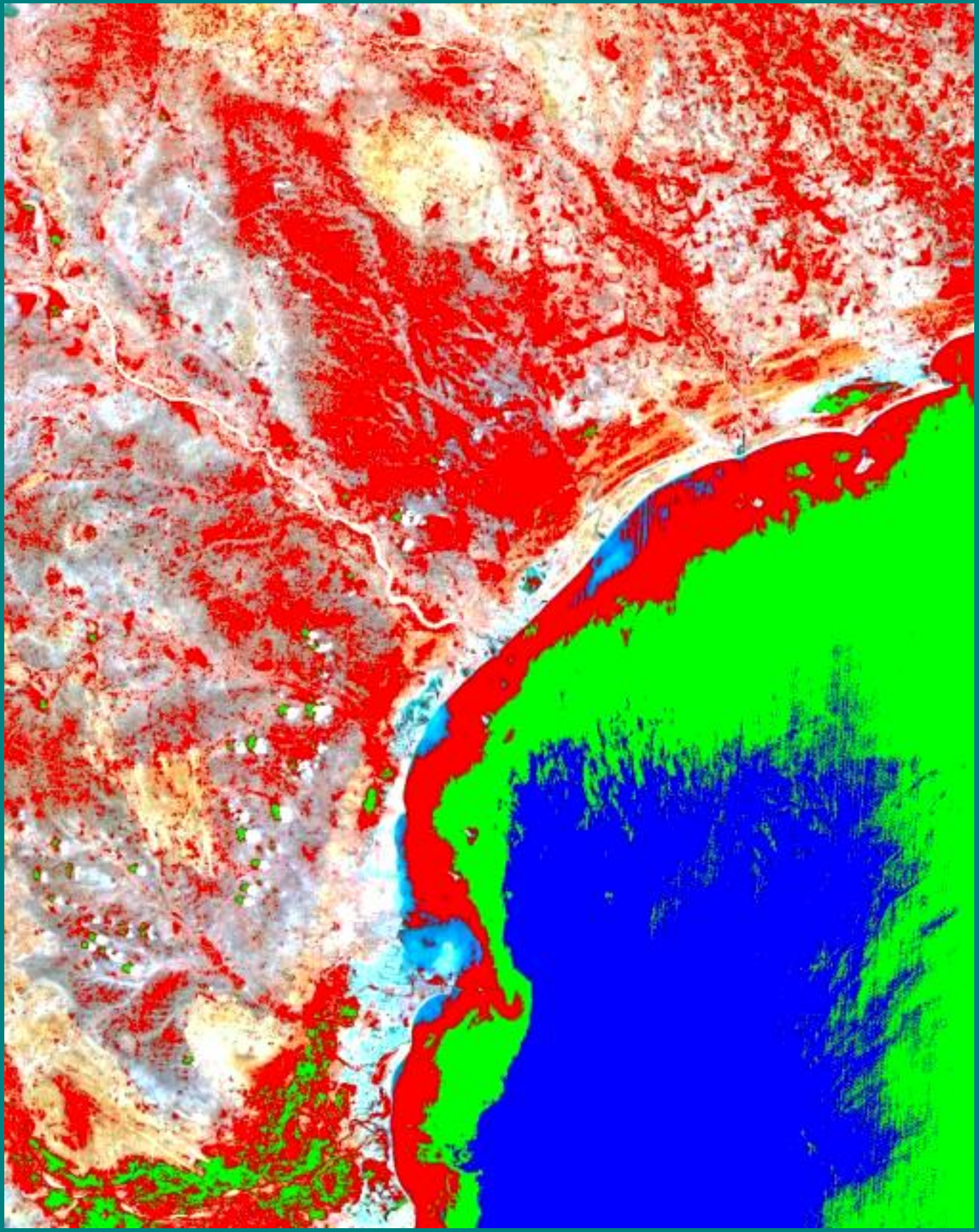


SOIL EROSION IN CHENNAI REGION



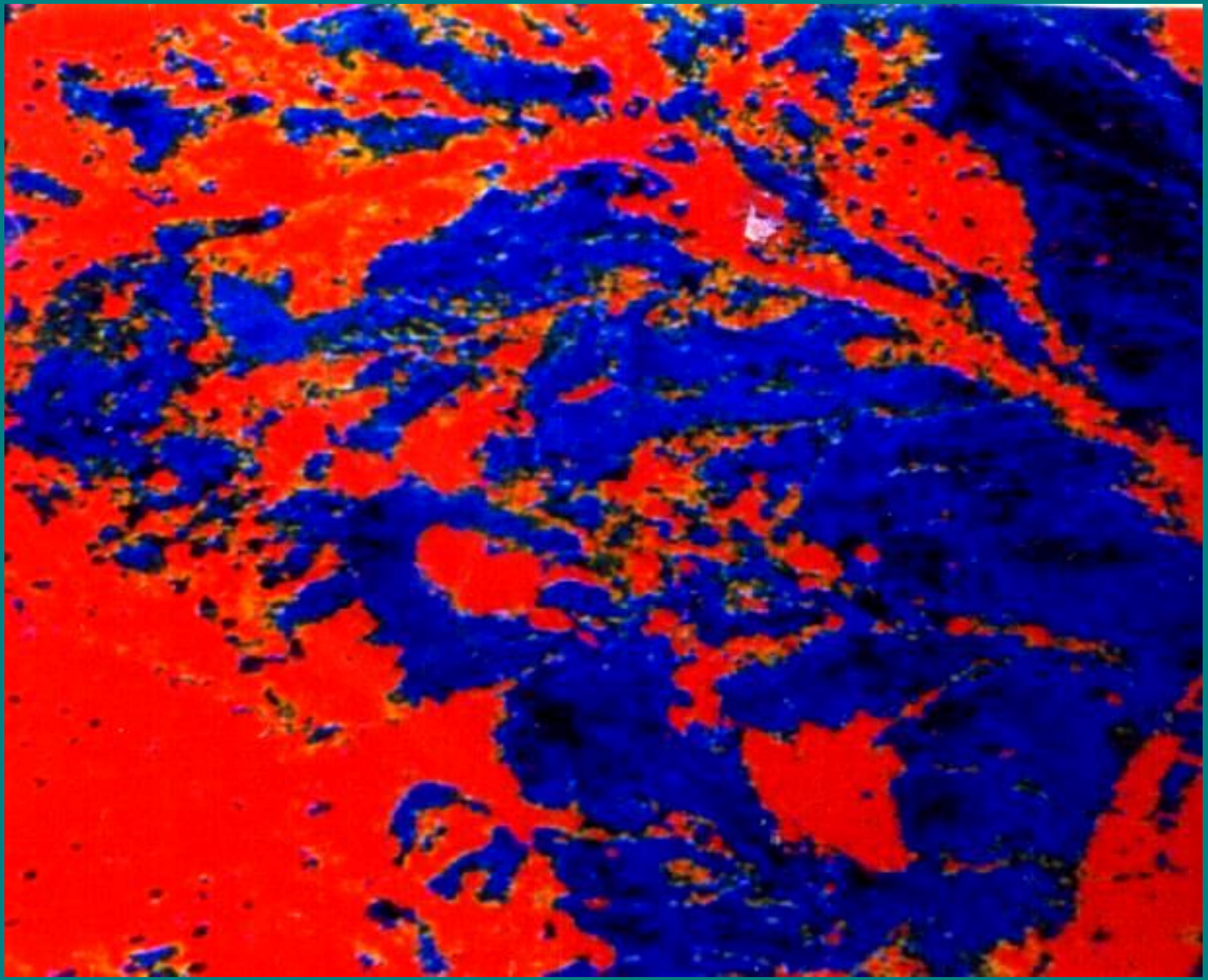


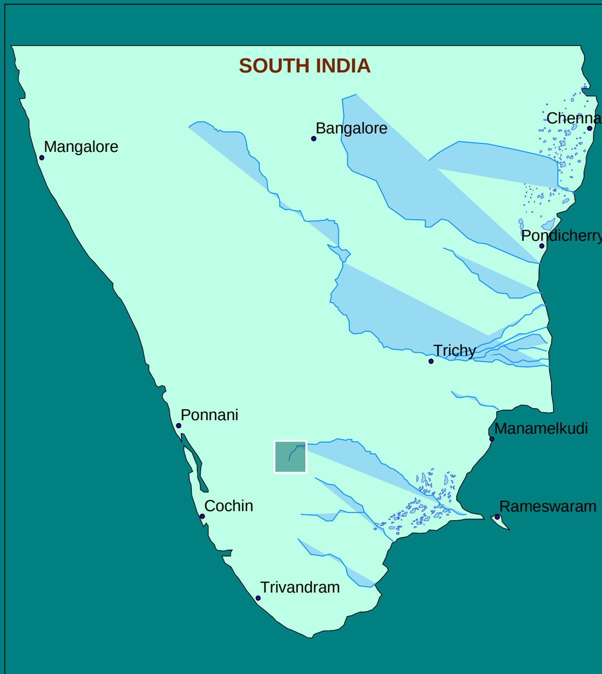
SOIL EROSION IN CHENNAI REGION – PROCESSED IMAGE



SOIL EROSION AND SEDIMENT DUMPING IN VAIPPAR REGION

SOIL EROSION IN VAIPPAR REGION

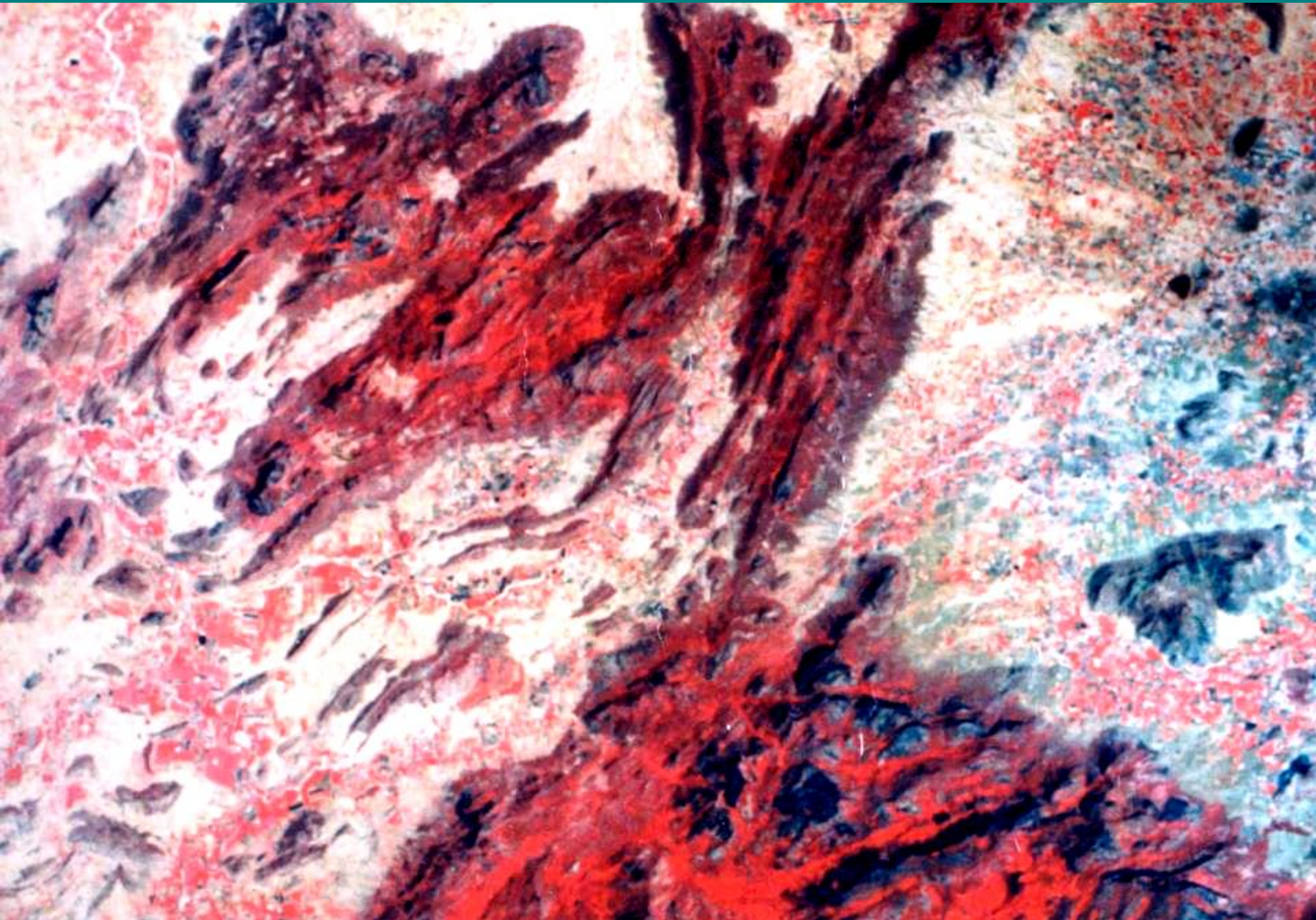




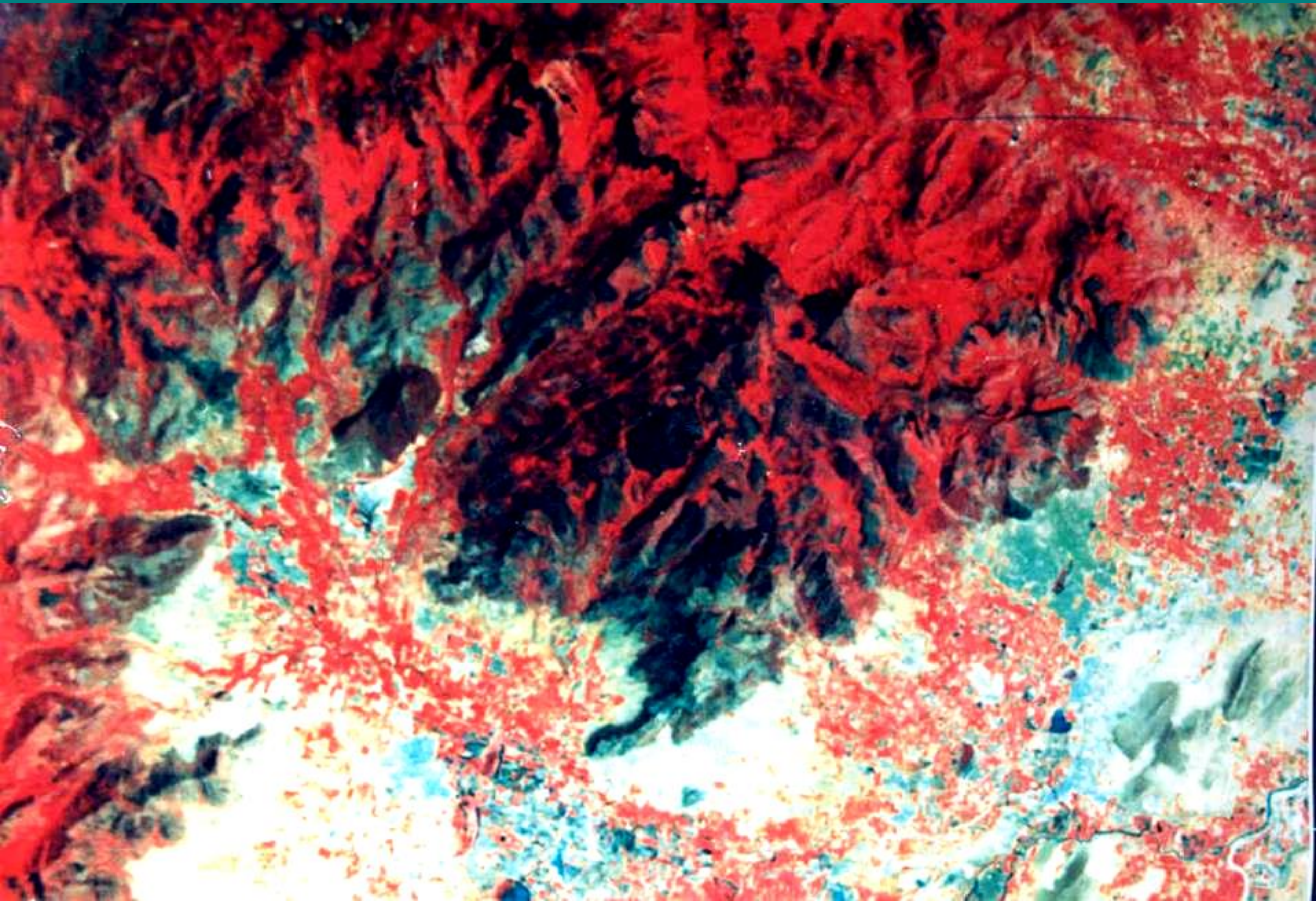
SOIL EROSION IN VAIGAI CATCHMENT

PARTS OF KODAI HILLS – FIRST ORDER DRAINAGES

PARTS OF KODAI HILLS – ACTIVE FOOT HILLS

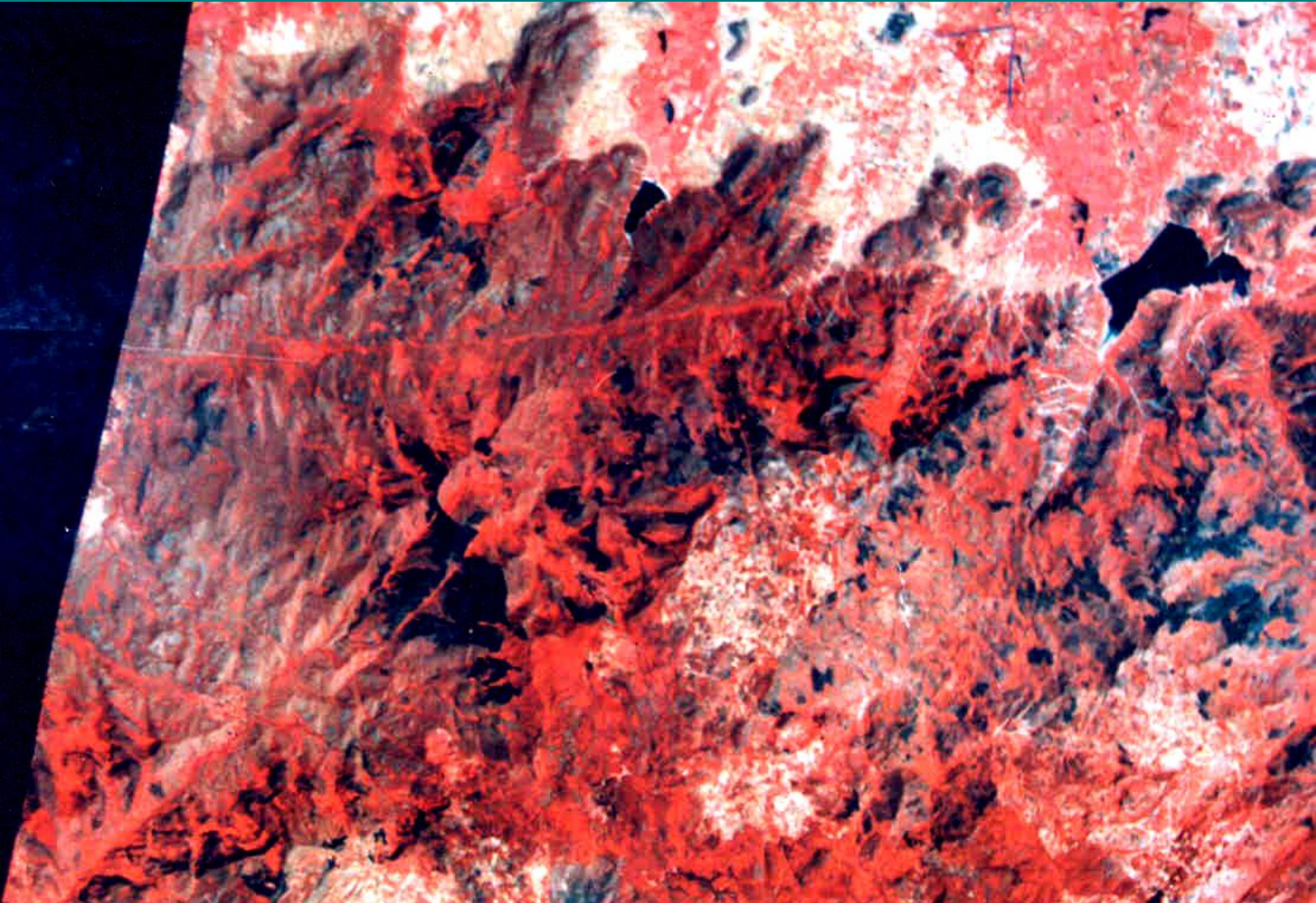


PARTS OF KODAI HILLS – ACTIVE SLOPES



PARTS OF KODAI HILLS – EROSION PRONE LITHOLOGY

PARTS OF KODAI HILLS – EROSION PRONE FRACTURES / LINEAMENTS



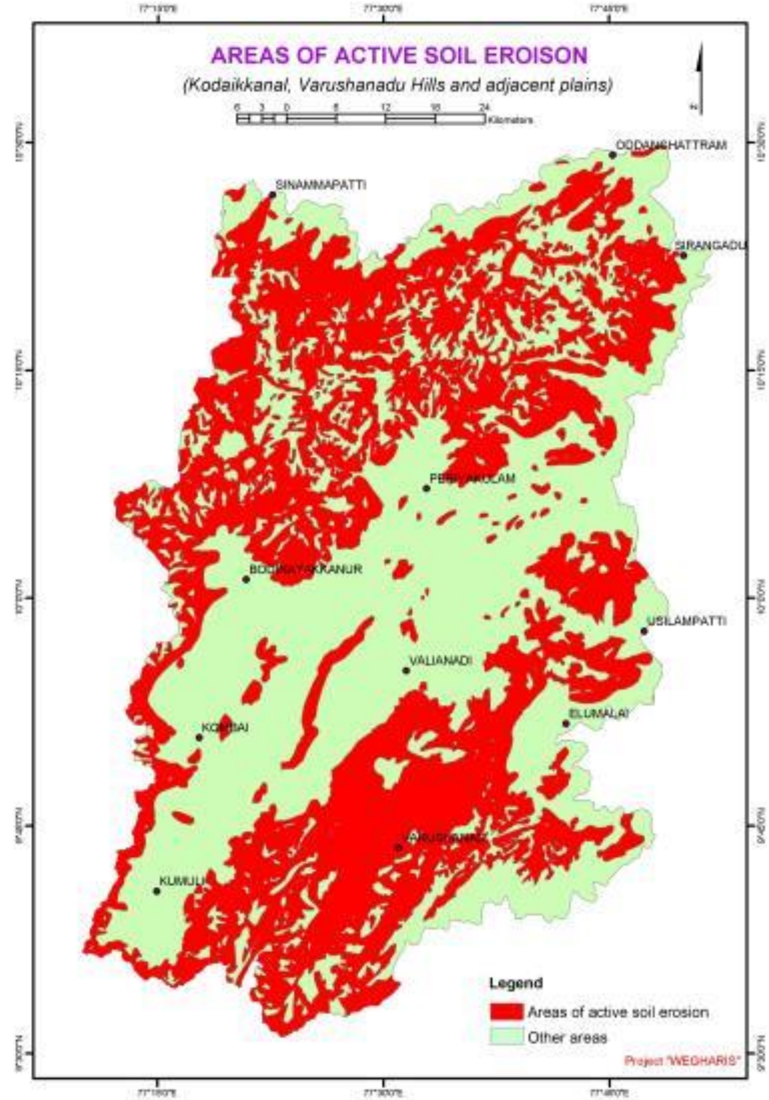

AREAS OF ACTIVE SOIL EROISON
(Kodaikkanal, Varushanadu Hills and adjacent plains)
ODDANCHATTRAM
SINAMMAPATTI
SIRANGADU
PERIYAKULAM
BODINAYAKKANUR
USILAMPATTI
VALIANADI
ELUMALAI
KOMBAI
VARUSHANAD
KUMULI
Legend
Areas of active soil erosion
Other areas
Project "WEGHARIS"

Fig. 4.10

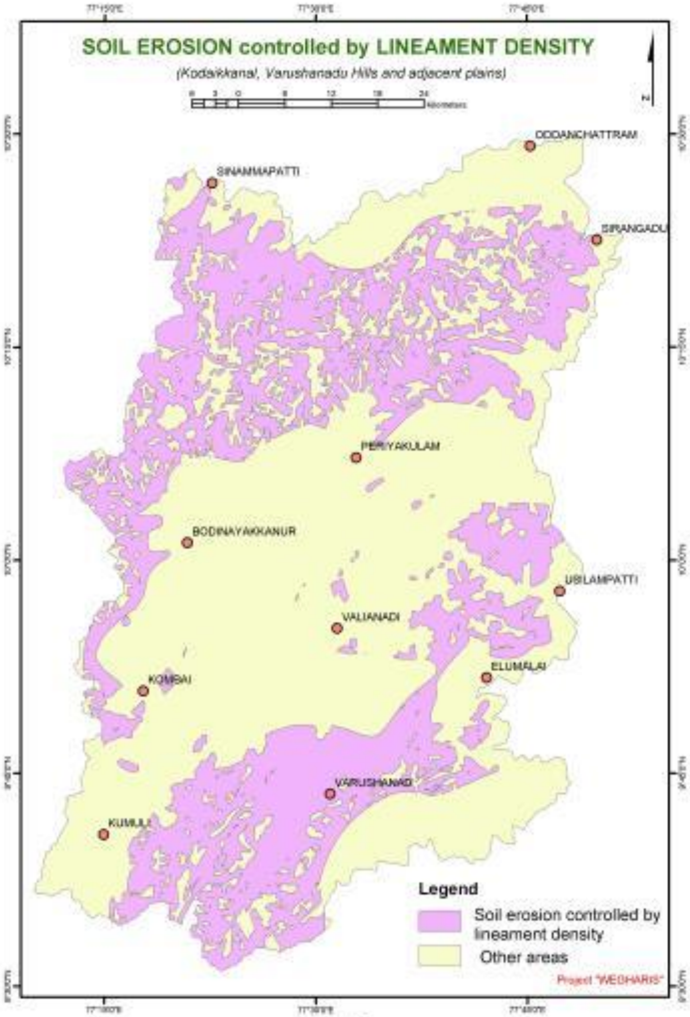

SOIL EROSION controlled by LINEAMENT DENSITY
(Kodaikkanal, Varushanadu Hills and adjacent plains)
ODDANCHATTRAM
SINAMMAPATTI
SIRANGADU
PERIYAKULAM
BODINAYAKKANUR
USILAMPATTI
VALIANADI
ELUMALAI
KOMBAI
VARUSHANAD
KUMULI
Legend
Soil erosion controlled by lineament density
Other areas
Project "WEGHARIS"

Fig. 2.5

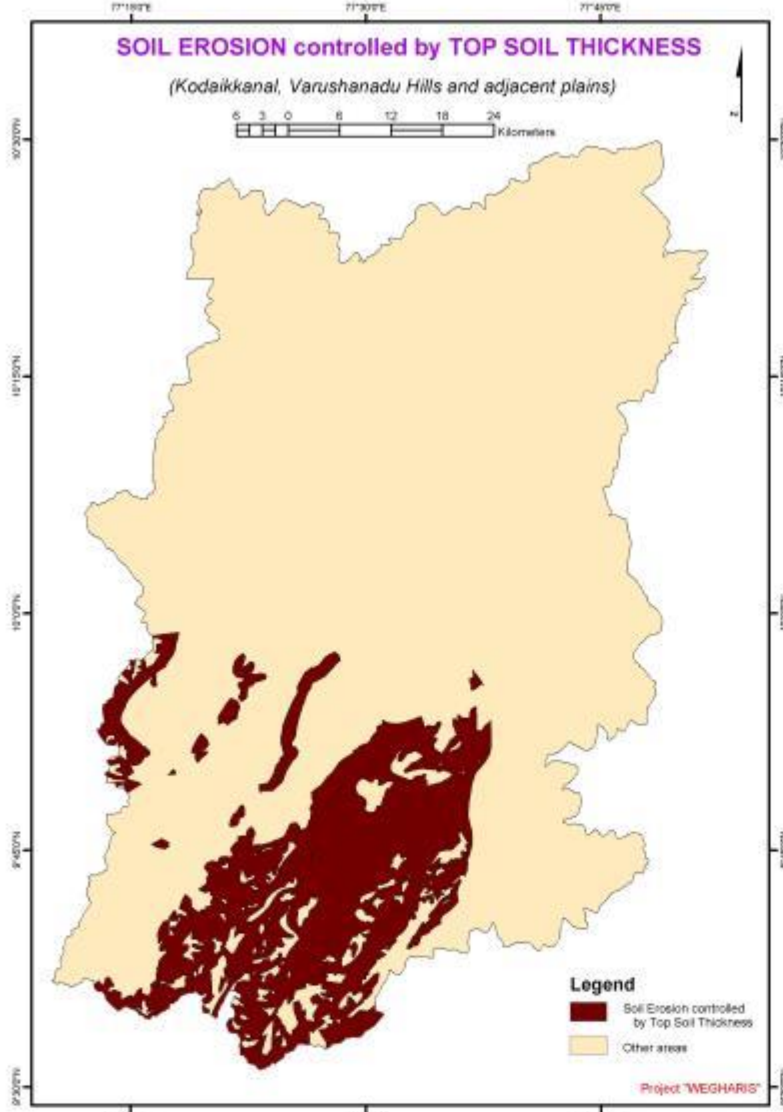
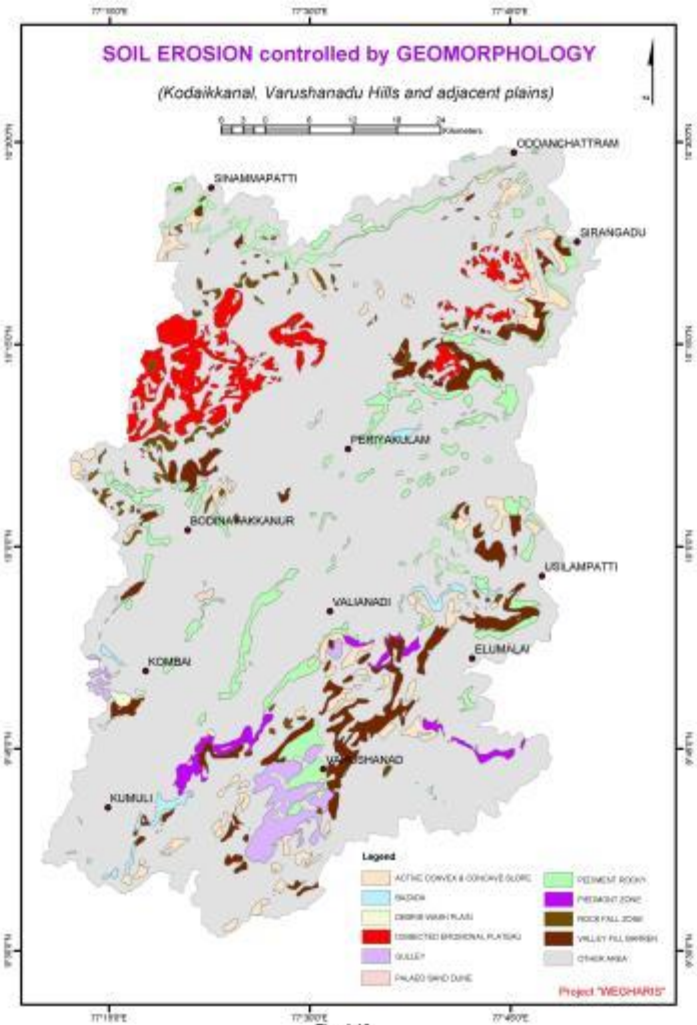

SOIL EROSION controlled by TOP SOIL THICKNESS
(Kodaikkanal, Varushanadu Hills and adjacent plains)
Kilometers
Legend
Soil Erosion controlled by Top Soil Thickness
Other areas
Project "WEGHARIS"

Fig. 4.12

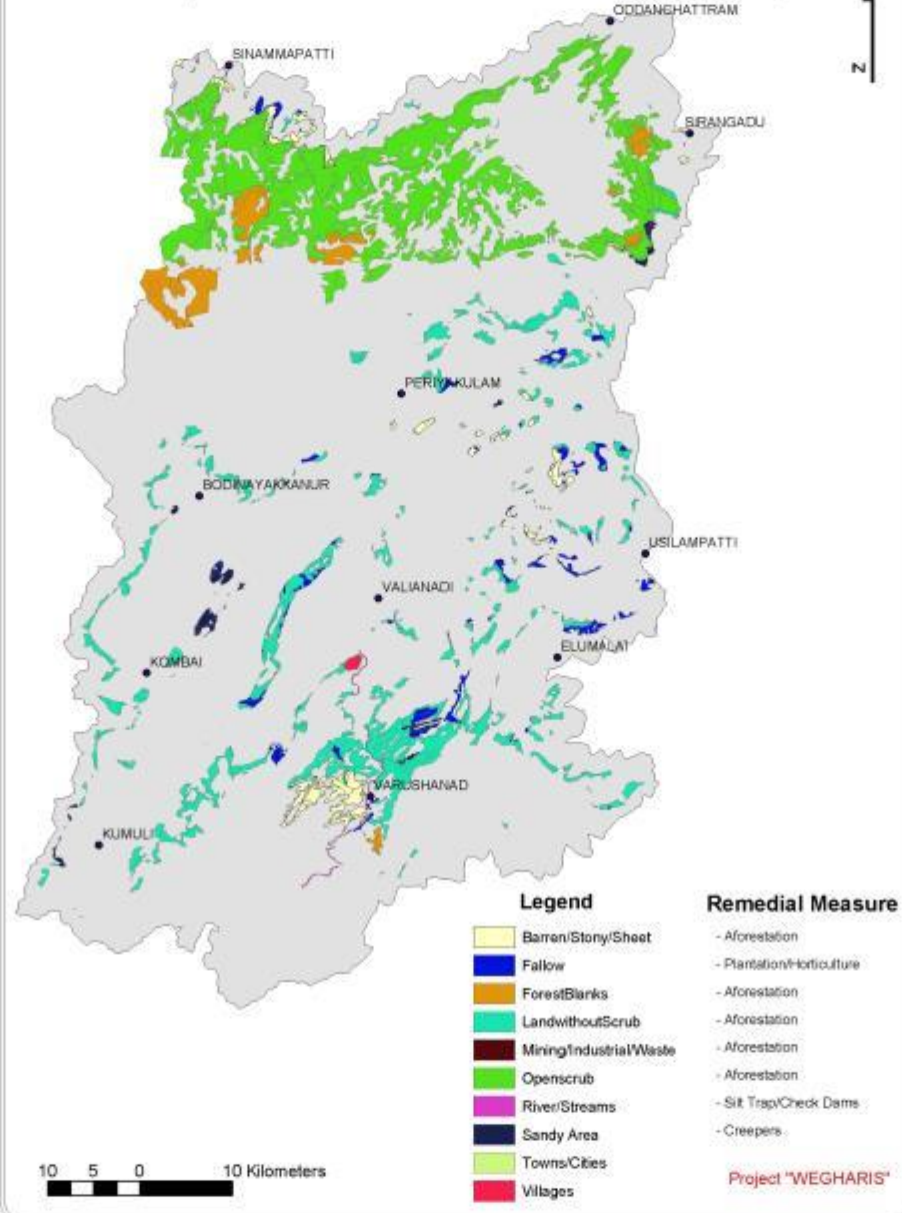


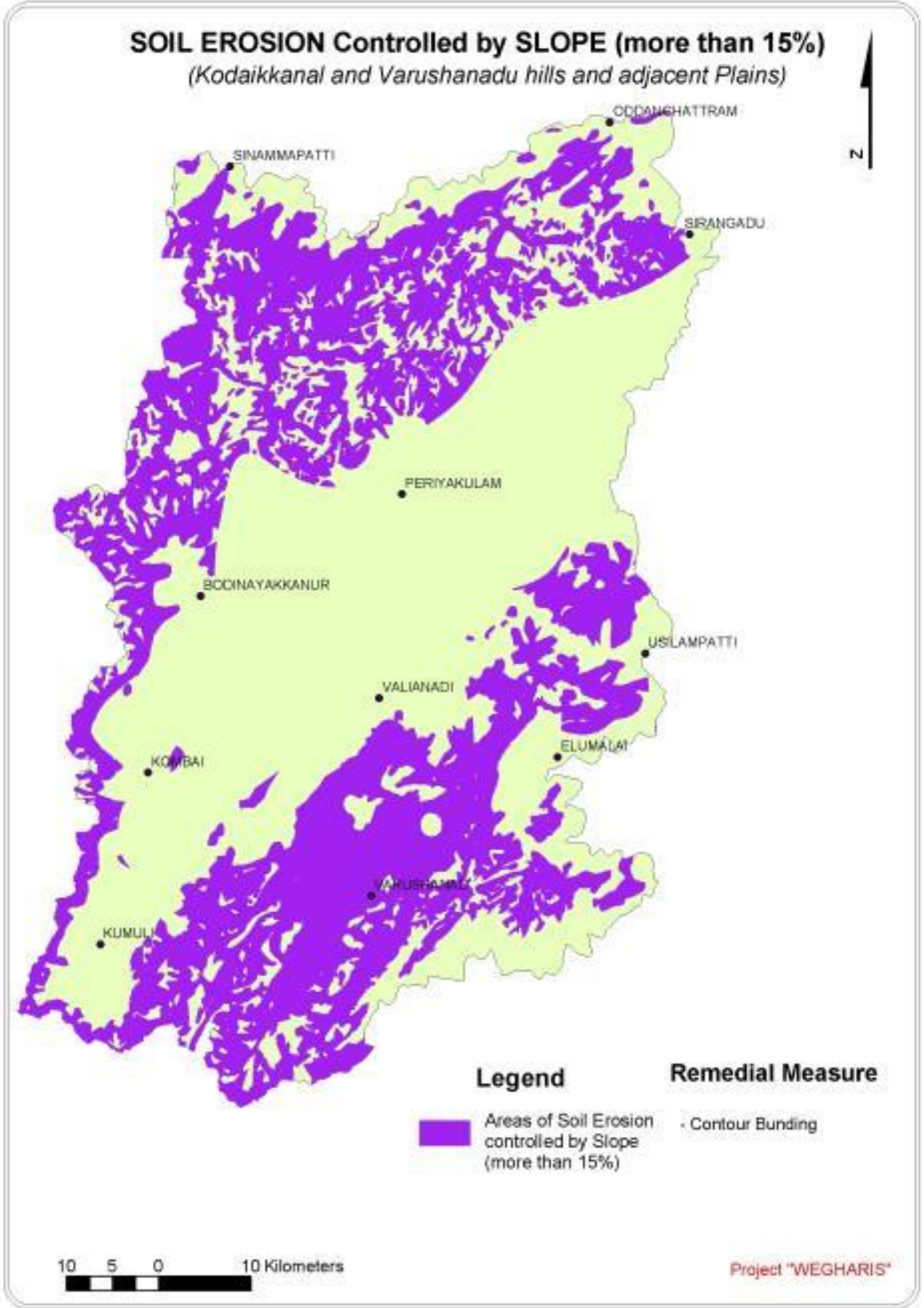
SOIL EROSION controlled by GEOMORPHOLOGY
(Kodaikkanal, Varushanadu Hills and adjacent plains)
ODDANCHATTRAM
SINAMMAPATTI
SIRANGADU
PERIYAKULAM
BODINAYAKKANUR
USILAMPATTI
VALIANADI
ELUMALAI
KOMBAI
VARUSHANAD
KUMULI
Legend

Fig. 4.13

Soil Erosion Controlled by Land Use/Cover

(Kodaikkanal and Varushanadu hills and adjacent Plains)




SOIL EROSION Controlled by SLOPE (more than 15%)
(Kodaikkanal and Varushanadu hills and adjacent Plains)
N
ODDANCHATTRAM
SINAMMAPATTI
SIRANGADU
PERIYAKULAM
BODINAYAKKANUR
USILAMPATTI
VALIANADI
ELUMALAI
KOMBAI
KUMULI
Legend
Remedial Measure
Areas of Soil Erosion controlled by Slope (more than 15%)
- Contour Bunding
10 5 0 10 Kilometers
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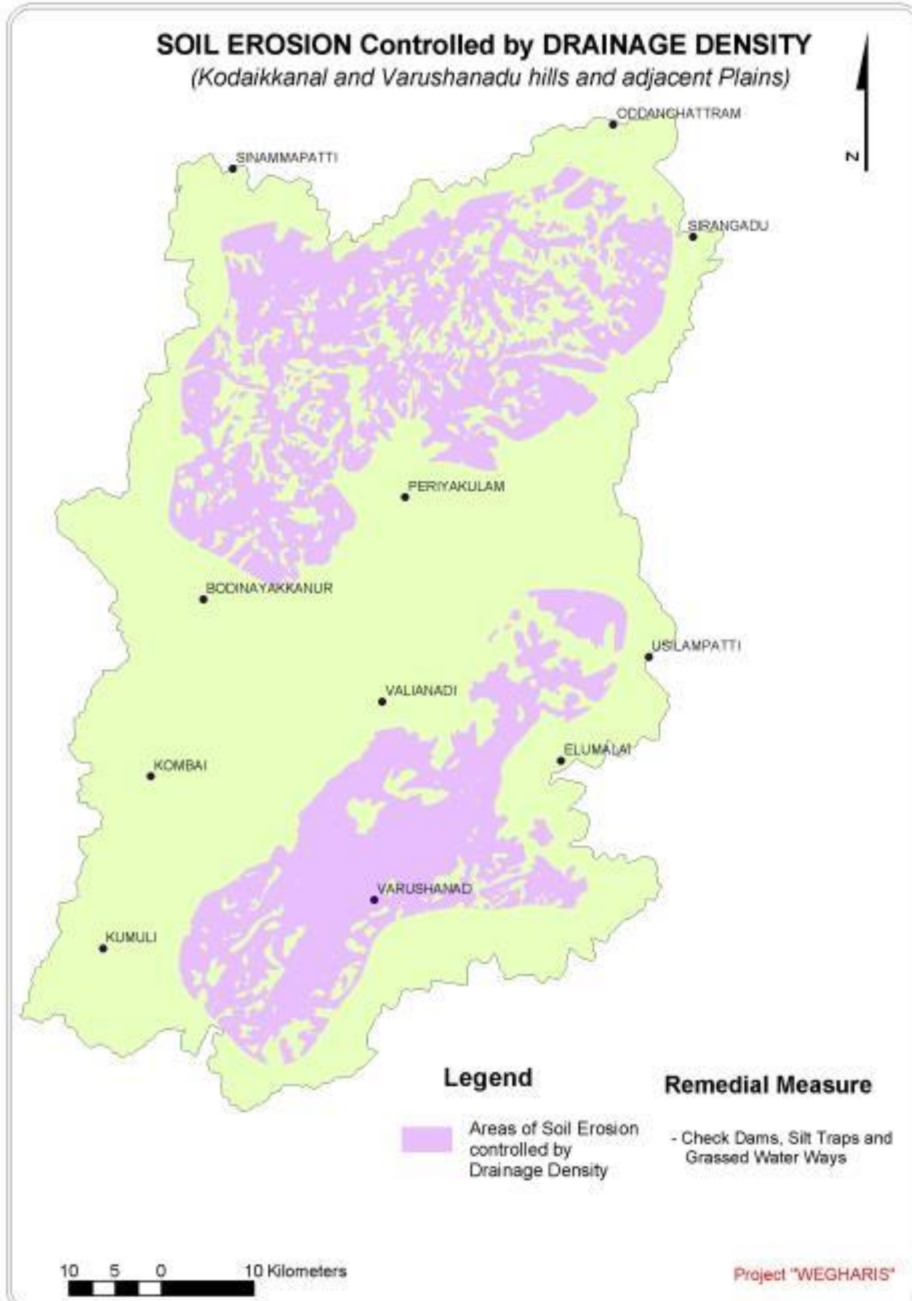
SOIL EROSION Controlled by DRAINAGE DENSITY
(Kodaikkanal and Varushanadu hills and adjacent Plains)
N
ODDANCHATTRAM
SINAMMAPATTI
SIRANGADU
PERIYAKULAM
BODINAYAKKANUR
USILAMPATTI
VALIANADI
ELUMALAI
KOMBAI
VARUSHANAD
KUMULI
Legend
Areas of Soil Erosion controlled by Drainage Density
Remedial Measure
- Check Dams, Silt Traps and Grassed Water Ways
10 5 0 10 Kilometers
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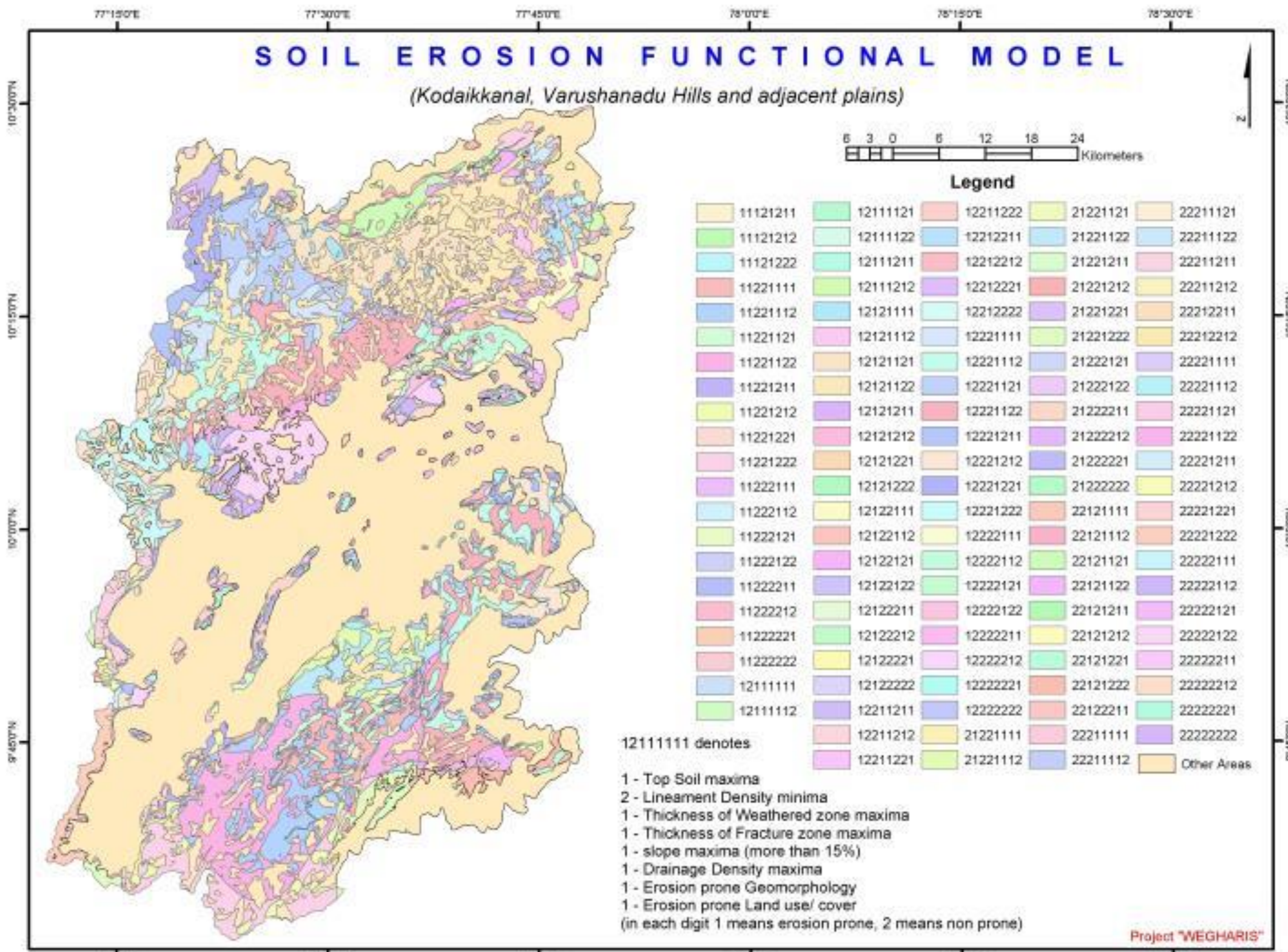
SOIL EROSION FUNCTIONAL MODEL
(Kodaikkanal, Varushanadu Hills and adjacent plains)
77°15'0"E
77°30'0"E
77°45'0"E
78°0'0"E
78°15'0"E
78°30'0"E
10°30'0"N
10°15'0"N
10°0'0"N
9°45'0"N
N
6 3 0 6 12 18 24 Kilometers
Legend
11121211
11121212
11121222
11221111
11221112
11221121
11221122
11221211
11221212
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11222111
11222112
11222121
11222122
11222211
11222212
11222221
11222222
12111111
12111112
12111121
12111122
12111211
12111212
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12121121
12121122
12121211
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12122111
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12122122
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12212221
12212222
12221111
12221112
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22121111
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22121122
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22121212
22121221
22121222
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22211111
22211112
22211121
22211122
22211211
22211212
22212211
22212212
22221111
22221112
22221121
22221122
22221211
22221212
22221221
22221222
22222111
22222112
22222121
22222122
22222211
22222212
22222221
22222222
Other Areas
12111111 denotes
1 - Top Soil maxima
2 - Lineament Density minima
1 - Thickness of Weathered zone maxima
1 - Thickness of Fracture zone maxima
1 - slope maxima (more than 15%)
1 - Drainage Density maxima
1 - Erosion prone Geomorphology
1 - Erosion prone Land use/ cover
(in each digit 1 means erosion prone, 2 means non prone)
Project "WEGHARIS"

Fig. 4.17

The Detailed Site Suitable Remedial Measures

Sl.No	SOIL EROSION CONTROLLED BY	REMEDIAL MEASURES
1	Drainage density	Gully Plugging, Check Daming
2	Slope	Check dam
3	Geomorphology	Gully Plugging, Afforestation, Silt trapping
4	Land Use / Land Cover	Afforestation in forest blank /open forest
5	Lineament Density	Gully filled Vegetation, Check daming
6	Drainage Density very High + Lineament Density Very High+ Bazada	Afforestation, Gully plugging, Gully Filled vegetation and Check daming
7	Drainage Density very High + Lineament Density Very High+ Valley fill	Afforestation, Gully Filled vegetation, gully plugging, Check dam, silt trap
8	Drainage Density very High + Lineament Density Very High+ Steep Slope	Placement of netting, gully filled vegetations, geotextiling, drainage diversion, surface and subsurface drains
9	Drainage Density very High + Lineament Density Very High+ Moderate Slope	Afforestation, Gully Filled vegetation, gully plugging, Check dam, silt trap and grassed water ways
10	Drainage Density very High + Lineament Density Very High+ Active Slope	Placement of netting, gully filled vegetations, geotextiling and silt trapping
11	Drainage Density very High + Lineament Density High+ Convex Slope	Grassed water ways, afforestation
12	Drainage Density Moderate + Lineament Density Moderate + Steep Slope	Afforestation, gully plugging, flattening of the slope, turfing with the soil binders among the grasses
13	Drainage Density Moderate + Lineament Density Very High+ Bazada + Scrub Land +Steep Slope	Plantation of Deep penetrating root, protection wall with weep wholes

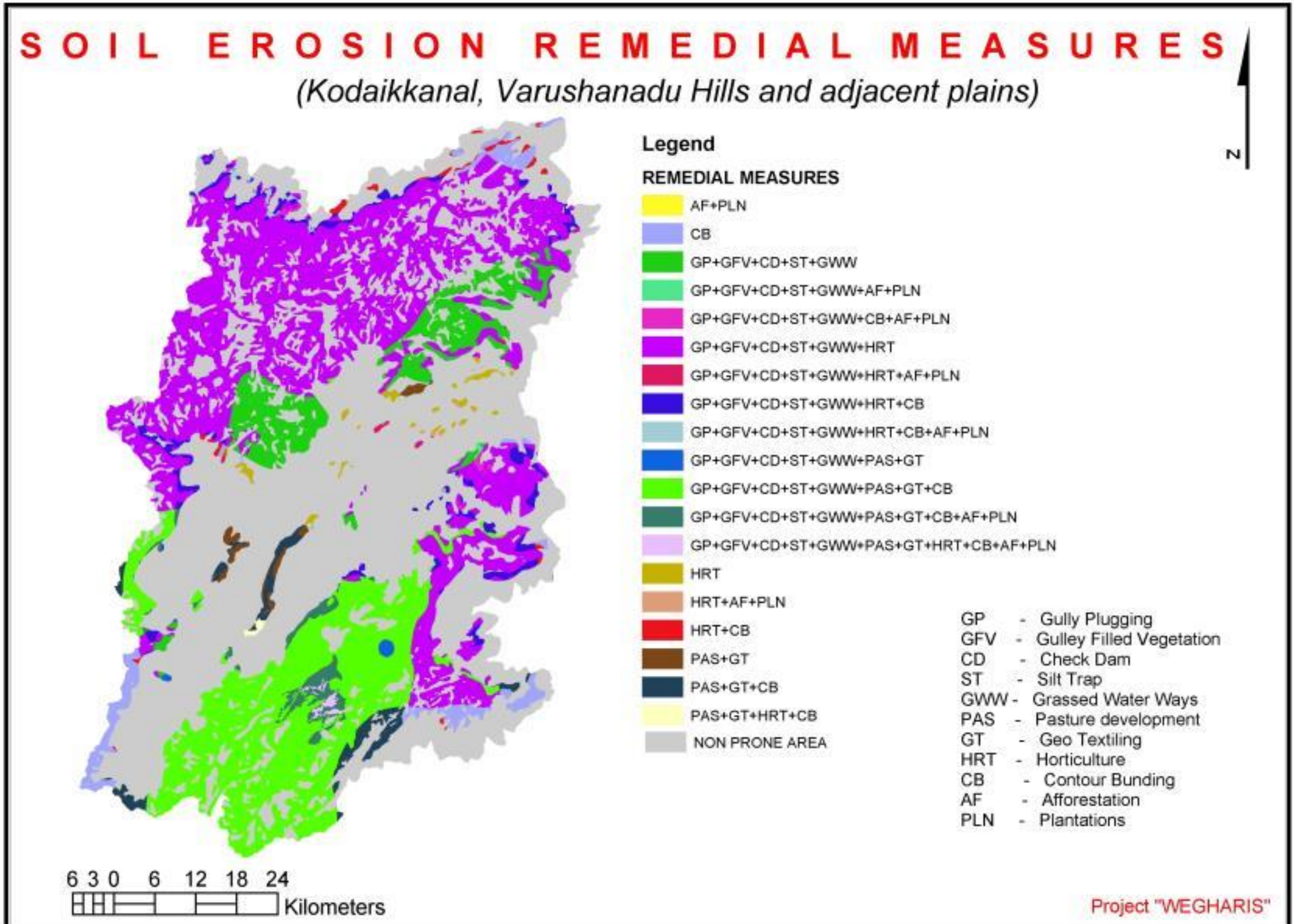

SOIL EROSION REMEDIAL MEASURES
(Kodaikkanal, Varushanadu Hills and adjacent plains)
Legend
REMEDIAL MEASURES
AF+PLN
CB
GP+GFV+CD+ST+GWW
GP+GFV+CD+ST+GWW+AF+PLN
GP+GFV+CD+ST+GWW+CB+AF+PLN
GP+GFV+CD+ST+GWW+HRT
GP+GFV+CD+ST+GWW+HRT+AF+PLN
GP+GFV+CD+ST+GWW+HRT+CB
GP+GFV+CD+ST+GWW+HRT+CB+AF+PLN
GP+GFV+CD+ST+GWW+PAS+GT
GP+GFV+CD+ST+GWW+PAS+GT+CB
GP+GFV+CD+ST+GWW+PAS+GT+CB+AF+PLN
GP+GFV+CD+ST+GWW+PAS+GT+HRT+CB+AF+PLN
HRT
HRT+AF+PLN
HRT+CB
PAS+GT
PAS+GT+CB
PAS+GT+HRT+CB
NON PRONE AREA
GP - Gully Plugging
GFV - Gulley Filled Vegetation
CD - Check Dam
ST - Silt Trap
GWW - Grassed Water Ways
PAS - Pasture development
GT - Geo Textiling
HRT - Horticulture
CB - Contour Bunding
AF - Afforestation
PLN - Plantations
N
6 3 0 6 12 18 24
Kilometers
Project "WEGHARIS"

Fig. 4.18

RESERVOIR SILTATION

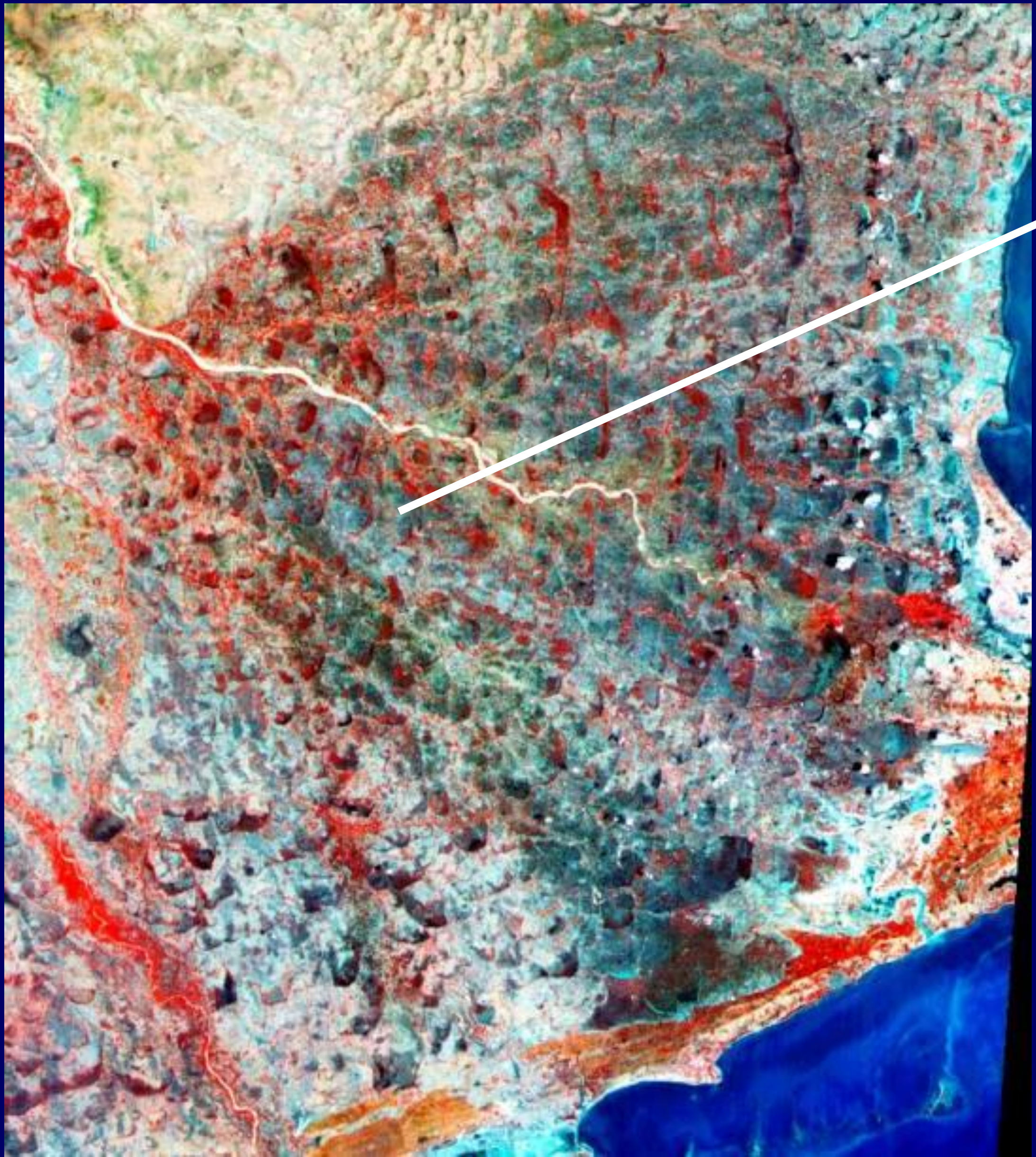
Identify silted reservoirs / tanks

Identify areas of soil erosion / silt supply

Suggest remedial measures to arrest soil erosion in the catchment itself.

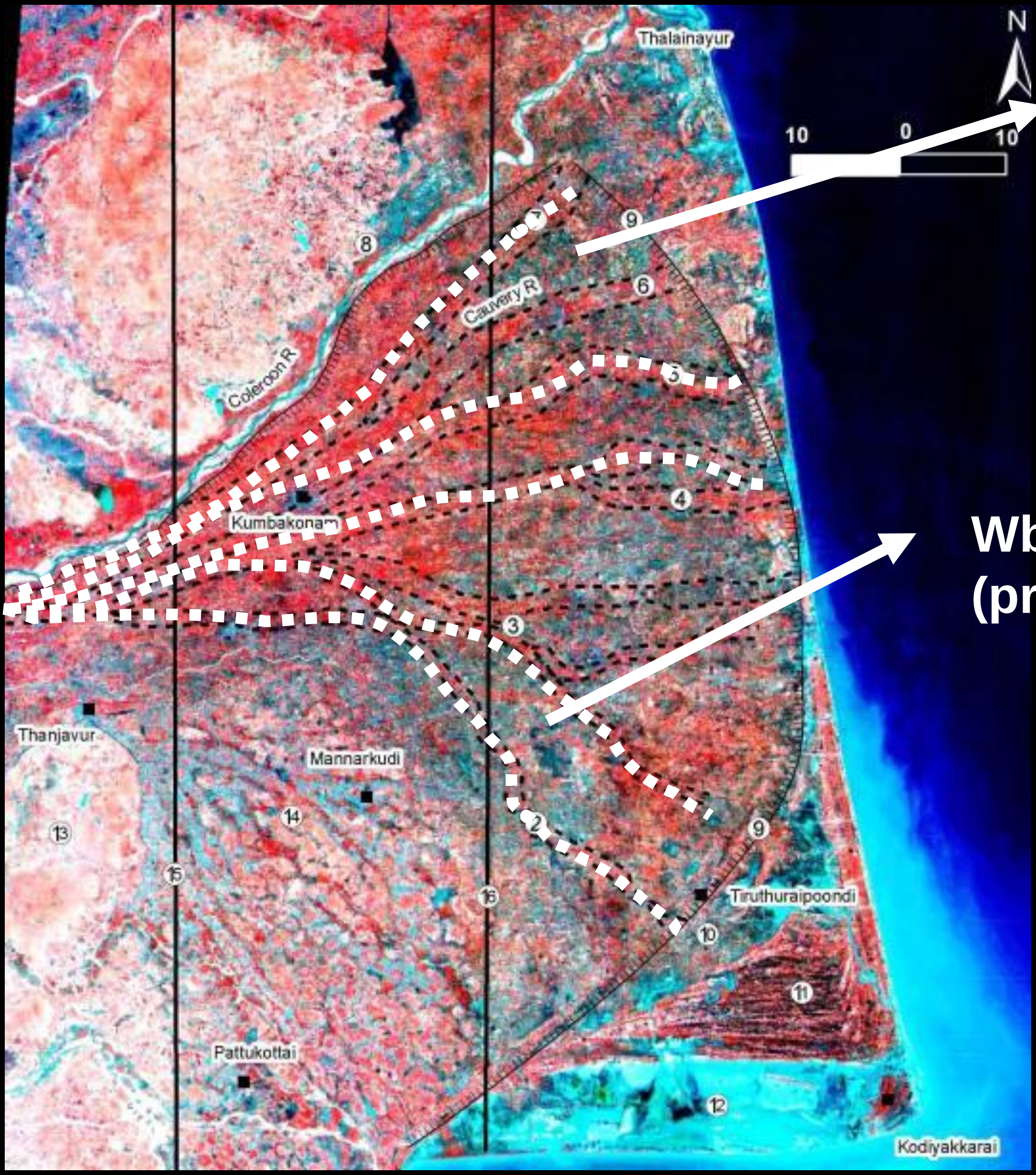
Silted foot hill Water Bodies

Lobate Delta – Vaigai



Water bodies lobate Deltas prone for heavy siltation

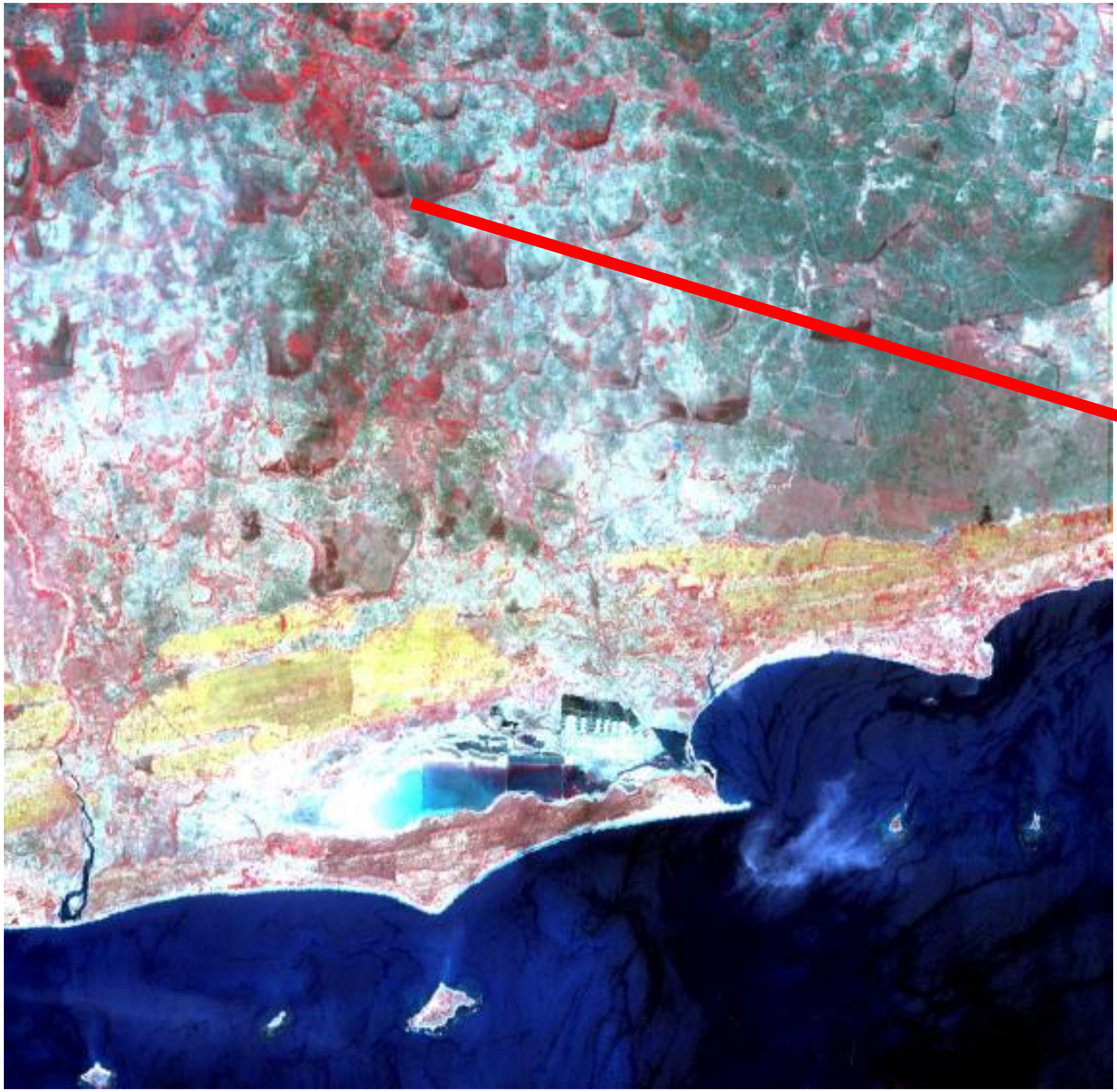
Arcuate delta - Cauvery



Wbs of active deltas
(prone for water logging

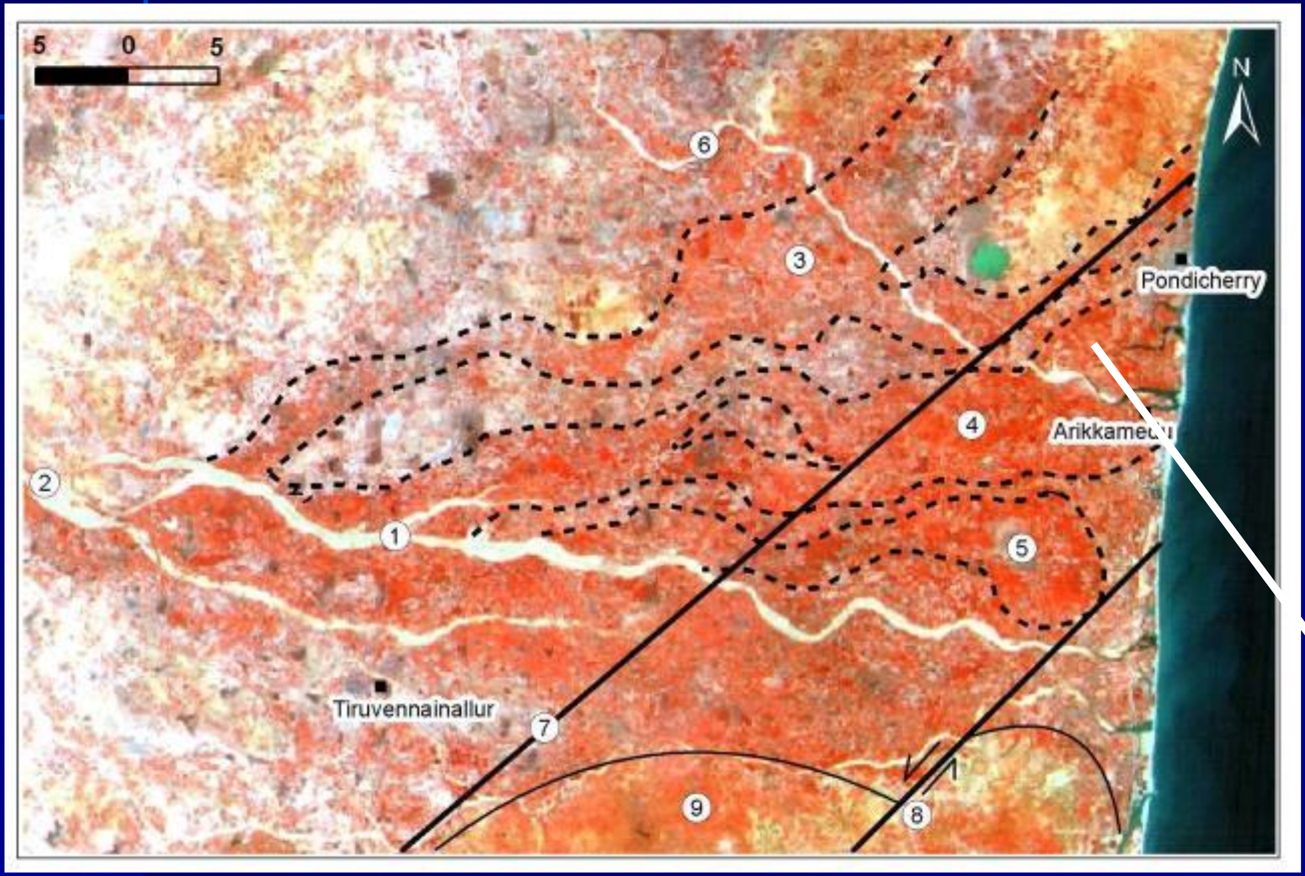
Wbs of abandoned delta
(prone for defunct)

Cuspate delta - Vaigai Pro Delta Region



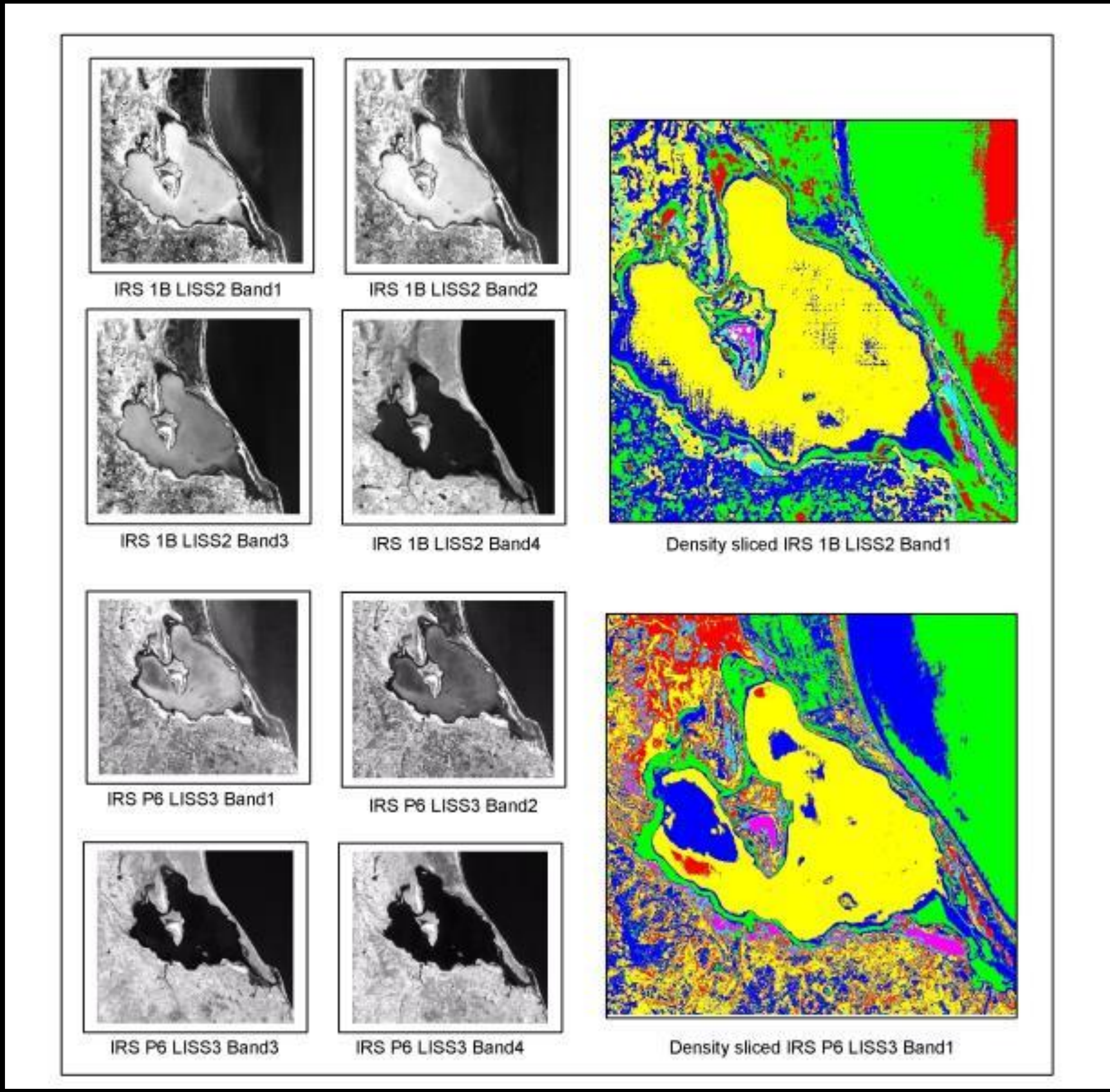
Wbs cuspate deltas prone for Water logging & flooding

Digitate Delta - Ponnaiyar



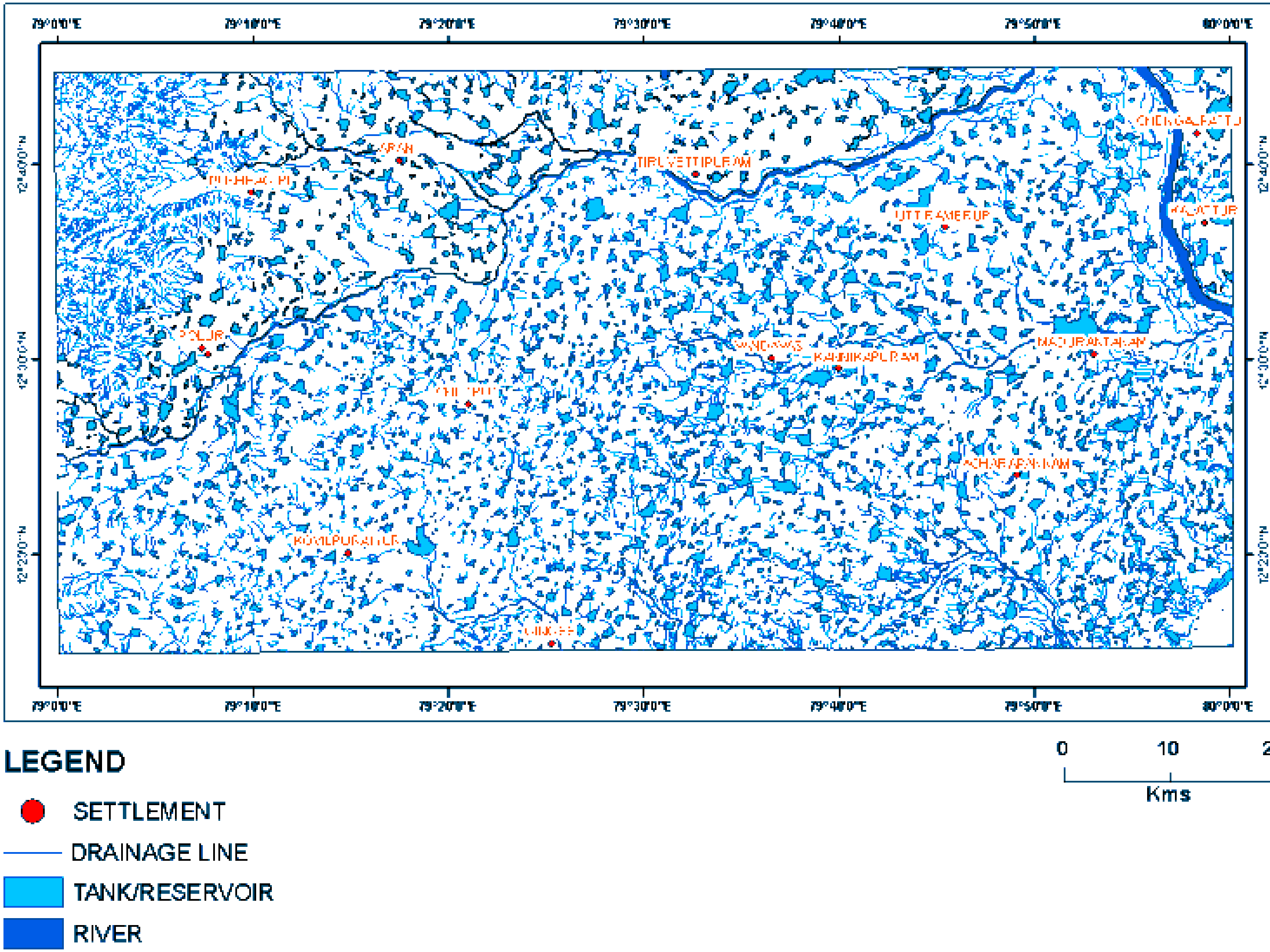
Digitate delta WBs prone for salt water incursion

Silt choking in Pulicat lake due to catchment uplifts , soil erosion and Silt supply

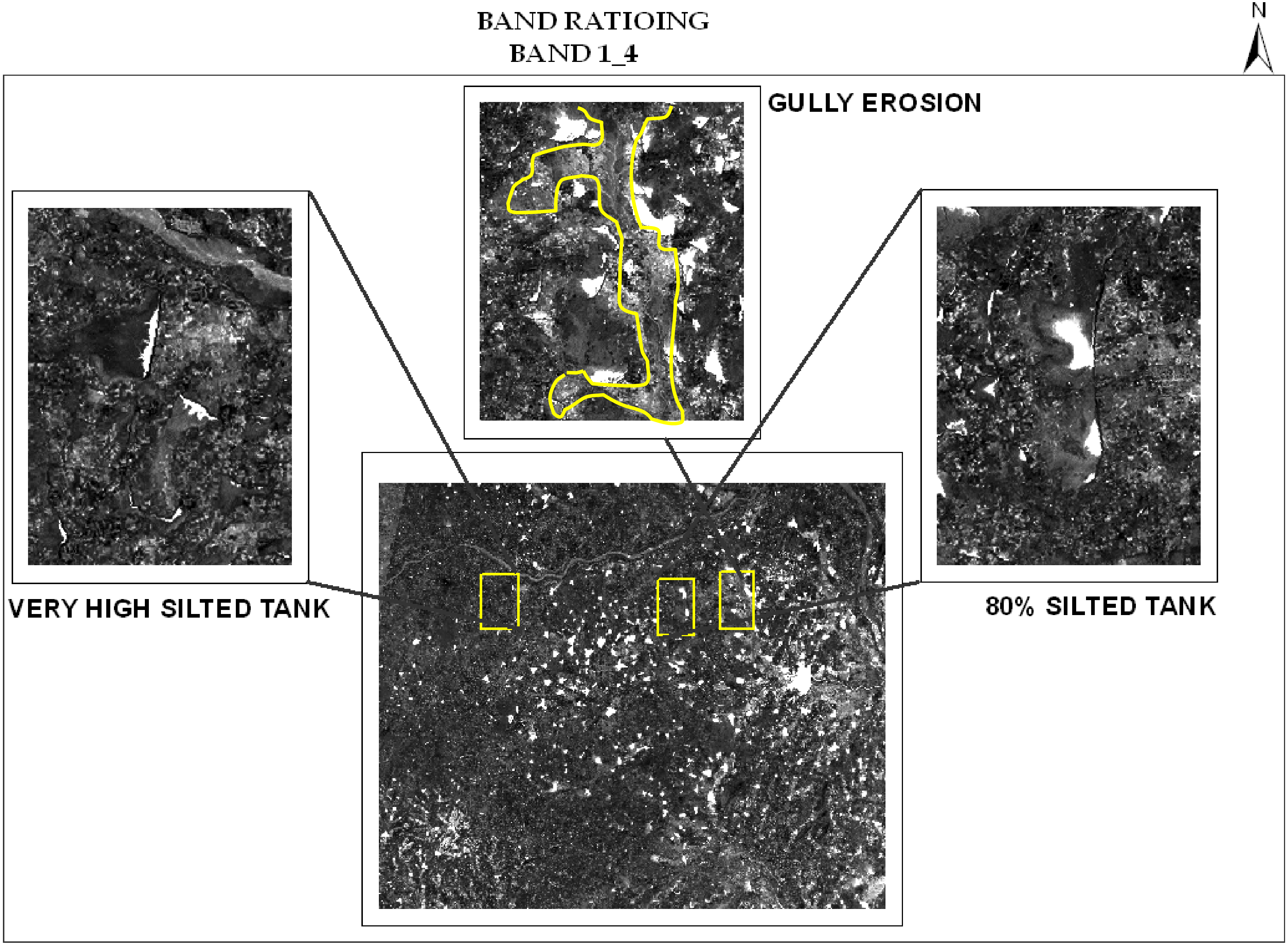


DRAINAGE MAP

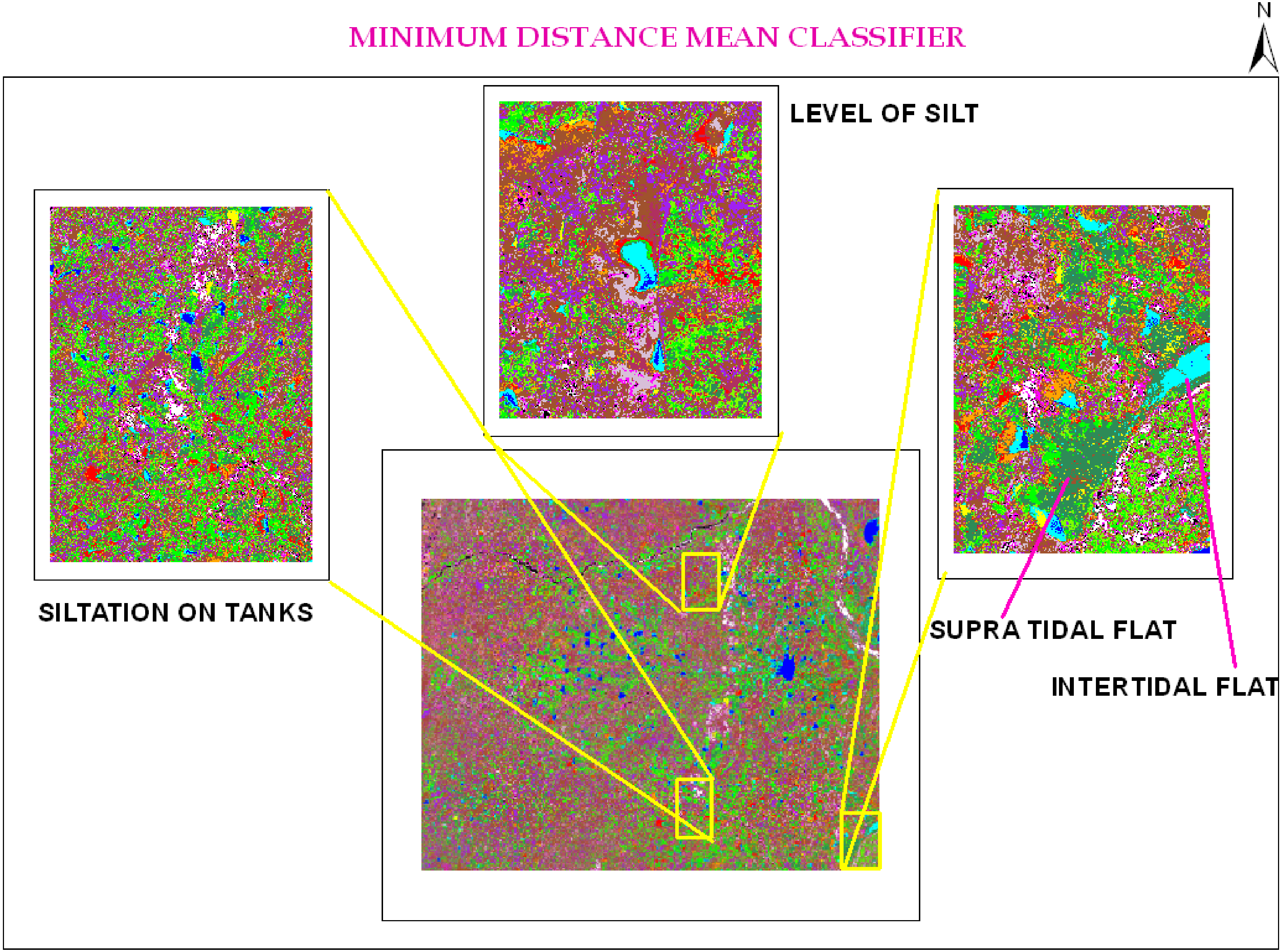
(PARTS OF THIRUVANNAMALAI, KANCHIPURAM AND VILLUPURAM DISTRICTS, TAMILNADU)



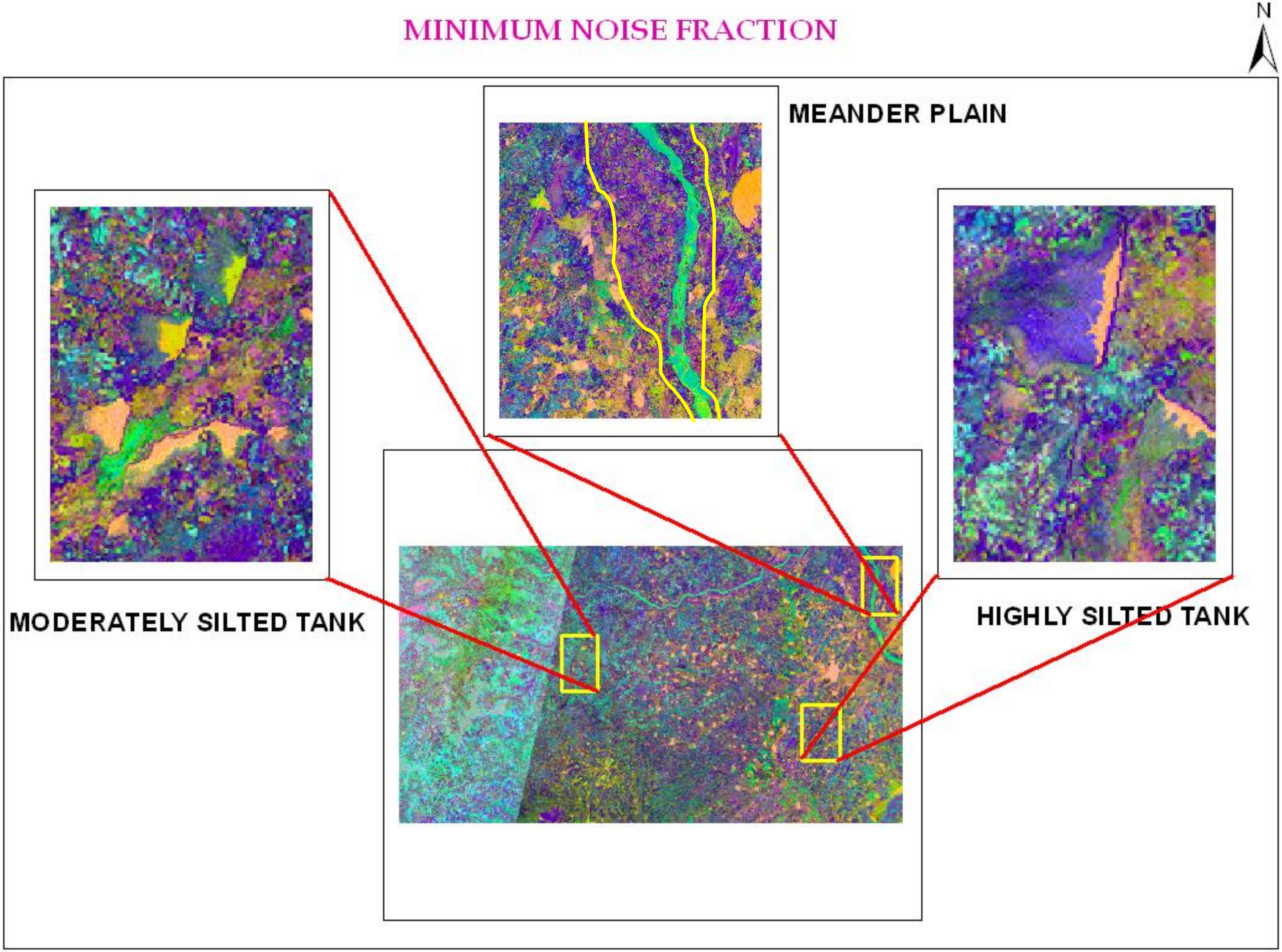
BAND RATIOING
BAND 1_4



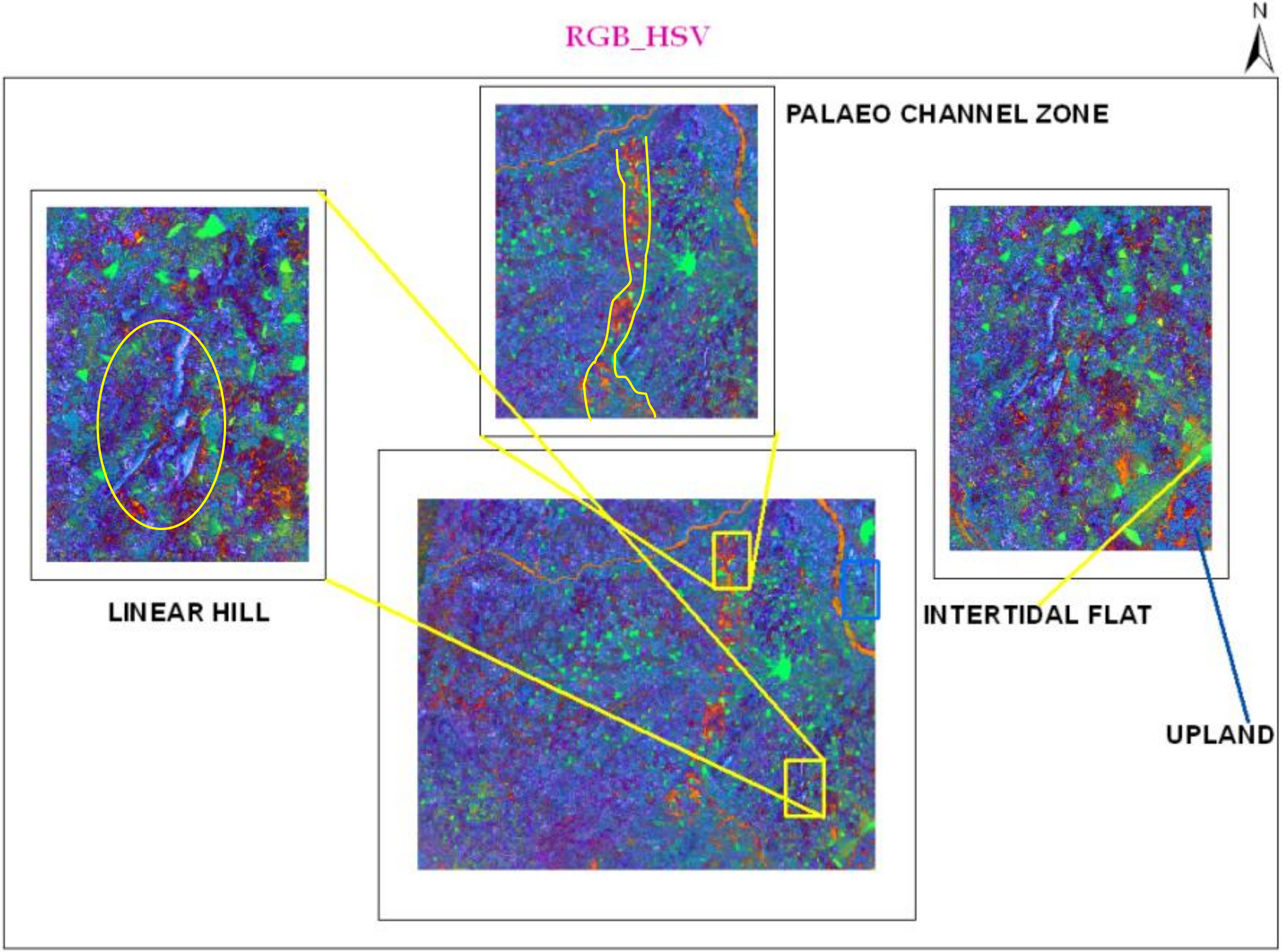
MINIMUM DISTANCE MEAN CLASSIFIER



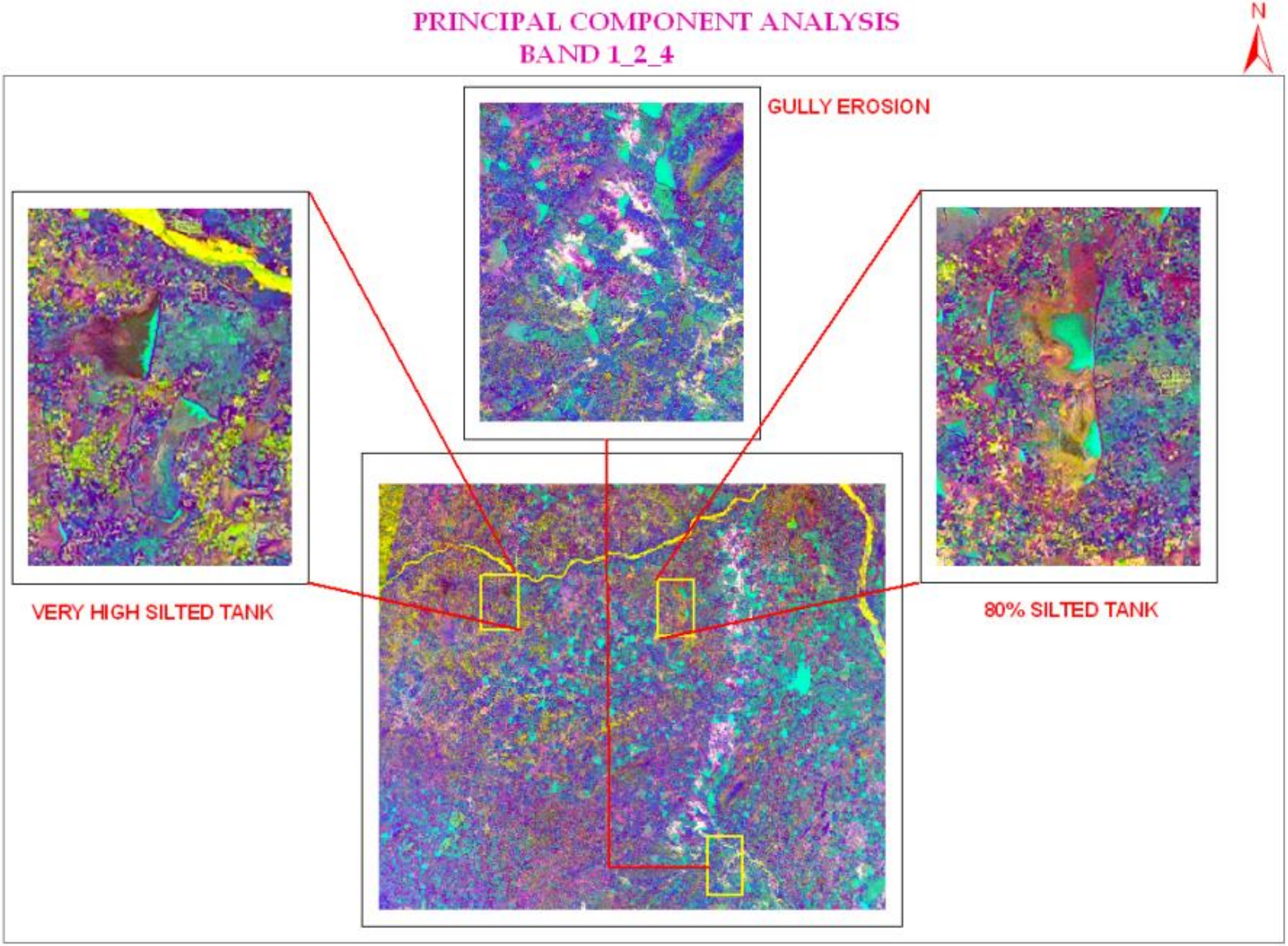
MINIMUM NOISE FRACTION



RGB_HSV



PRINCIPAL COMPONENT ANALYSIS
BAND 1_2_4



(1) TOTALLY DEFUNCT AND VEGETATED

(2) TOTALLY DEFUNCT TANK

(3) DESILTED FISH FARM

(4) SILT TRAP

(5)RESERVOIR OUTLET

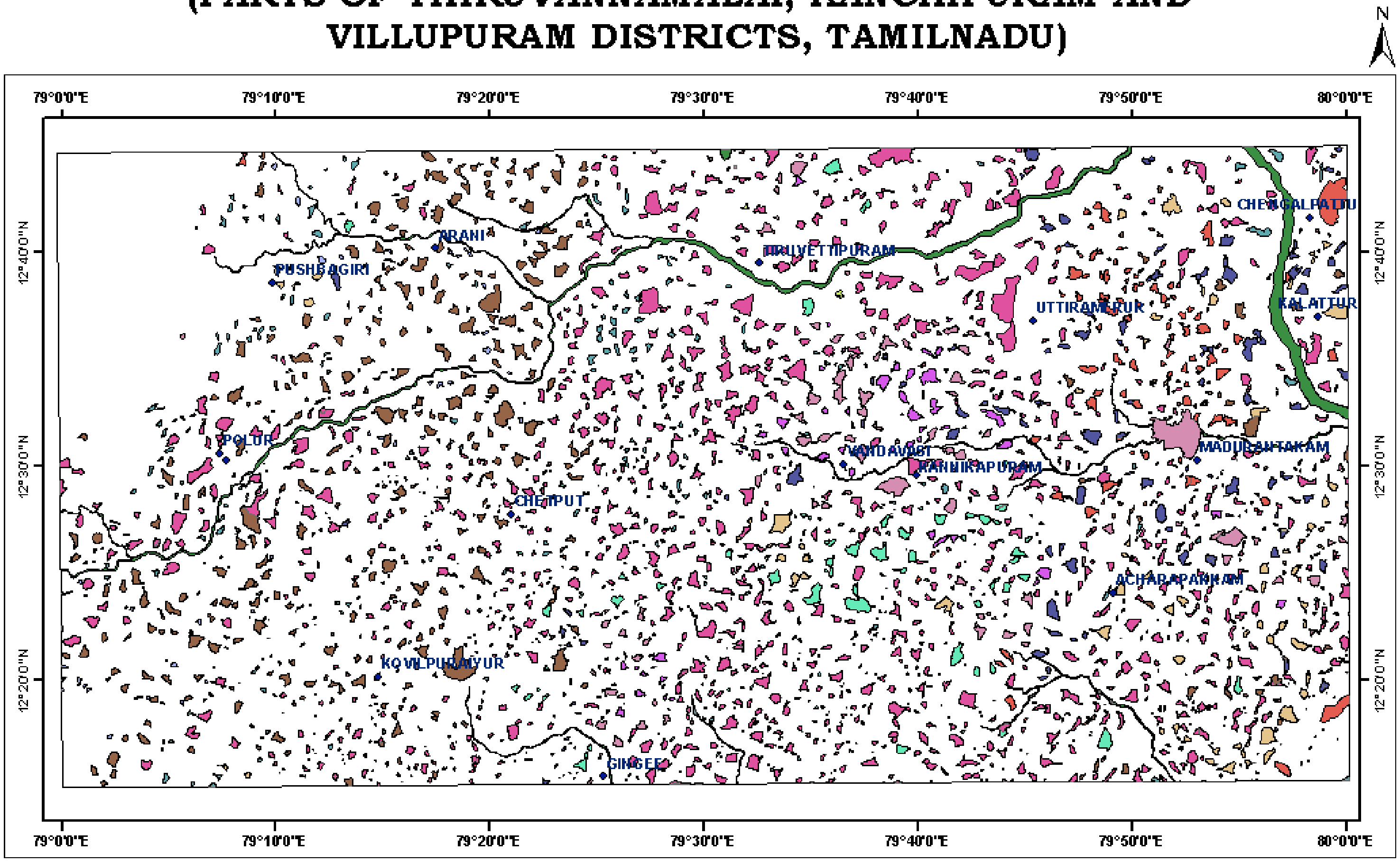
(6)CONSTRUCTED BUND

(7)HAND AUGER DRILL

(8)SILT THICKNESS

SILT LEVEL MAP

(PARTS OF THIRUVANNAMALAI, KANCHIPURAM AND VILLUPURAM DISTRICTS, TAMILNADU)



LEGEND

0 10 20
Kms

SETTLEMENT		
RIVER	80-100% SILTED VEGETATED	40-60% SILTED VEGETATED
TOTALLY DEFUNCT TANK	60-80% SILTED	20-40% SILTED
TOTALLY DEFUNCT VEGETATED	60-80% SILTED VEGETATED	20-40% SILTED VEGETATED
80-100% SILTED	40-60% SILTED	<20% SILTED

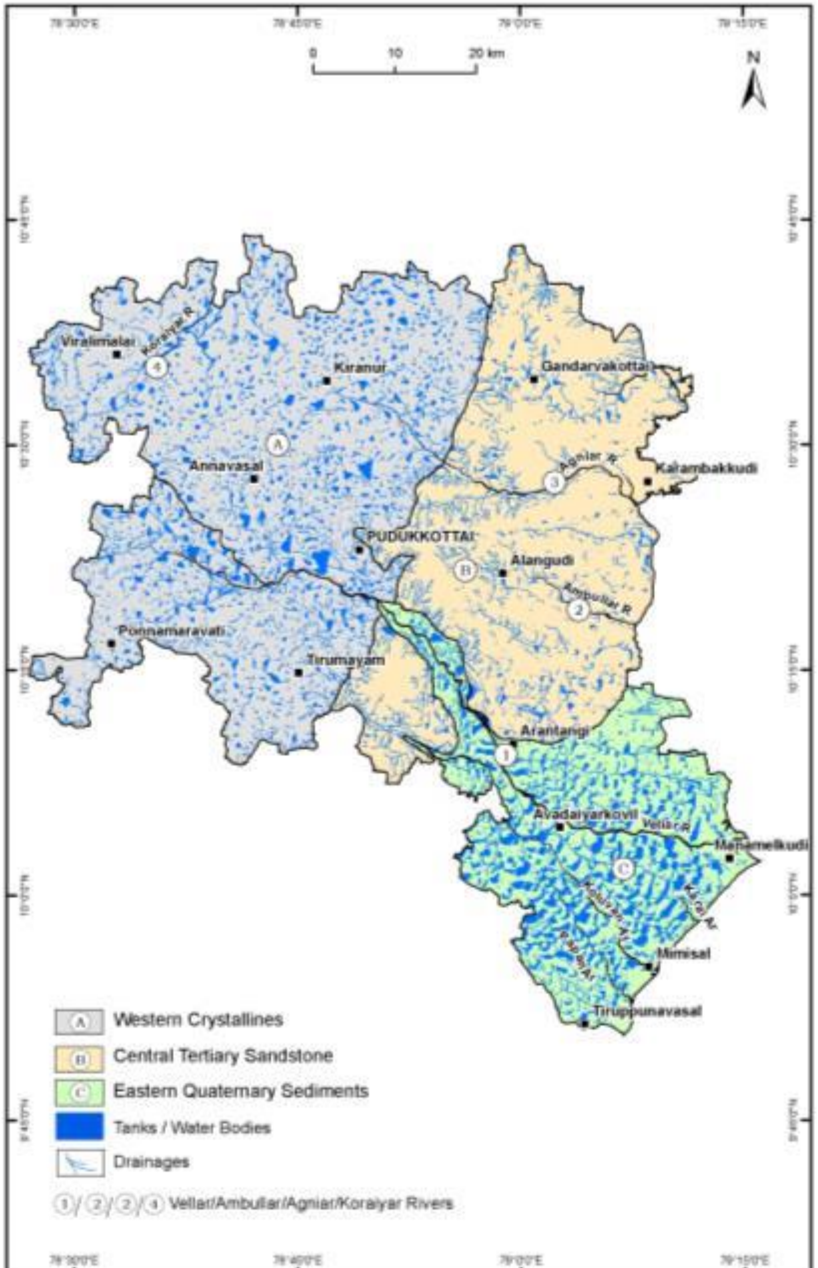


Fig. 5.1. Drainages and Tanks - Pudukkottai District

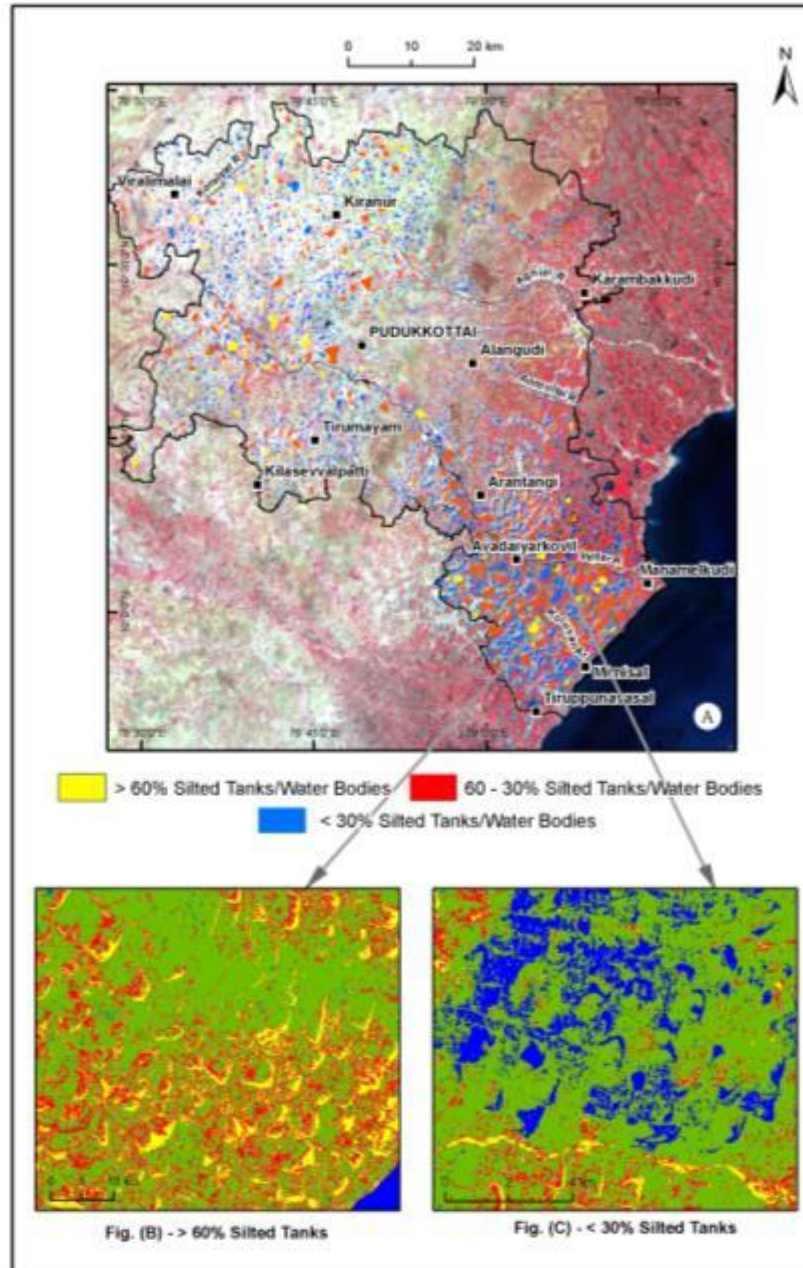


Fig. 5.2 IRS FCC (A) and Density Sliced (B and C) Images showing Silted Water Bodies

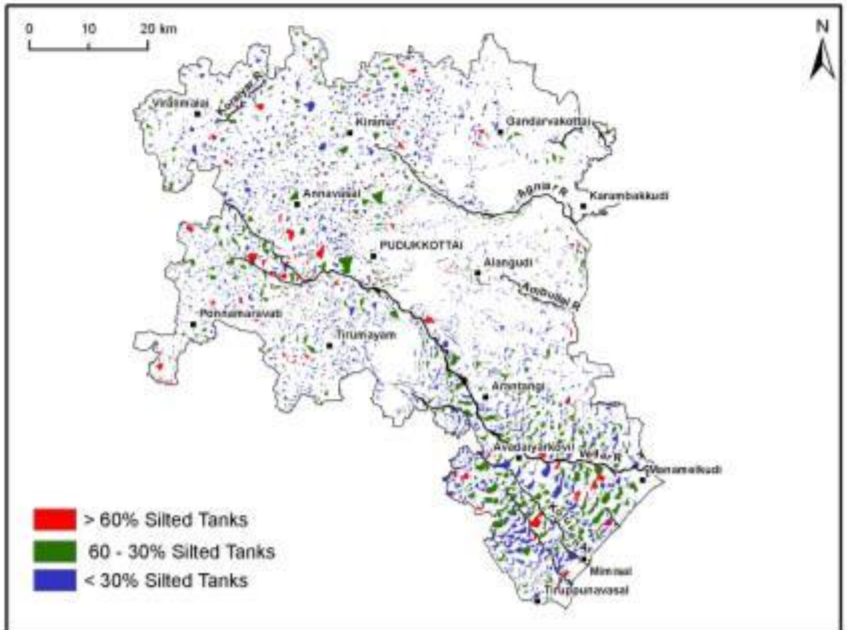


Fig. 6.22 Silted Tanks/Water Bodies

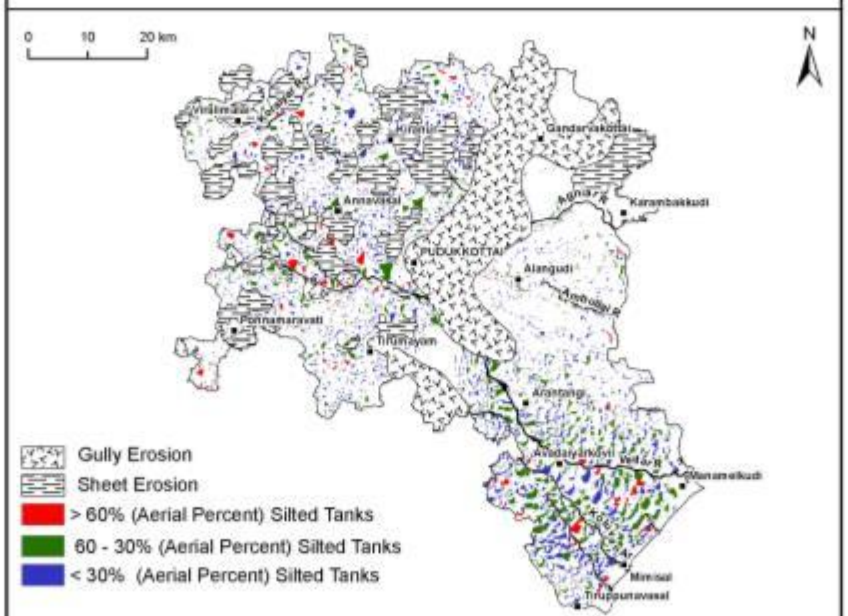


Fig. 6.23 Silted Tanks/Water Bodies - Gully and Sheet Erosion

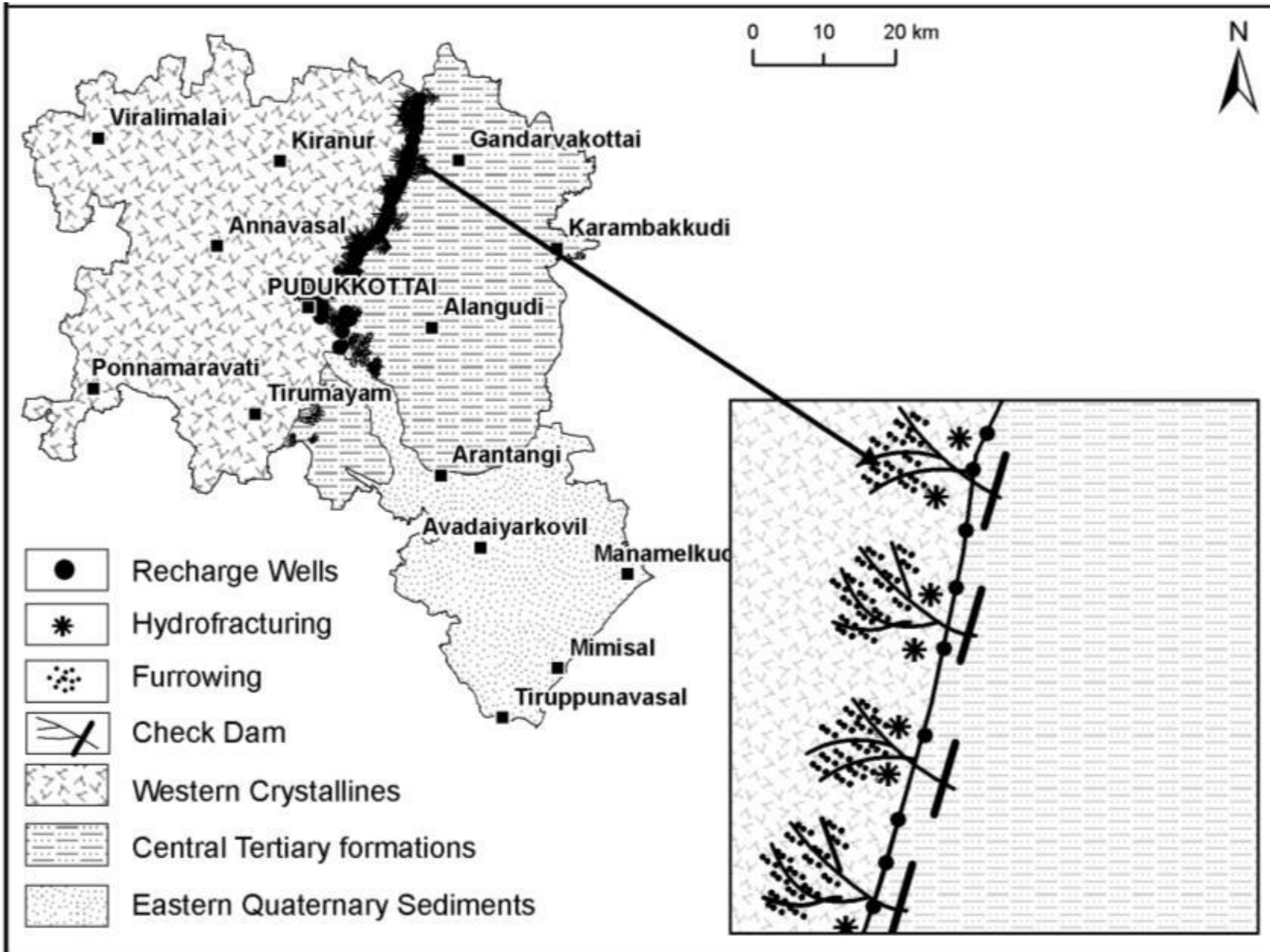


Fig.6.35 Check Dams in Upland