GIS and Remote Sensing

EGE 2421/EGS 2401

GIS IN WATER RESOURCE MANAGEMENT

Lecture No. 05

Felix Mutua, PhD

Wednesday, October 11, 2023

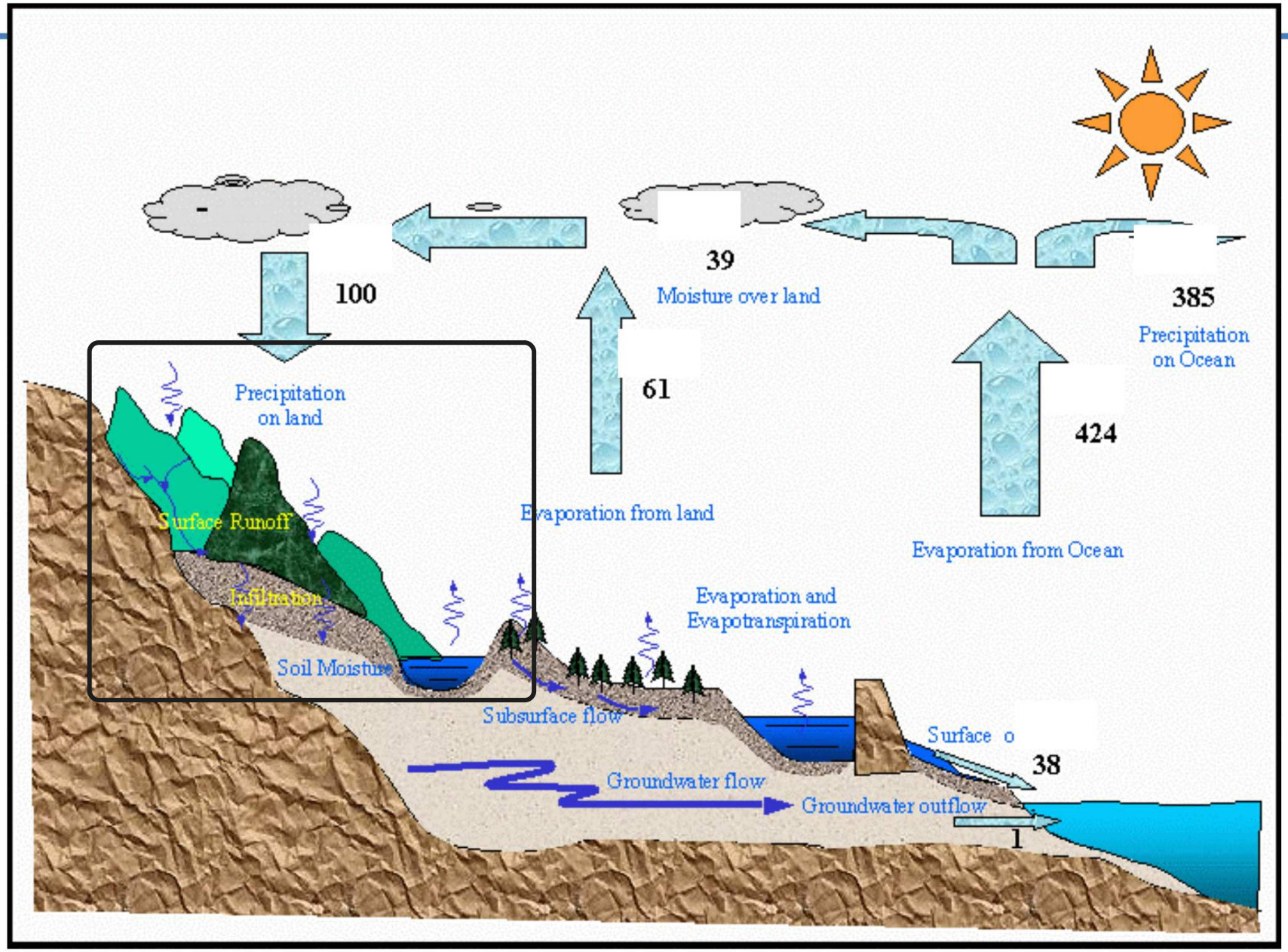
Lecture Plan

Week	Topic		Week	Topic	
1	Overview		8	Networks – I *(concepts, network problems)*	
2	Review of GIS analysis Techniques		9	Networks – II *(building networks, optimization)*	
3	GIS in Agriculture (concepts, application areas, Crop Suitability Analysis)		10	Networks – III *(routing, tracking)*	
4	Natural resource Management – I (concepts, application areas)		11	Utility Management *(concepts, viewsheds,lineof sight)*	
5	Natural resource Management – II *(Groundwater)*		12	Health and Disease control *(concepts in epidemiology)*	
6	GIS in Business *(store location, consumer profiling)*		13	Governance *(crime, districting, LIS, census)*	
7	CAT I		14	CAT II	

Our water sources are under pressure.

The hardness of this challenge should not be under-estimated!

GIS use in the hydro cycle



Applications of GIS in Water Resources Management

- Remote Sensing
- Watershed management
- Flood management
- Groundwater
- Water quality
- Permitting

Remote Sensing

- Use of aerial photography and/or satellite
- imagery to assess water resources
- Allows rapid assessment of large areas, and selection of subsets for detailed analyses
- Water has distinctive spectral properties; water absorbs radiation – in infrared imagery, water appears black
- Water quality can also be picked up from remote sensing – turbidity and/or depth

Remote Sensing

- Provides a static ‘snapshot’ of water conditions; not an active system like stream monitoring gauges, etc
  - Strong temporal scale component
- Used for:
  - Flood plain delineation
  - Flood assessment
  - Monitoring changes in stream channels
  - In association with traditional GIS, can provide
  - information for all GIS/Water Resources projects

Watershed Management

- Terrain modeling
- Flow modeling
- Debris flow probability
- Terrain modeling
  - Creation of DEMs
  - Automated watershed extraction from topography
  - Flow determination – direction and accumulation

Flood Management

- Flood plain delineation
  - Use of satellite imagery
  - Assessment/modeling of topography
  - Soil
  - Hydrology
- Channel characteristics
- Inundation modeling
- Infrastructure analysis
- Risk modeling and mitigation

Flood Management

- Channel characteristics
  - Channel cross-section
  - Channel length
  - Channel shape
  - Changes over time
  - Channel erosion and depositional features
- Inundation modeling
  - Prediction of return periods
  - Simulation of models on contemporary situation
  - Assessment of potentially flood-prone sites
  - Implementation of mitigation measures
  - Large-scale and small-scale mitigation

Flood Management

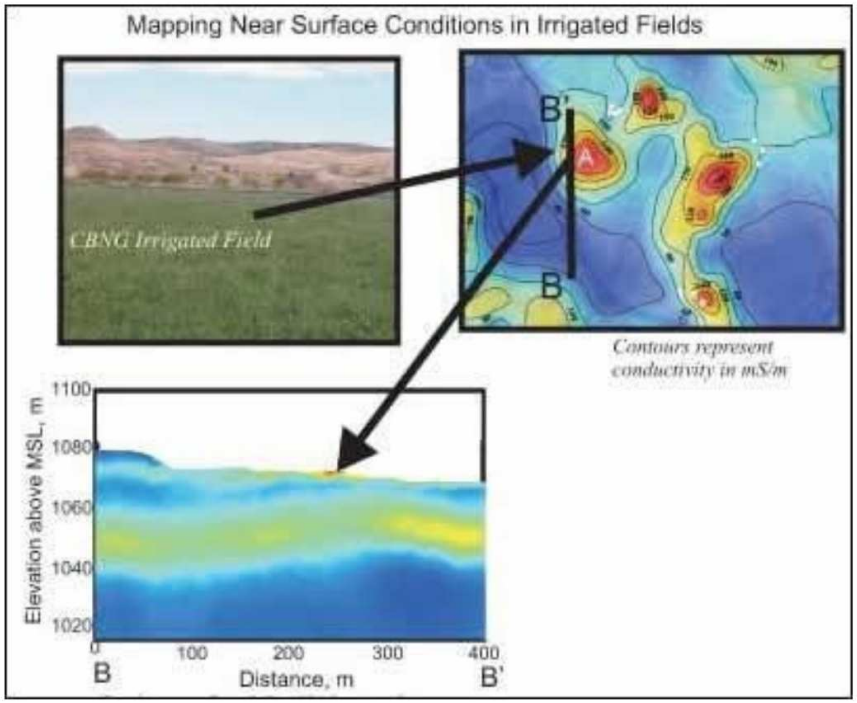
- Infrastructure analysis
  - From analysis of inundation models, determine effects on infrastructure
  - Assessment of bridge and other structures that span river channels
  - Assessment of dykes and other mitigation structures that run parallel to channel : Effects of these on sedimentation and erosion processes downstream
  - Assessment of road and other critical networks and facilities with respect to flood hazards

Flood Management

- Risk modeling and mitigation
  - From inundation models and infrastructural analyses, can compute risk factors, and determine probabilities, return periods, and acceptable risk
  - Can begin planning appropriate engineering mitigation plans
  - Mitigation can range from legislation (zoning) to engineering
  - All have to consider socio-economic realities with respect to:
    - Demand for land for development
    - Cost of implementing mitigation
    - Environmental impact of mitigation downstream

Groundwater

- Modeling subsurface flow – rate, advection, concentration
- Well and spring models



Water Quality

- Management of surface and subsurface water
  - Instrument-based assessments
  - Used in conjunction with GIS/GPS, ties location of sample collection to map to show patterns and distributions
  - Water quality measurements of oxygen, pH, bacterial content, etc
  - Measures flow rates and turbidity

Water Quality

- Use of passive and active water quality monitoring systems
  - Depends on costs and risk; may not need advanced active system on a river that floods often, but is far from any settlement or developments
  - Need to consider quantity of measuring stations; more stations equal greater detail and accuracy but greater cost

Permitting

- Population and consumption demand analyses and forecasts
- Water quality modeling
- Flow analyses
- EIA and development review and approval
- Engineering
- Population and consumption demand
- analyses and forecasts
  - Consider population and consumption characteristics as end users of water resources
  - Includes domestic, commercial, industrial and civil uses
  - Need to know the location and distribution of these

Permitting

- Water quality modeling
  - Level of quality monitoring is a function of the use of the resource
  - Water may be used for:
    - Generation of hydro-electricity
    - Agricultural irrigation
    - Human consumption
- Flow analyses
  - Looks at:
    - Rate of flow of water for downstream flood control
    - Content and concentrations of dissolved and suspended particles for pollution control and sedimentation analyses

Permitting

- EIA and development review and approval
  - Important when considering major infrastructural development within watersheds and along rivers or flood plains
  - Downstream impacts important
  - Range from major capital development projects, such as dams, to smaller activities such as sand-mining
  - Implications may extend to other jurisdictions, locally and internationally

Permitting

- Engineering
  - For:
    - Generation of hydro-electricity
    - Agricultural irrigation
    - Human consumption
    - Flood control
    - Transport
    - Extraction of resource
  - Consider topography and other natural physical elements, and population/demand centres to determine means to supply resource from source

WATERSHED MODELLING

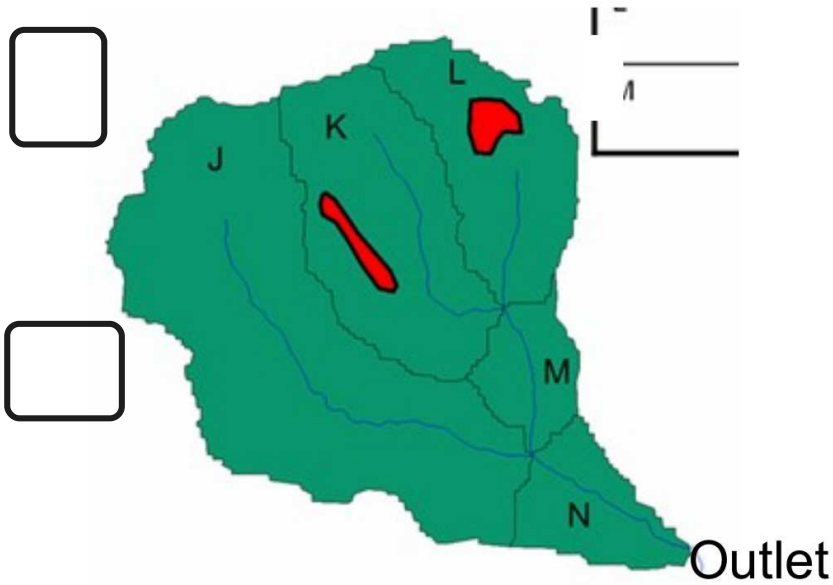
October 11, 2023

Watershed modeling

- Segment level watersheds can be used in watershed modeling
- Also compiled flow tables for each watershed

Flow table

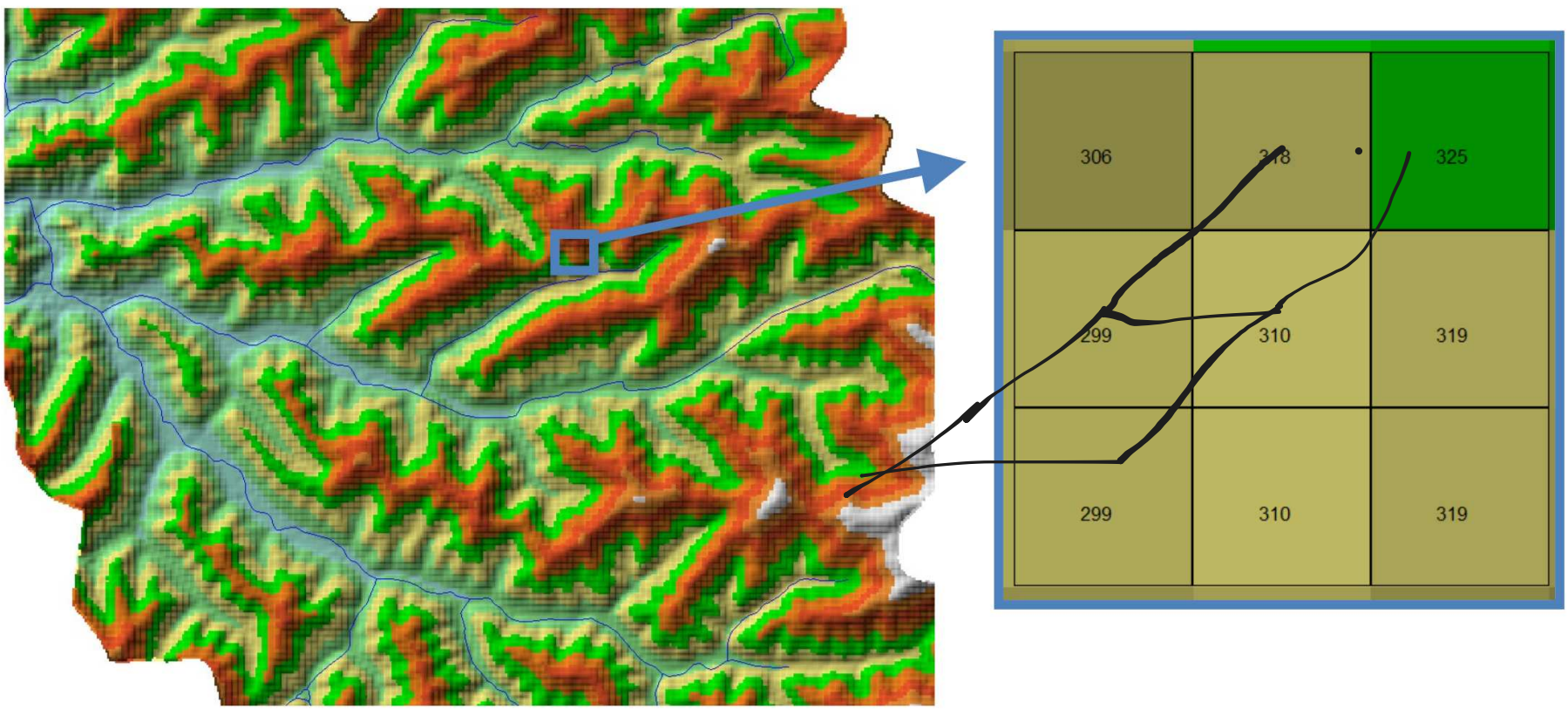
shed1	shed2	flowdir
NONE	J	START
NONE	K	START
NONE	L	START
J	N	In
K	M	In
L	M	In
M	N	In

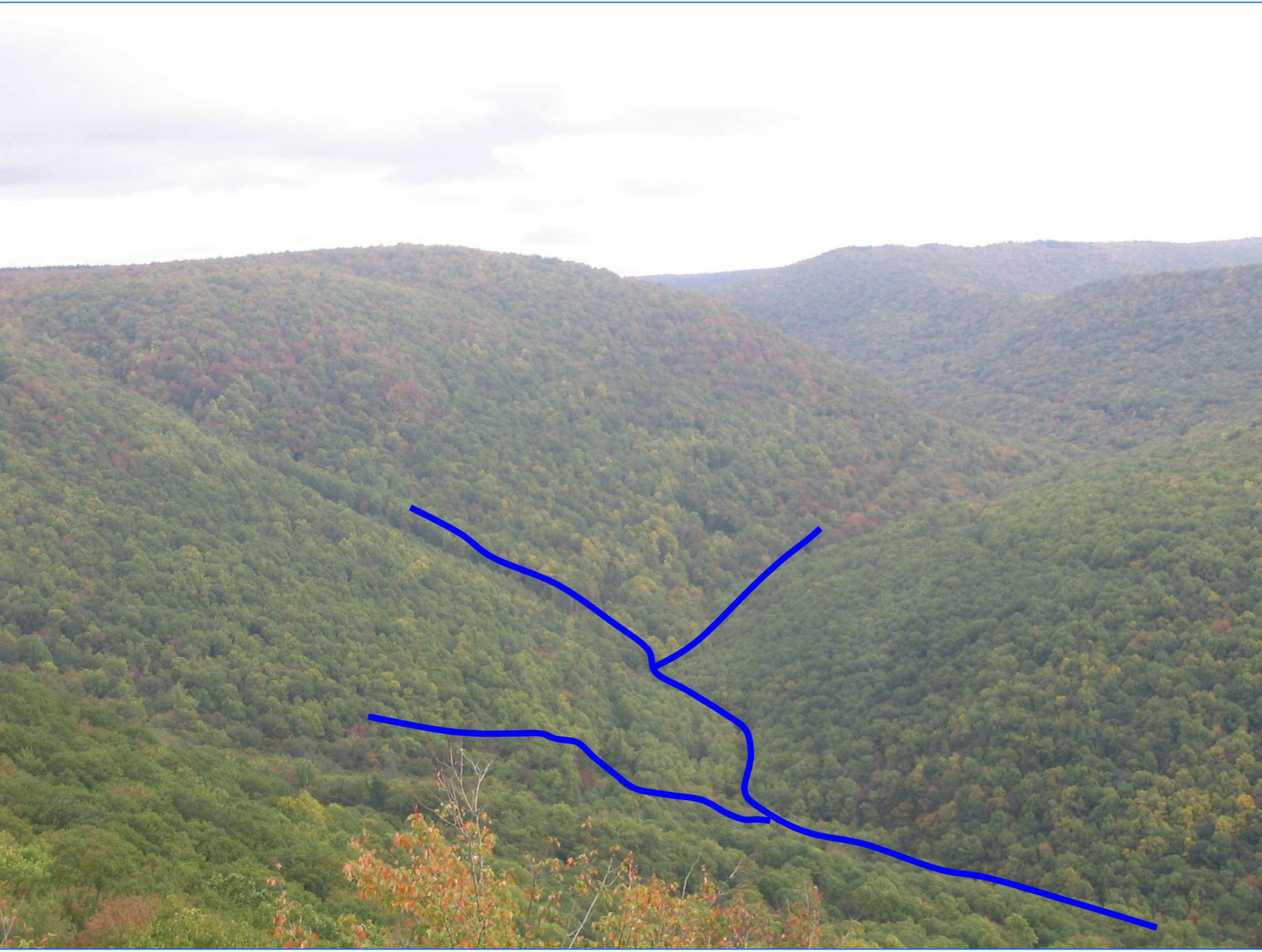


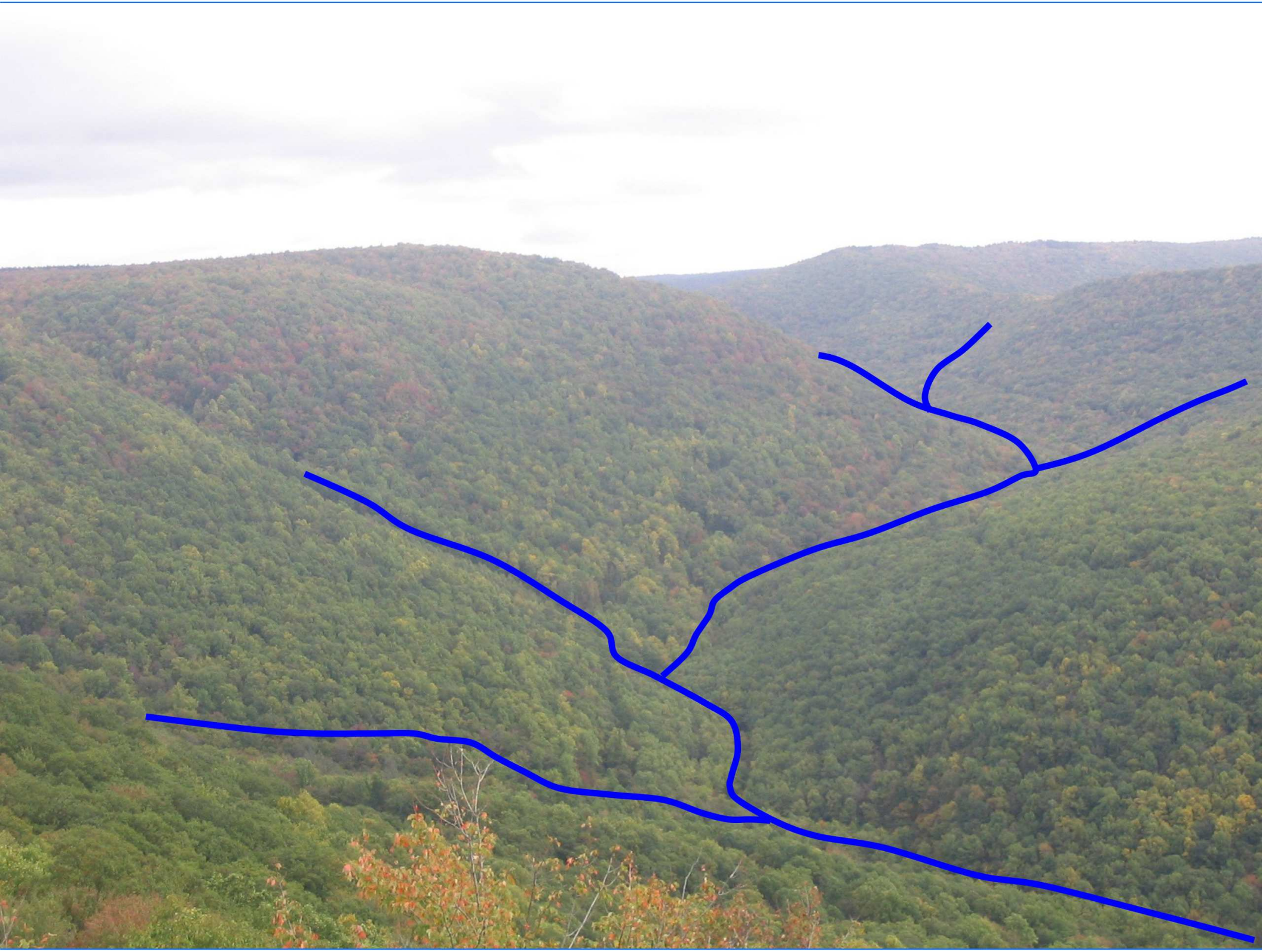
Watershed Schematic:
Simplified segment-level watersheds and associated flow table

Elevation surface or grid

- The starting point for all hydrological modeling in GIS
- USGS Digital elevation model 30m or 10m elevation cells, or 3m for WV
- Each cell or grid represents a value for the elevation







GROUNDWATER EXPLORATION

Case study : Noyyal, Tamil Nadu, Sri Lanka

October 11, 2023

IDENTIFICATION OF GROUNDWATER POTENTIAL ZONES AND NON-NATURAL RECHARGE SITES BY USING GIS AND RS

- Remote sensing and Geographic Information System has become one of the leading tools in the field of hydrogeological science, which helps in assessing, monitoring and conserving groundwater resources.

- Analysis of remotely sensed data along with Survey of India topographical sheets and collateral information with necessary field checks helps in generating the base line information for groundwater targeting.

- The geology, geomorphology, slope, drainage density, lineament density and land use/land cover maps have been used for the preparation of groundwater potential zones

- The geology, geomorphology, slope, drainage density, lineament density, rainfall, water level and land use/land cover maps have been used for the preparation of Non-Natural recharge sites

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WEIGHTED INDEX OVERLAY ANALYSIS

- The occurrence and movement of groundwater in an area is controlled by various factors. The influence of all factors need not be the same in the area. Therefore, each parameter was assigned a weightage depending on its influence towards the movement and storage of groundwater.

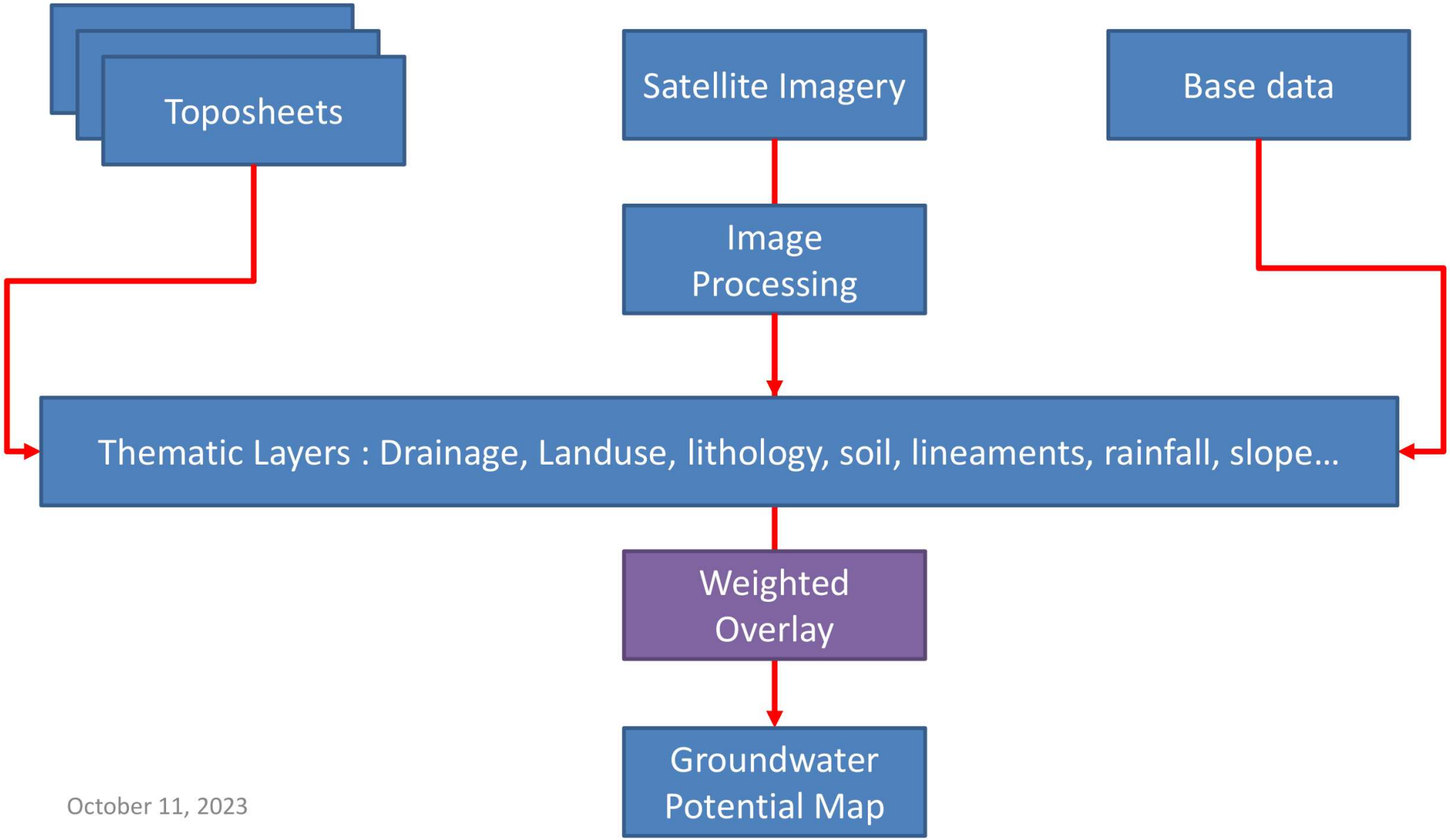
- The weightage for the major relationship between two factors was assigned 1 and the weightage for the minor relationship between two factors was assigned as 0.5. Finally, the total weight of each factor represents the weight for groundwater potential and Non-Natural recharge.

- The occurrence and movement of groundwater in an area is controlled by various parameters in each factors. The influence of all parameters need not be the same in the area. Therefore, each parameter is assigned a rank depending on its influence on the movement and storage of groundwater. The parameter has been categorised into five zones from groundwater potential and Non-Natural recharge point of view.

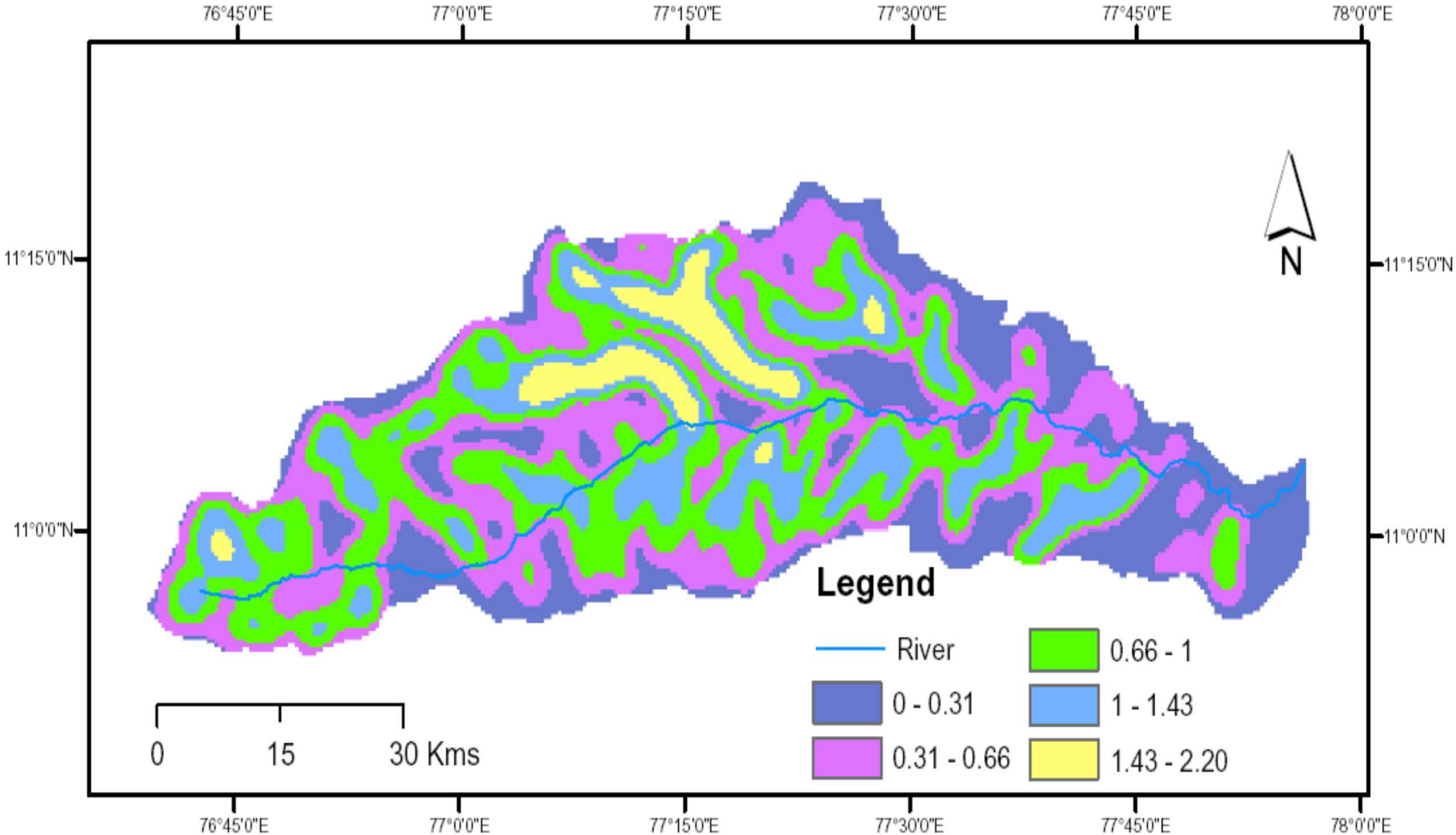
- The percentage influence for groundwater potential zone and the score of each recharge potential factors was calculated as 100 multiplied by the weight of the recharge potential divided by the total weight of the each recharege potential factor

- The final map has been categorized into five zones in which ranking 1 denotes poorly zone, 2 denotes moderately zone, 3 denotes moderate to good zone, 4 denotes good zone and 5 denotes very good zone for groundwater potential and Non-Natural recharge.

Delineating Groundwater Potential

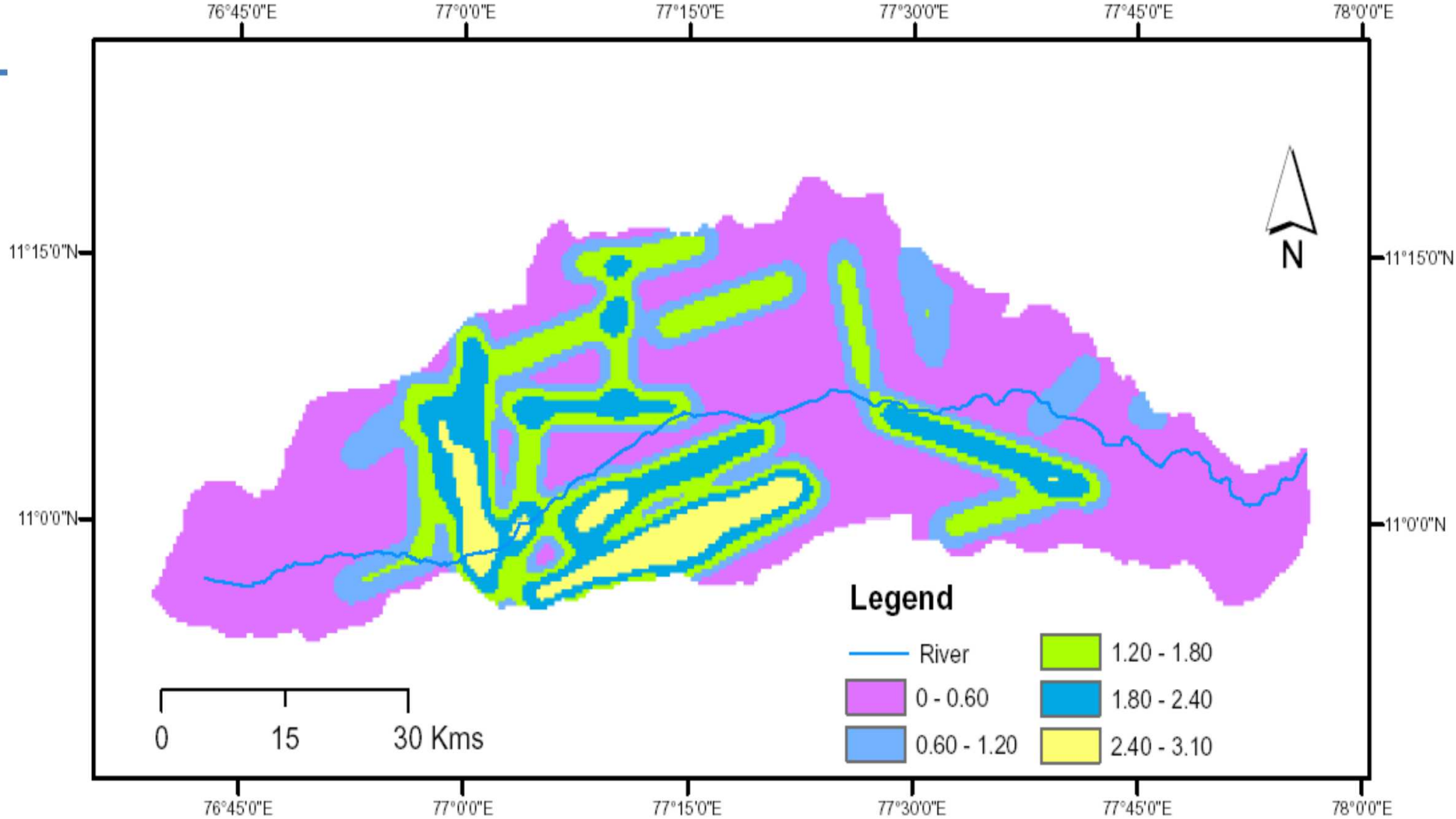


Drainage Density Map(km/km^2)



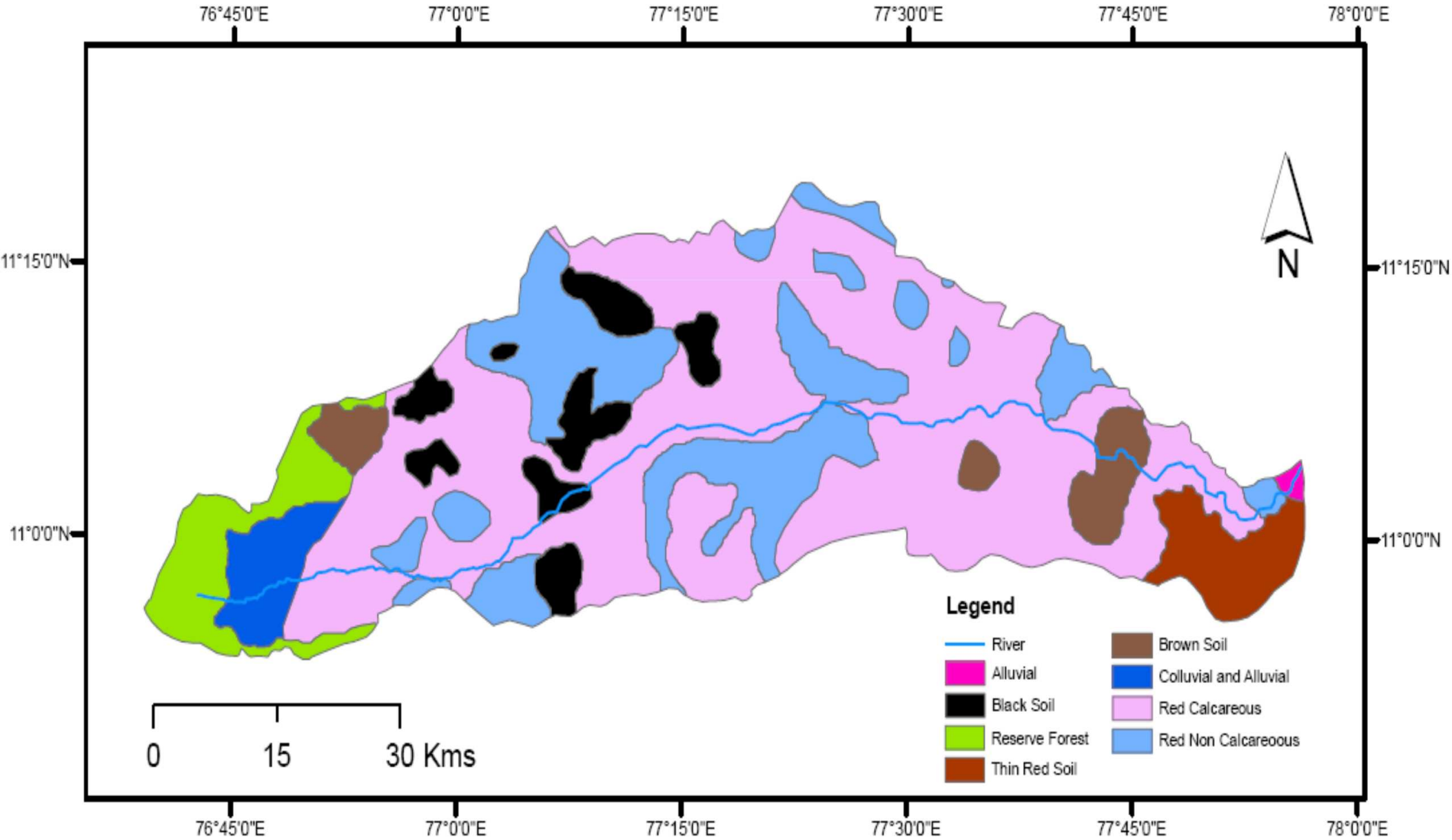
Total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin

Lineament Density Map(km/km^2)



A lineament is a linear feature in a landscape which is an **expression of an underlying geological structure such as a fault**. Typically a lineament will appear as a fault-aligned valley, a series of fault or fold-aligned hills, a straight coastline or indeed a combination of these features

Soil Map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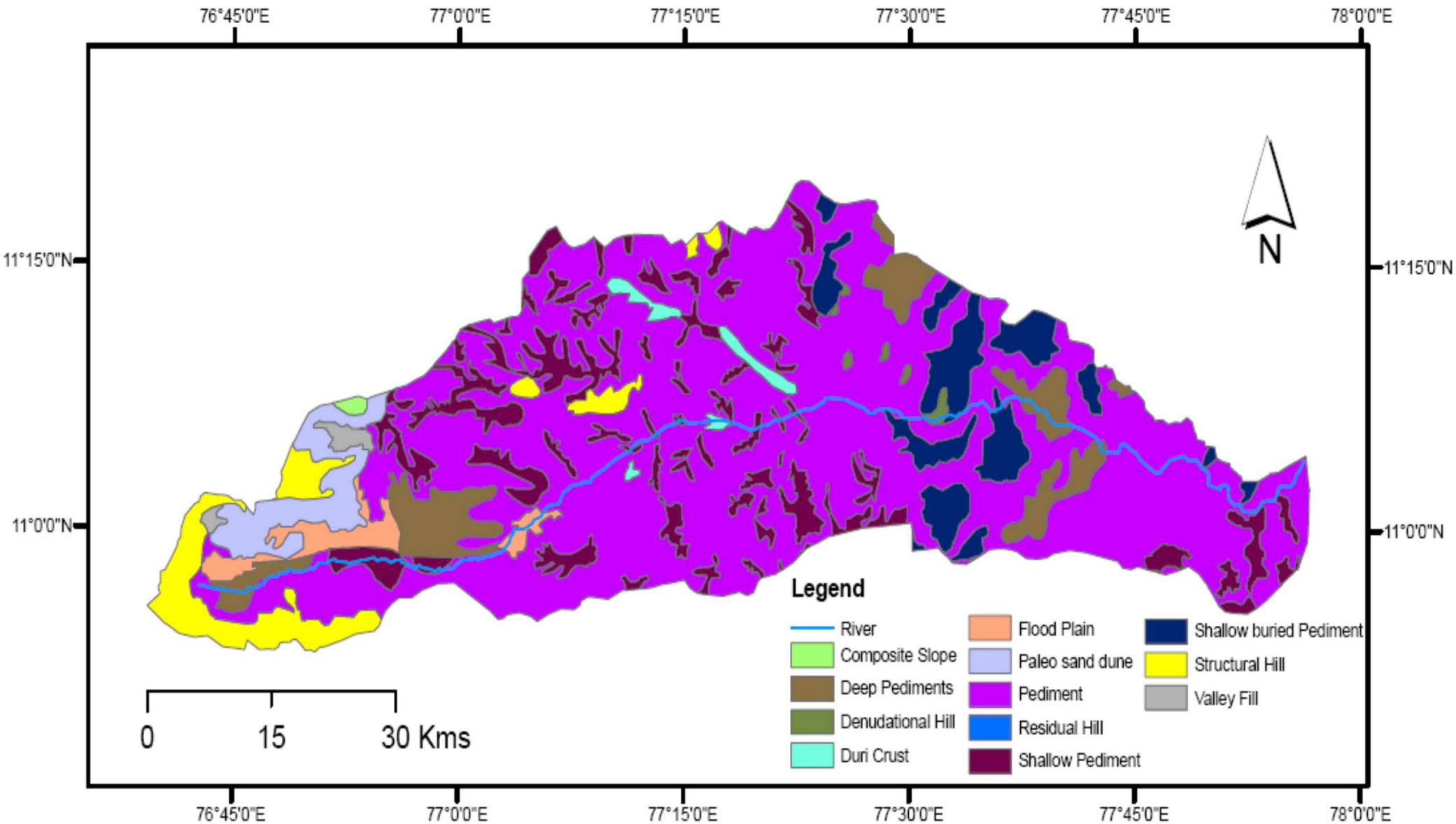
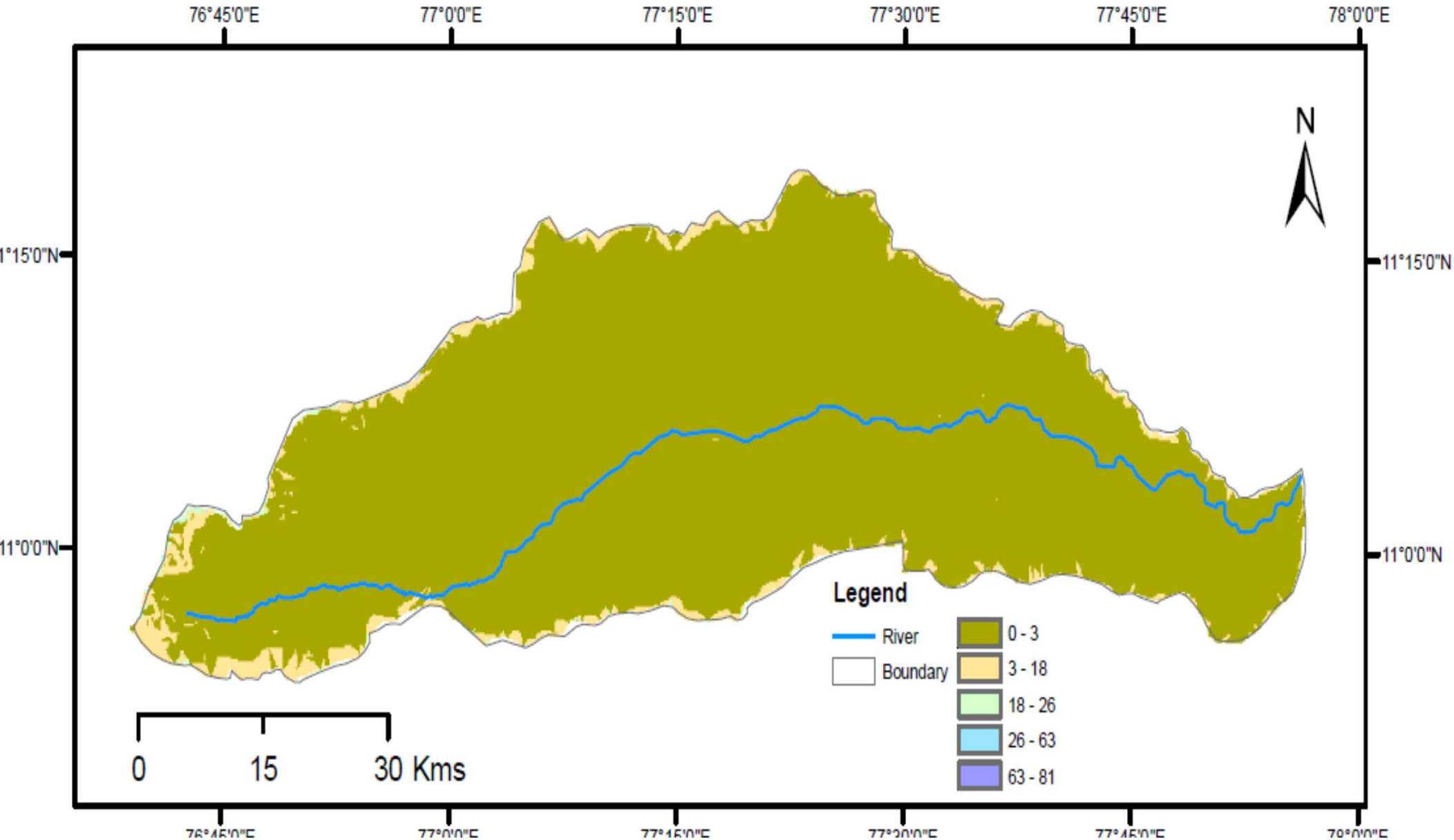
11°0'0"N
N
Legend
River
Alluvial
Black Soil
Reserve Forest
Thin Red Soil
Brown Soil
Colluvial and Alluvial
Red Calcareous
Red Non Calcareoous
0
15
30 Kms

Geomorphology Map



topographic and bathymetric features created by physical, chemical or biological processes operating at or near the Earth's surface

Slope Map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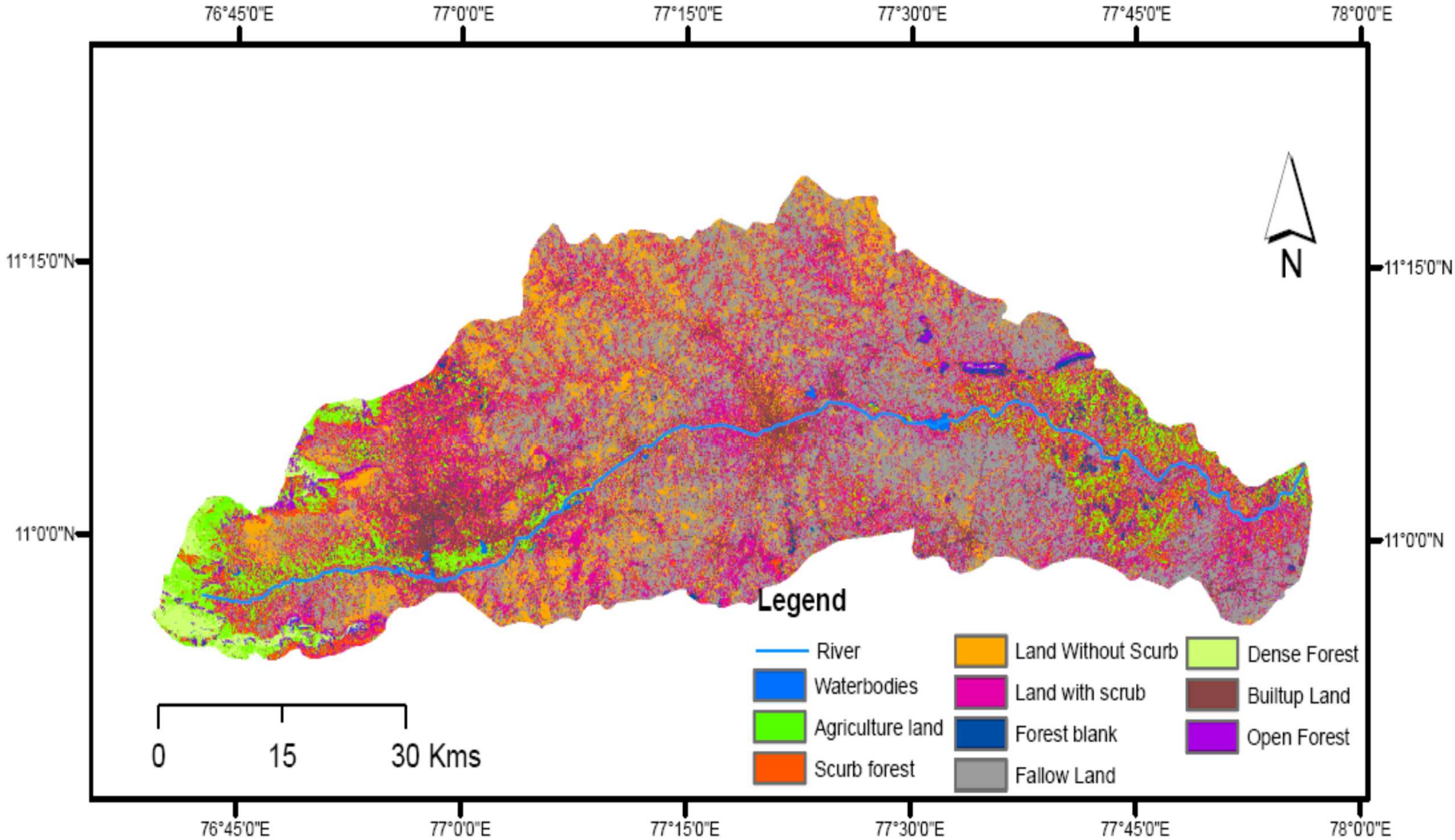
77°15'0"E
77°30'0"E
77°45'0"E
78°0'0"E
11°15'0"N
11°0'0"N
N
Legend
River
Boundary
0 - 3
3 - 18
18 - 26
26 - 63
63 - 81
0
15
30 Kms

Land Use/land Cover Classification



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Weightage Influence for Groundwater Potential

S.No	Factors	Major Relationship	Minor Relationship	Weightage
1	Geology	Drainage density, Lineament density	Land use/land cover	2.5
2	Lineament density	Drainage density,	Land use/land cover	1.5
3	Land use/land cover	Drainage density,	Slope, Geology, Soil	2.5
4	Geomorphology	Slope, Geology, Drainage density	Land use/land cover, Soil	4
5	Soil	Land use/land cover, Geomorphology	Geology, Drainage density	3
6	Drainage density	Land use/land cover, Slope		2
7	Slope	Land use/land cover, Geomorphology	Drainage density	2.5

Weightage Influence for Non-Natural Recharge Sites

S.No	Factors	Major Relationship	Minor Relationship	Weightage
1	Geology	Drainage density, Lineament density	Land use/land cover	2.5
2	Lineament density	Drainage density, Land use/land cove	Slope	2.5
3	Land use/land cover	Drainage density,	Slope, Geology, Soil	2.5
4	Geomorphology	Slope, Geology, Drainage density	Land use/land cover, Soil	4
5	Soil	Land use/land cover, Geomorphology	Geology, Drainage density	3
6	Drainage density	Land use/land cover,	Slope, Geomorphology	2
7	Slope	Drainage density, Rainfall, Geomorphology	Land use/land cover	3.5
8	Rainfall	Land use/land cover, Geomorphology	Slope	2.5
9	Water level	Rainfall. Lineament density, Geology	Land use/land cover, Slope	4

Percentage Influence of Various Parameters on Groundwater Potential and Non-Natural Recharge Sites

Factors	Percentage of Influence	
	Groundwater Potential	Non-Natural Recharge Sites
Geology	13	8
Lineament density	9	10
Land use/land cover	15	6
Geomorphology	20	16
Soil	15	10
Drainage density	13	8
Slope	16	14
Rainfall	-	10
Water level	-	6

Factors of Thematic Layers and its Parameters

Thematic map	Parameter	Boolean Overlay Rank	WIOA Rank	Fuzzy Logic Rank
Geology	Unclassified Gneiss	1	4	0.80
	Lime Stone	1	4	0.80
	Charnokite	0	2	0.40
	Pink Granite	0	1	0.20
	Pink Granite & Gneiss	1	4	0.80
	Basic Rock	1	5	0.99
	Complex Gneiss	1	1	0.20
	Valley Fill	1	4	0.80
Soil	Colluvial & Alluvial	1	5	0.99
	Brown Soil	0	2	0.40
	Red Calcareous	1	4	0.80
	Black Soil	0	1	0.20
	Red Non Calcareous	0	2	0.40
	Thin red Soil	1	4	0.80
	Alluvial Soil	1	5	0.99

Thematic map	Parameter	Boolean Overlay Rank	WIOA Rank	Fuzzy Logic Rank
Geomorphology	Structural hill	0	1	0.20
	Shallow pediment	0	2	0.40
	Duri crust	0	1	0.20
	Shallow buried pediment	0	2	0.40
	Residual hill	0	1	0.20
	Denudational hills	0	1	0.20
	Deep pediment	1	4	0.80
	Valley fill	1	4	0.80
	Pediment	0	1	0.20
	Flood plain	1	5	0.99
	Composite slope	0	1	0.20
	Paleo sand dune	1	5	0.99
Land use / land cover	Crop land	1	4	0.80
	Fallow land	1	4	0.80
	Scrub forest	1	3	0.60
	Built up land	0	1	0.20
	Water bodies	1	5	0.99
	Land with scrub	0	2	0.40
	Land without scrub	1	3	0.60

Lineament density, Drainage density and Slope

Thematic map	Parameter	Boolean Overlay Rank	WIOA Rank	Fuzzy Logic Rank
Lineament density (km/km^2)	0-0.600	0	1	0.20
	0.600-1.200	1	2	0.40
	1.200-1.800	1	3	0.60
	1.800-2.400	1	4	0.80
	2.400-3.100	1	5	0.99
Drainage density (km/km^2)	0 − 0.31169	1	5	0.99
	0.31169 − 0.658	1	4	0.80
	0.658 − 0.995	1	3	0.60
	0.995 − 1.432	1	2	0.40
	1.432 − 2.20	0	1	0.20
Slope	0 − 1	0	1	0.20
	1 -3	1	2	0.40
	3 -7	1	3	0.60
	7 -15	1	4	0.80
	>15	1	5	0.99

Rank of Parameters for Identifying Non-Natural Recharge Sites

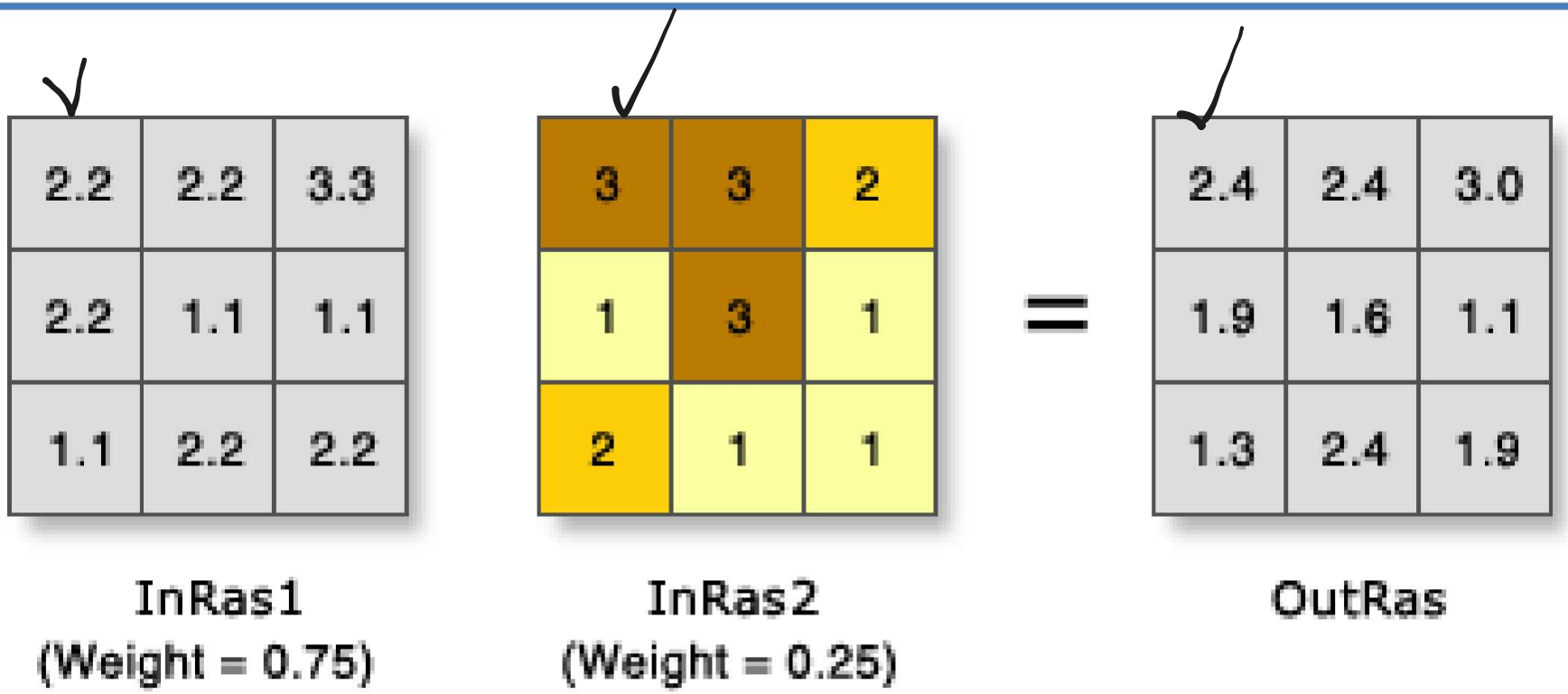
S.No	Factors	Parameters	Rank
1	Soil	Reserved forest	NA
		Colluvial & Alluvial	5
		Brown Soil	2
		Red Calcareous	4
		Black Soil	1
		Red Non Calcareous	2
		Thin red Soil	4
		Alluvial Soil	5
2	Geology	Unclassified Gneiss	4
		Lime Stone	4
		Charnokite	2
		Pink Granite	1
		Pink Granite & Gneiss	4
		Basic Rock	5
		Complex Gneiss	1
		Valley Fill	4

3	Geomorphology	Structural hill	1
		Shallow pediment	2
		Duri crust	1
		Shallow buried pediment	2
		Residual hill	1
		Denudational hills	1
		Deep pediment	4
		Valley fill	4
		Pediment	1
		Flood plain	3
		Composite slope	1
		Paleo sand dune	5
		Reserved forest	NA

4	Lineament Density	0-0.600	1
		0.600-1.200	2
		1.200-1.800	3
		1.800-2.400	4
		2.400-3.100	5
5	Drainage Density	0 − 0.31169	5
		0.31169 − 0.658	4
		0.658 − 0.995	3
		0.995 − 1.432	2
		1.432 − 2.20	1
6	Slope Gradient	0 − 1	4
		1 -3	5
		3 -7	3
		7 -15	2
		>15	1

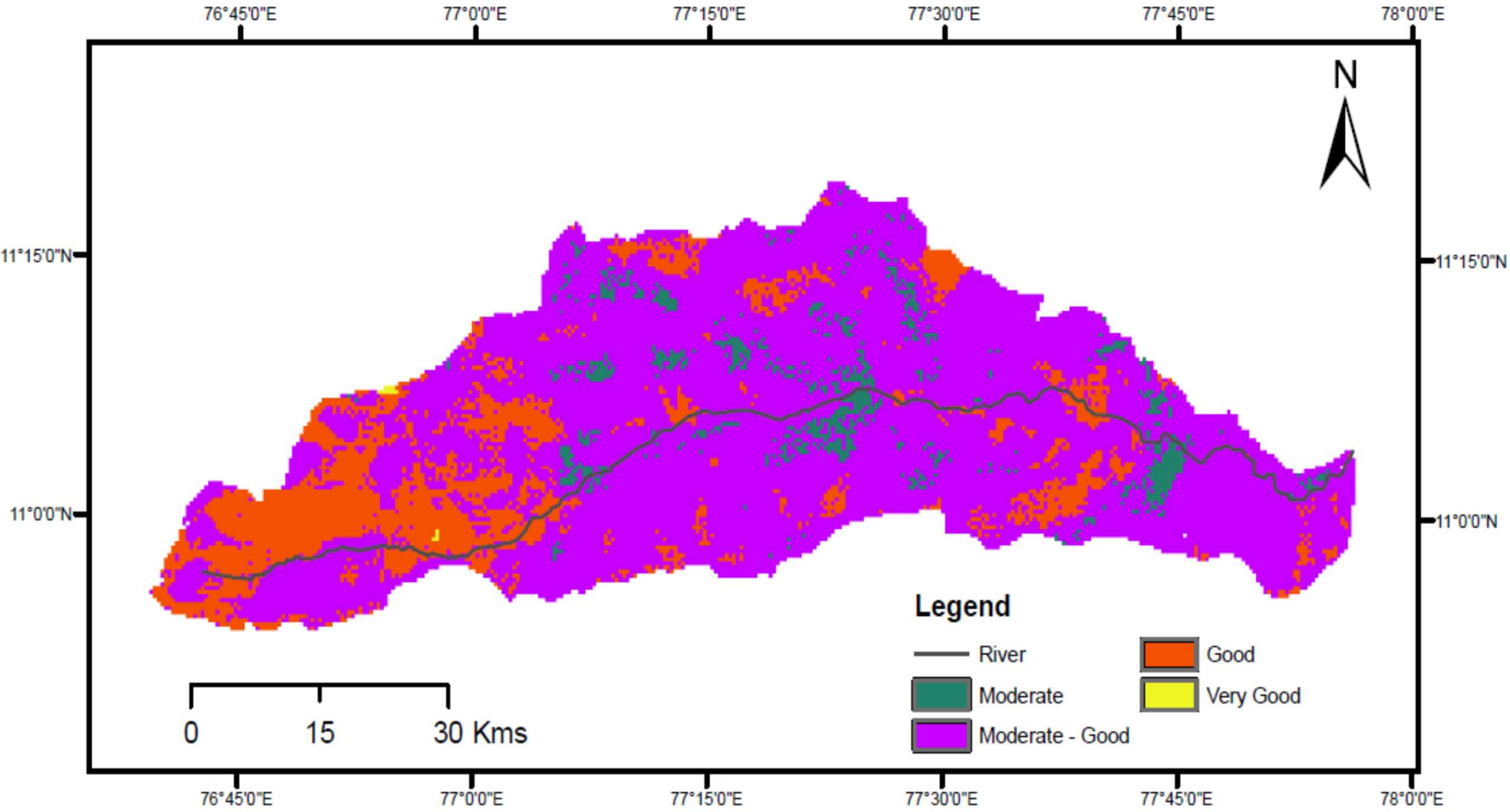
7	Land use/Land cover	Dense forest	NA
		Crop land	4
		Fallow land	4
		Scrub forest	3
		Built up land	1
		Water bodies	3
		Forest blank	NA
		Land with scrub	3
		Land without scrub	4
		Open forest	NA
8	Water Level in m	1.8 – 10	5
		10.1 – 15	4
		15.1 – 20	3
		20.1 – 26	2
		26.1 - 32	1
9	Rainfall	352 – 541	1
		541.1 – 640	2
		640 – 811	3
		811 – 1103	4
		1103 - 1500	5

Overlay Analysis

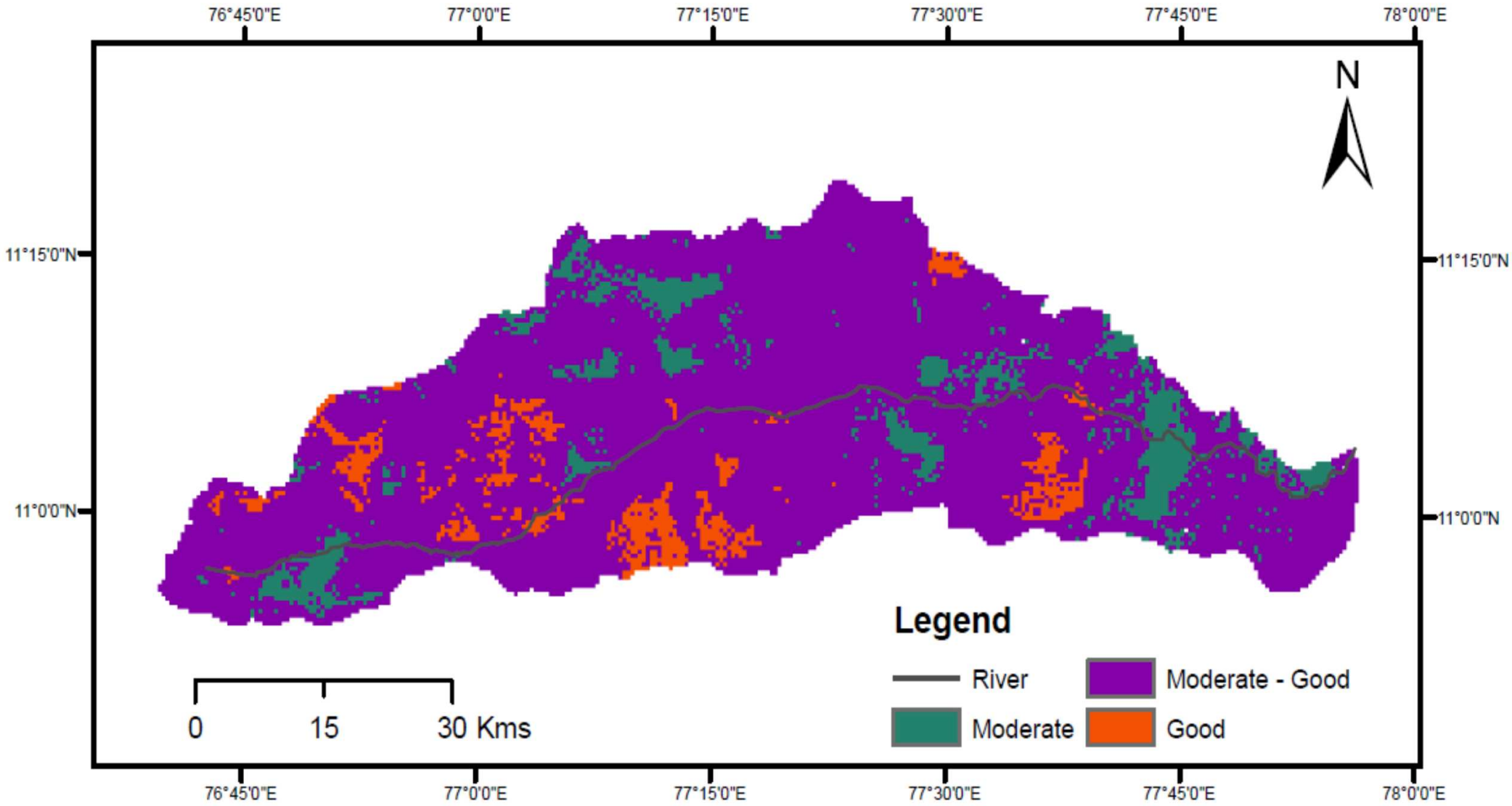


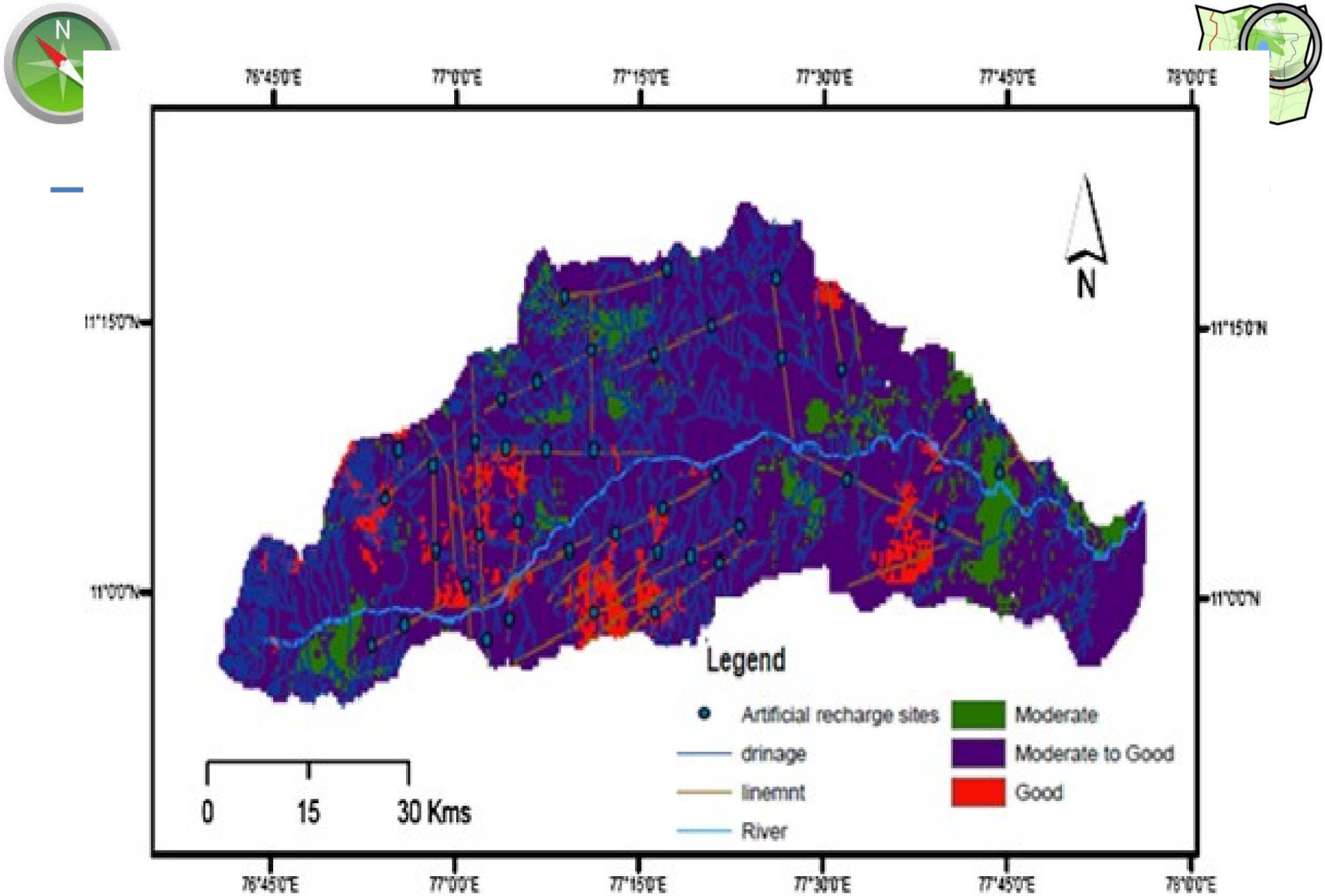
*In the illustration, the cell values are multiplied by their weight factor, and the results are added together to create the output raster. For example, consider the upper left cell. The values for the two inputs become (2.2 * 0.75) = 1.65 and (3 * 0.25) = 0.75. The sum of 1.5 and 0.75 is 2.4.*

Groundwater Potential Map



Non-Natural Recharge Sites Map

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77°45'0"E
78°0'0"E
11°15'0"N
11°0'0"N
N
Legend
Artificial recharge sites
drinage
linemnt
River
Moderate
Moderate to Good
Good
0
15
30 Kms

Conclusions

- In the present study, map generated by superimposing the drainage map and lineament map helped to locate the favorable sites for the artificial recharge which is shown in fig. 13.
- Based on Fig. 13, 39 artificial recharge sites were identified, of which 4 sites fall in the 'good' recharge zone, 2 sites fall in the 'moderately suitable' recharge zone and 33 sites fall in the 'moderate to good suitable' recharge zone.
- As far as the artificial recharge structures are concerned, mainly check dams and perculation ponds are recommended at the identified sites for artificial recharge in the study area.
- These structures are small-scale structures that can be built across lower order streams in order to enhance infiltration into the subsurface formations.

Cont.

- The Non-Natural recharge was predominant in moderate to good category (occupies 83.52% of the study area) due to the presence of pediments and gneiss, red calcareous and thin red soil with high lineament density.

- The good category (occupies 6.12% of the study area) was found in few patches of south western side and western side of the study area due to the presence of red calcareous, flood plain, pediment, shallow pediment and deep pediment, valley fill, unclassified gneiss, charnockite, complex gneiss and fallow land.

- The moderate category (occupies 10.36% of the study area) was found in western, south eastern and north eastern side of the study area due to the presence of red calcareous, black soil, colluvial and alluvial soil, shallow buried pediment, shallow pediment, pediment, charnockite, complex and unclassified gneiss.