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A METHOD FOR INTEGRATED ASSESSMENT OF VULNERABILITY TO DROUGHT

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Drought: The Facts

Drought differs from other natural hazards

- Difference in perception and absence of universal definition)
- Droughts are regional, recurring, natural phenomenon.
- They are driven by regional climatic factors.
- Drought characteristics vary across the climatic regions.
- Severity is described through multiple indicators and indices.
- Assessment of severity & impacts of droughts is complex

Drought: The Facts

Contd….

- Up to now, much of the research efforts were steered at monitoring and understanding climatic and hydrological events, which contribute to water scarcity, (e.g. drought hazard) than coping with drought (e.g., protection and mitigation) and managing vulnerability to drought (Downing & Bakker, 2000).

- Current drought management efforts: largely reactive, ad-hoc & crisis based rather than proactive mitigation.

RISK OF DROUGHT

Drought risk involves two major components

Hazard x Vulnerability = Risk

(natural event)

(Physiographic & social factors)

Climatology

Population growth and shifts
Urbanization
Soils and land use practices
Environmental degradation
Water use trends
Government policies
Awareness
Technology / Coping ability

Vulnerability

- Vulnerability refers to the degree of susceptibility of society to a hazard, which could vary either as a result of variable exposure to the hazard, or because of coping abilities (e.g. protection and mitigation), or both (Anderson, 1994)
- Even from season to season, vulnerability can vary from extreme crisis to complete safety (Wilhelmi & Wilhite, 2002).

Importance of Vulnerability

Vulnerability plays crucial role in identifying appropriate actions that need to be taken to reduce adversity before the potential for damage is realized.

The assessment of vulnerability to drought for a region/area and discernment of regional drought characteristics (frequency, duration and severity) are more relevant parameter in sizing water conservation and storage schemes towards combating and abetting droughts.

Vulnerability Assessment

- Regional climatic factor
- Physiographic factor
- Hydrologic factor
- Social factor (population, concentration of economic activities etc.)
- Coping ability

etc….. , etc…..

Vulnerability Assessment

Various factors could be accounted through following determinants

- Reach location in basin: Upper, middle, lower reach. (elevation, slope & stream order)
- Land Use: Forest, cropland, grassland and non-agril. lands
- Soil: root-zone water holding capacity. - Difference between FC and WP for soil depth up to 1.0 m below ground surface (SWHC>200mm less risk and SWHC<100mm at high risk).
- Availability of streamflow in time and space.
- Availability of utilizable ground water
- Population concentration: least, below average, **average**, and above average
- Crop water requirement (demand per unit of land area.
- Access to Irrigation. Irrigated and non-irrigated areas.
- Rainfall deficit & Soil moisture deficit or seasonal crop moisture deficiency.

ASSESSING VULNERABILITY TO DROUGHT

1. **Static factor of vulnerability** (***Physiographic factors:*** *w.r.t. space*)
   - Topographic factors (General Slope and drainage etc.)
   - Soil (Soil water holding capacity)
   - climatic components (Precipitation & ET),

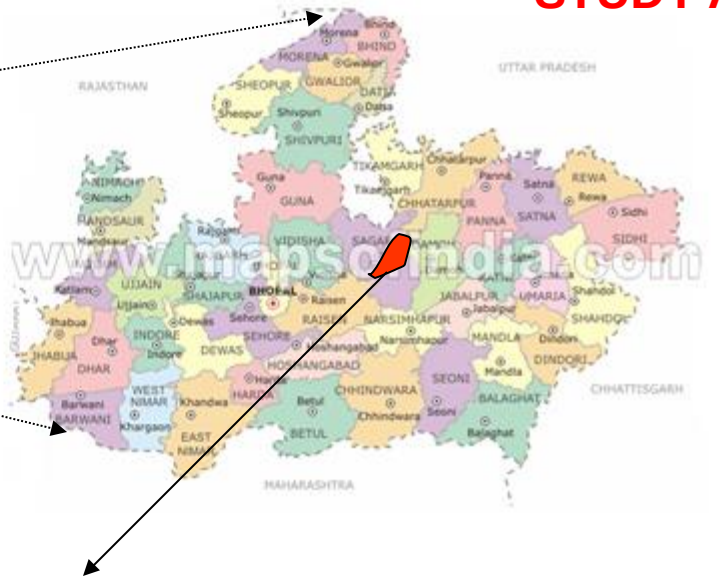
2. **Semi-static factors of vulnerability** (*w.r.t. space and long-term temporal variability)*
   - Irrigation support
   - Status of surface water storage availability
   - Status Ground water availability
   - Population density (Population concentration, industrial/ commercial activities)
   - Land use
   - Regional cropping system
   - Region-specific activities (like cattle farming/wildlife preservation etc)

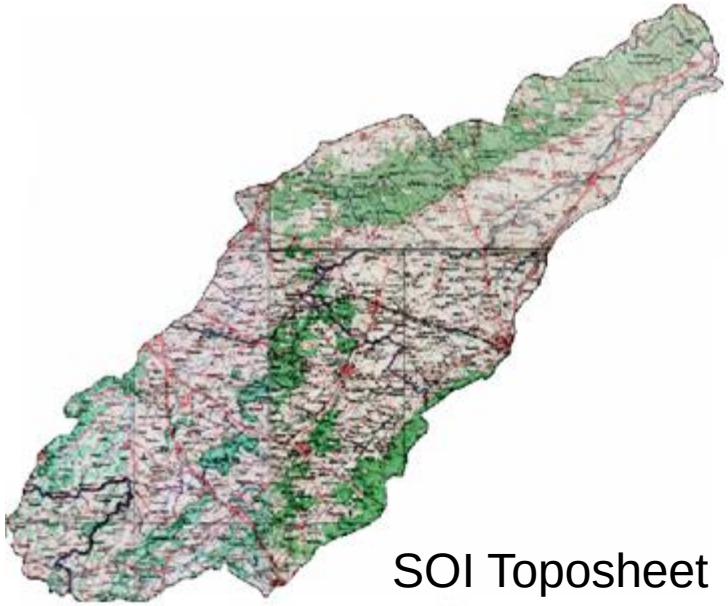
3. **Variable factors of vulnerability** (*w.r.t. space and time*)
   - Rainfall (monthly/seasonal/annual)
   - Stream flow
   - Storages (if any)

--- **Classification and spatial representation of drought vulnerability using geographic processing techniques**

--- **Evaluation of weight of the factors that contribute to drought risk / vulnerability.**

STUDY AREA

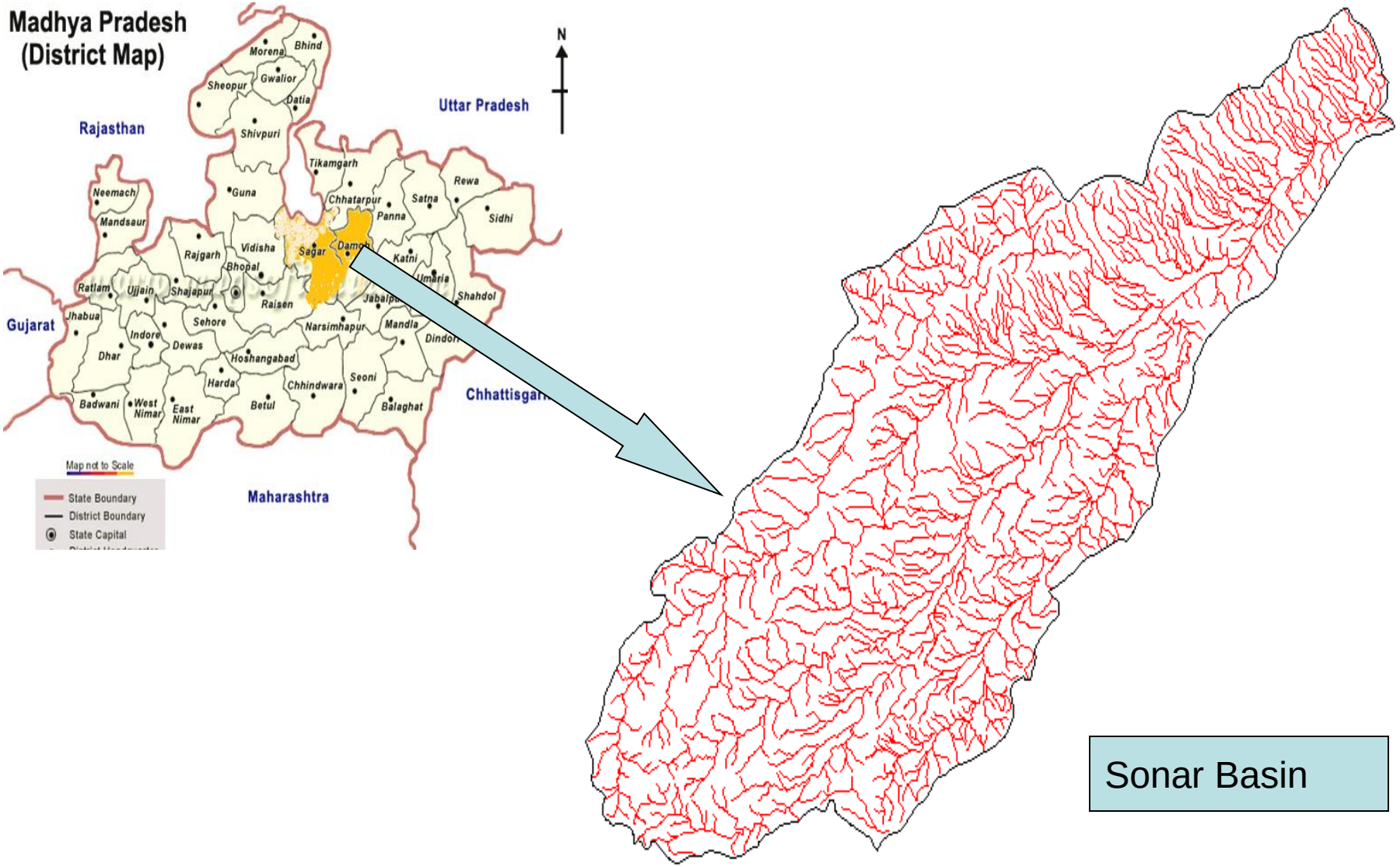




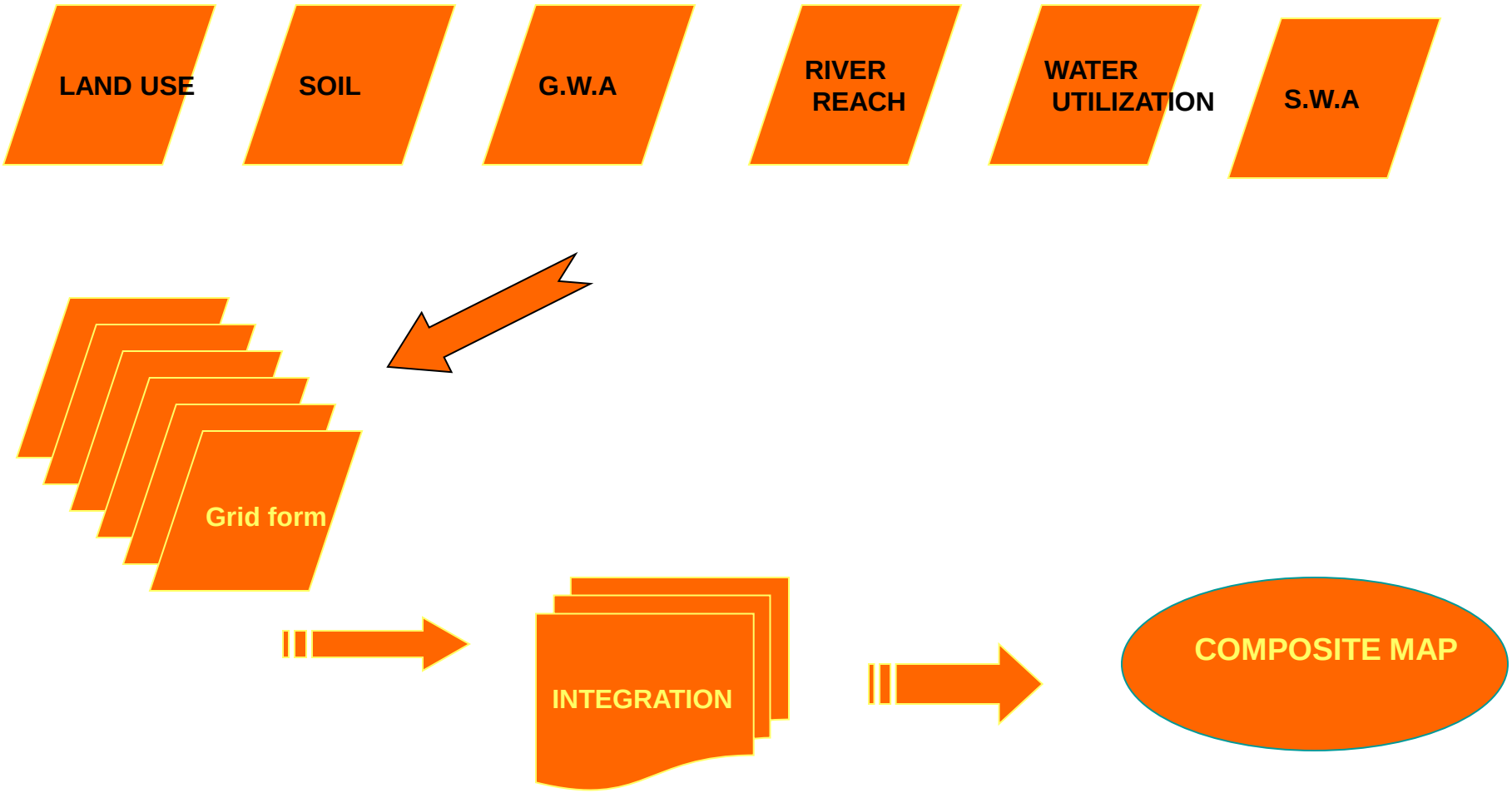
SOI Toposheet

LISS-3
February 1997

Study Area


Madhya Pradesh
(District Map)
N
Morena
Bhind
Sheopur
Gwalior
Datia
Uttar Pradesh
Rajasthan
Shivpuri
Tikamgarh
Neemach
Guna
Chhatarpur
Satna
Rewa
Mandsaur
Panna
Sidhi
Rajgarh
Vidisha
Sagar
Damoh
Katni
Bhopal
Umaria
Ratlam
Ujjain
Shajapur
Raisen
Jabalpur
Shahdol
Gujarat
Jhabua
Sehore
Narsimhapur
Mandla
Indore
Dewas
Dindori
Dhar
Hoshangabad
Harda
Chhindwara
Seoni
Chhattisgarh
Badwani
West Nimar
East Nimar
Betul
Balaghat
Map not to Scale
State Boundary
District Boundary
State Capital
Maharashtra
Sonar Basin

Flow Chart of Integration of vulnerability factors



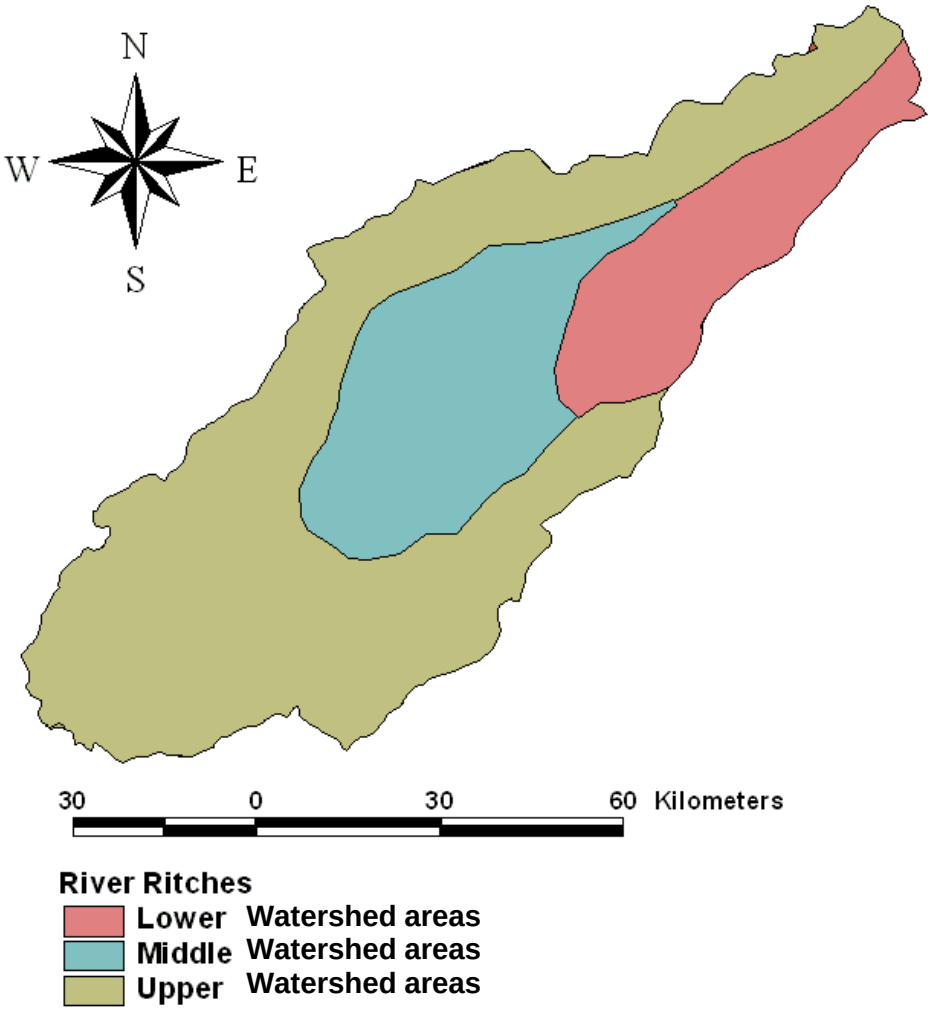
Assessing vulnerability to Drought (Weighing Scheme)

Vulnerability factor	Vulnerability	Drought Vulnerability class's score (weight)
Reach watershed areas	Lower watershed areas Middle watershed areas Upper watershed areas	2 3 4
Rainfall departure (%)	-20- -25 % -25- -35 % -34- -50% <-50 %	2 3 4 5
Soil type	Clay Clay loam Sandy clay loam Sandy loam Gravelly sandy loam	1 2 3 4 5
Land use types	Water bodies Barren/waste land Forestland Agricultural Habitation	-20 (masking area) 1 2 4 5
Surface water availability	Surplus Moderated deficit Highly deficit Critically deficit	0 1 3 5
Water utilization	Low High Very high	2 4 5
Groundwater availability	Surplus Moderated deficit Highly deficit Critically deficit	0 2 4 5

Irrigation Support (canal)	Complete irrigation Tank/Lift irrigation Unirrigated	-20 (Masking) 3 5

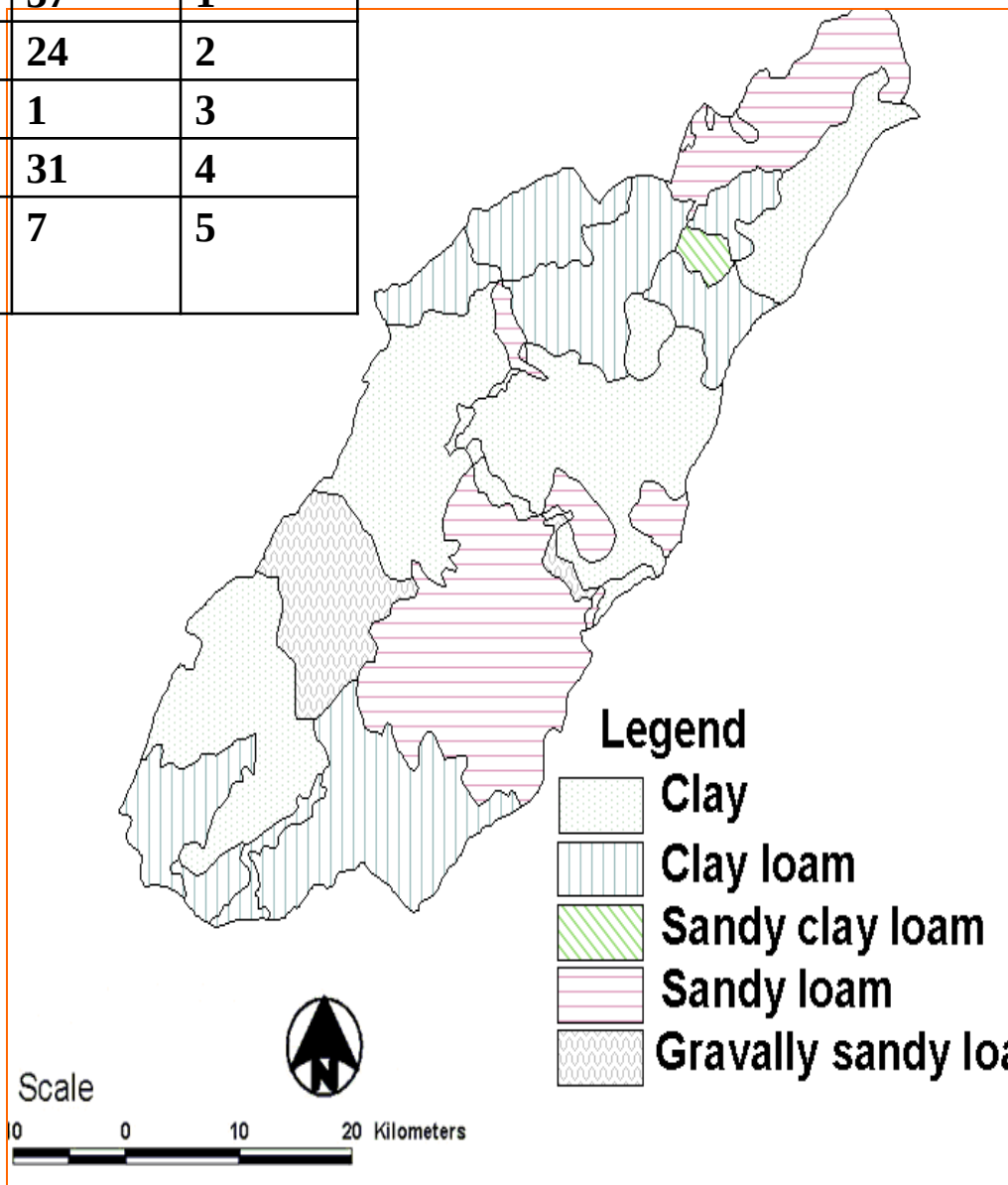
Classification of physiographic indicator

Elevation
Slope
Stream order

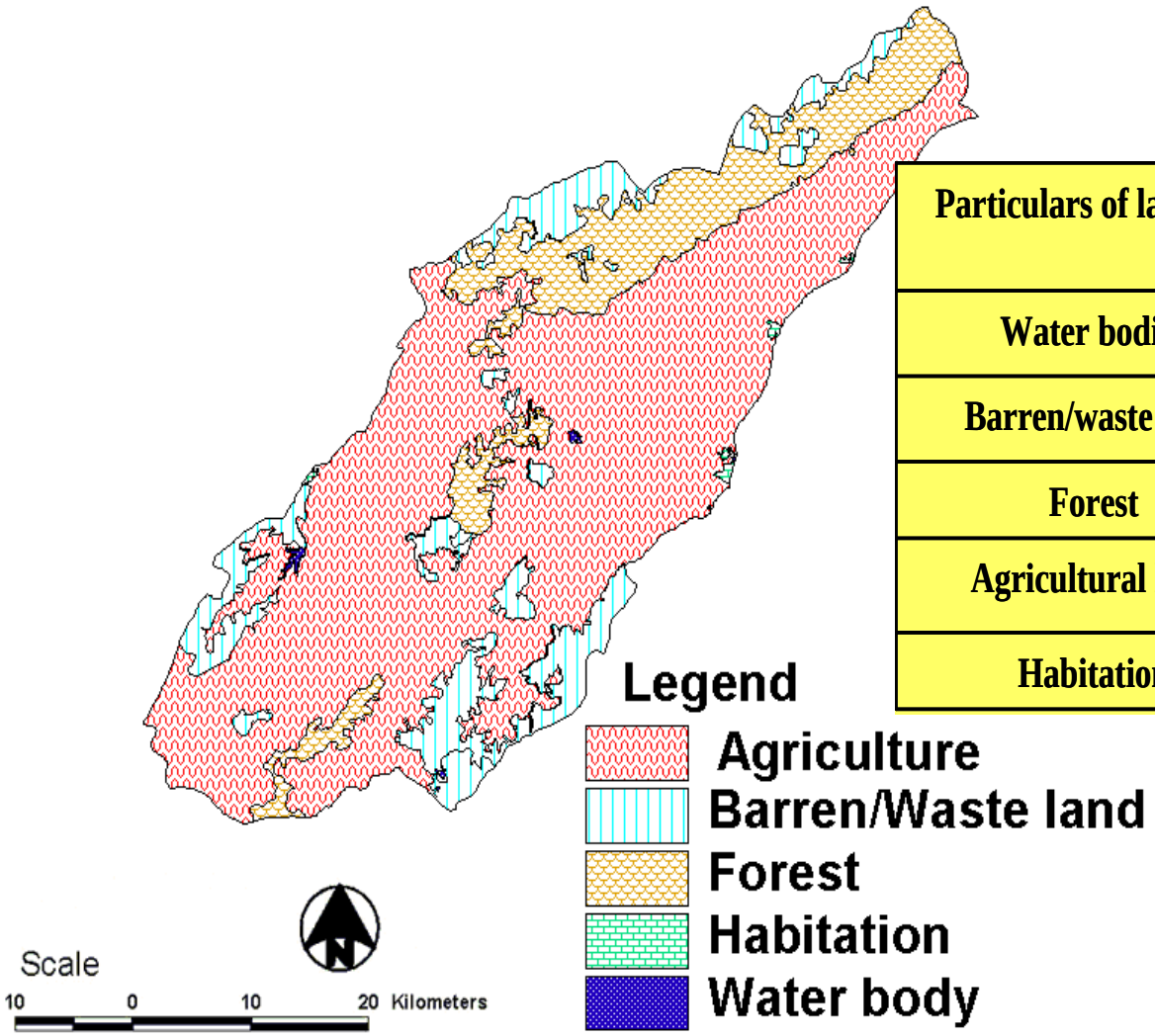


Soil

Soil type	Water holding capacity at 1m depth	Area in Km^2	Area in %	Weight
Clay	**100-120 mm**	**2422.25**	**37**	**1**
Clay Loam	**90-100 mm**	**1612.77**	**24**	**2**
Sandy Clay Loam	**70-90 mm**	**49.08**	**1**	**3**
Sandy Loam	**50-70 mm**	**2013.08**	**31**	**4**
Gravelly Sandy Loam	**< 40 mm**	**452.82**	**7**	**5**

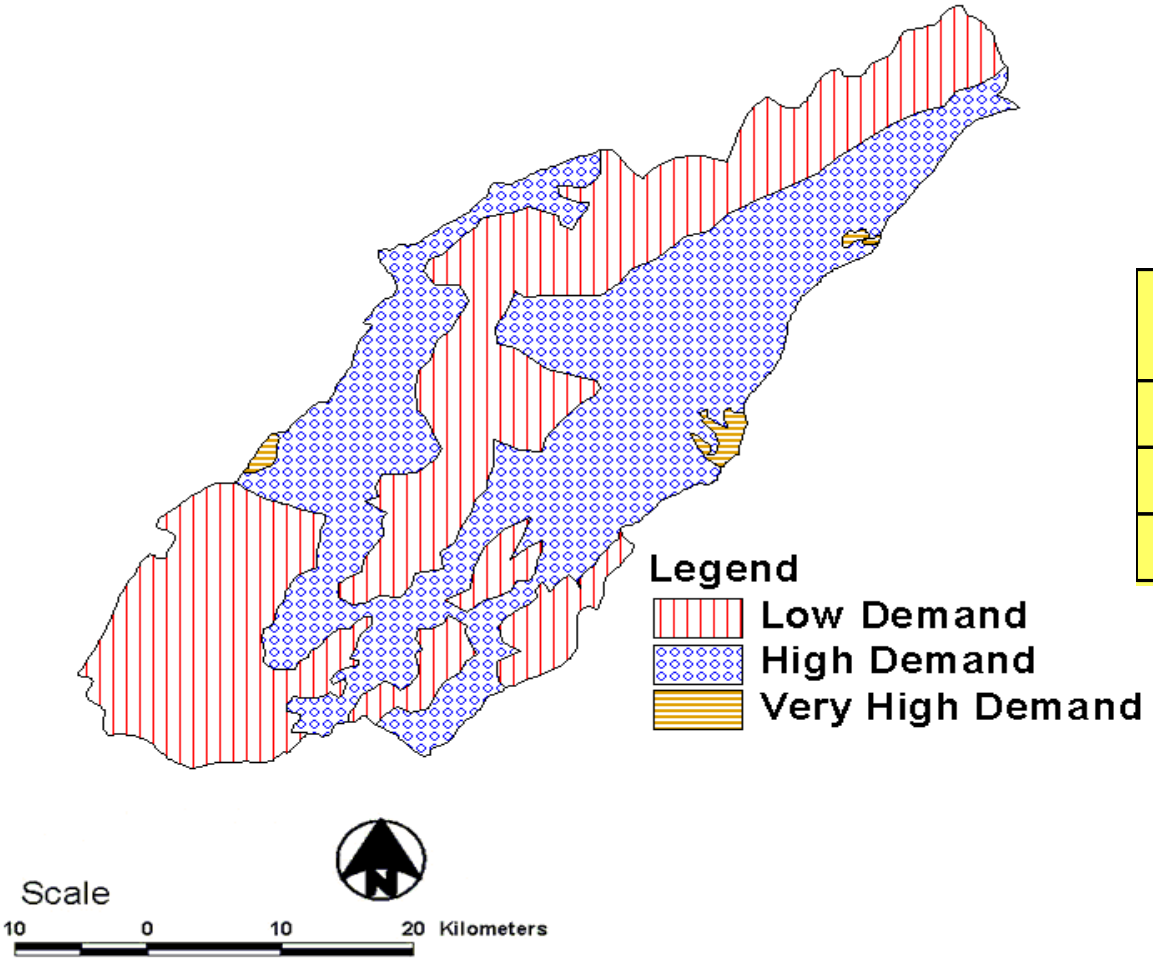


Land use



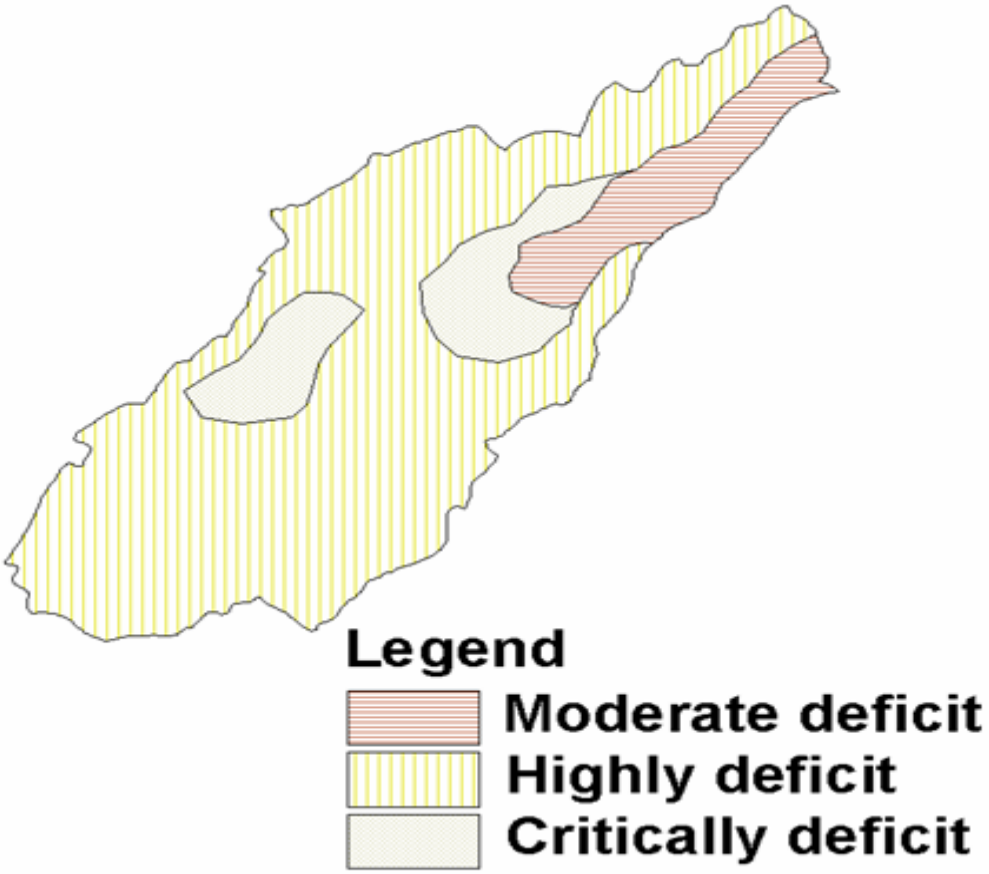
Particulars of land use	Area in (km^2)	Area in %	Weight
Water bodies	8.20	0.12	0
Barren/waste land	897.34	13.48	1
Forest	1068.92	16.06	2
Agricultural land	4659.24	70.07	4
Habitation	16.08	0.24	5

Water utilization



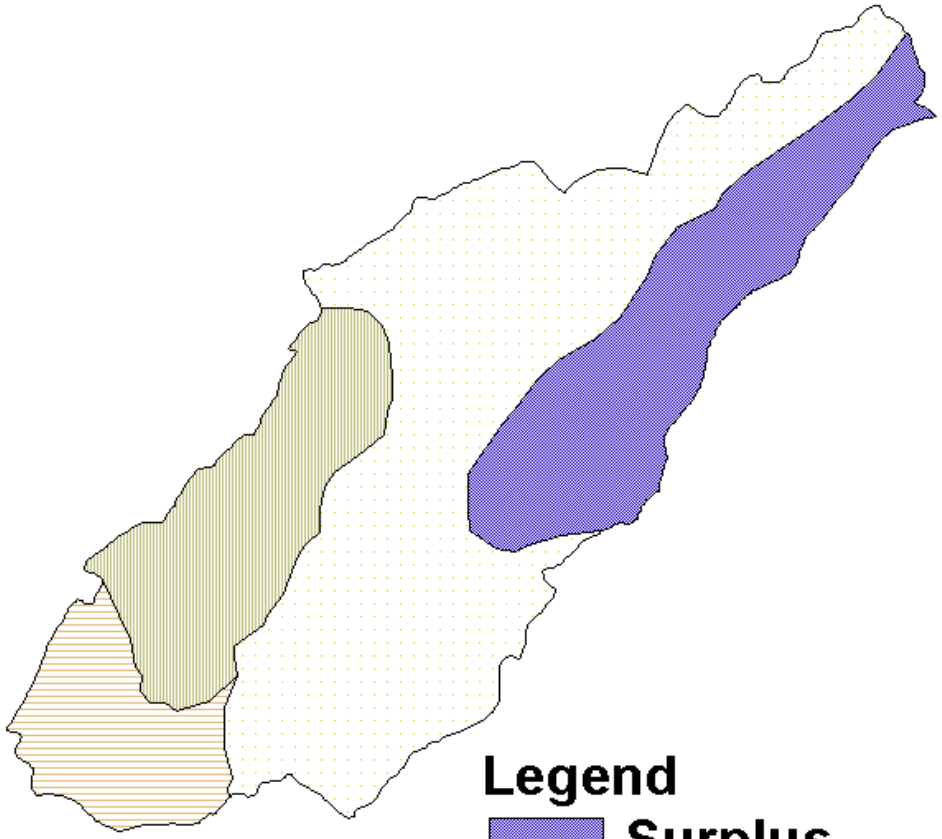
Class of Water utilization	Area(km^2)	Area in %	Weight
Low Demand	3202.59	48.89	1
High Demand	3285.74	50.16	4
Very High	61.67	0.95	5

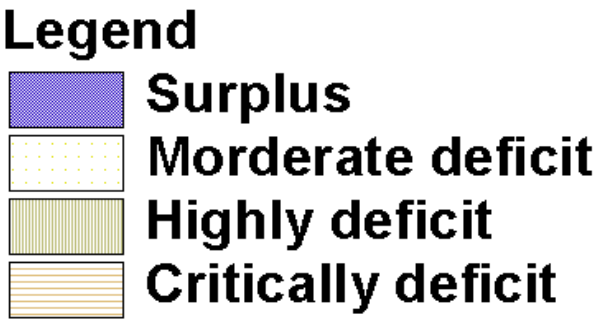
Ground water availability

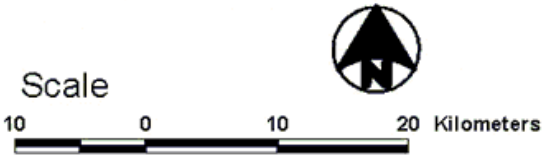


Type	Ground water availability Area (km^2)	Area in %	Weight
Surplus	Nil	Nil	Nil
Moderate deficit	721.82	11.02	1
Highly deficit	850.68	12.99	3
Critically deficit	4977.50	75.99	5

Surface water availability

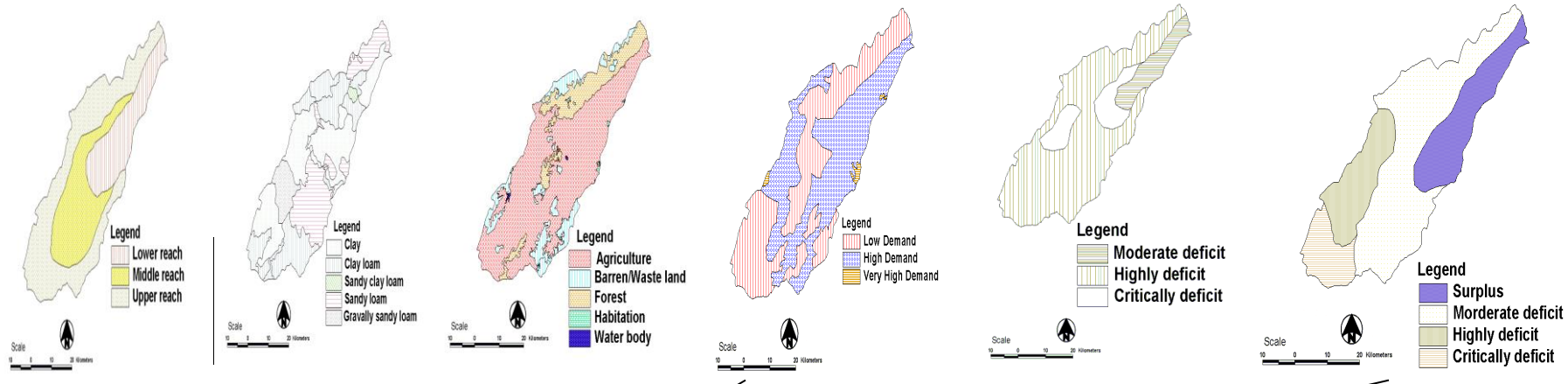


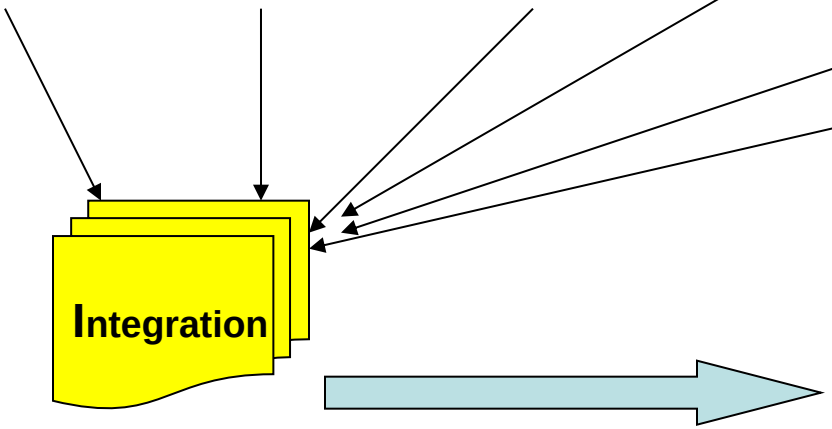


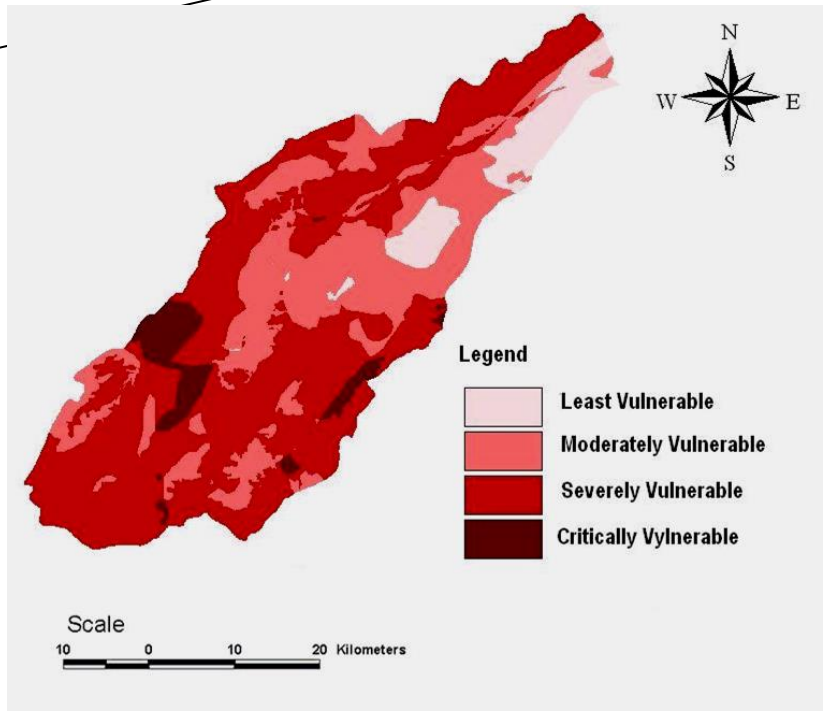


Type	Surface water availability Area(km^2)	Area in %	Weight
Surplus	1394.14	20.95	1
Moderate deficit	3417.85	51.37	3
Highly deficit	1138.90	17.14	4
Critically deficit	701.66	10.54	5

Integration of factors

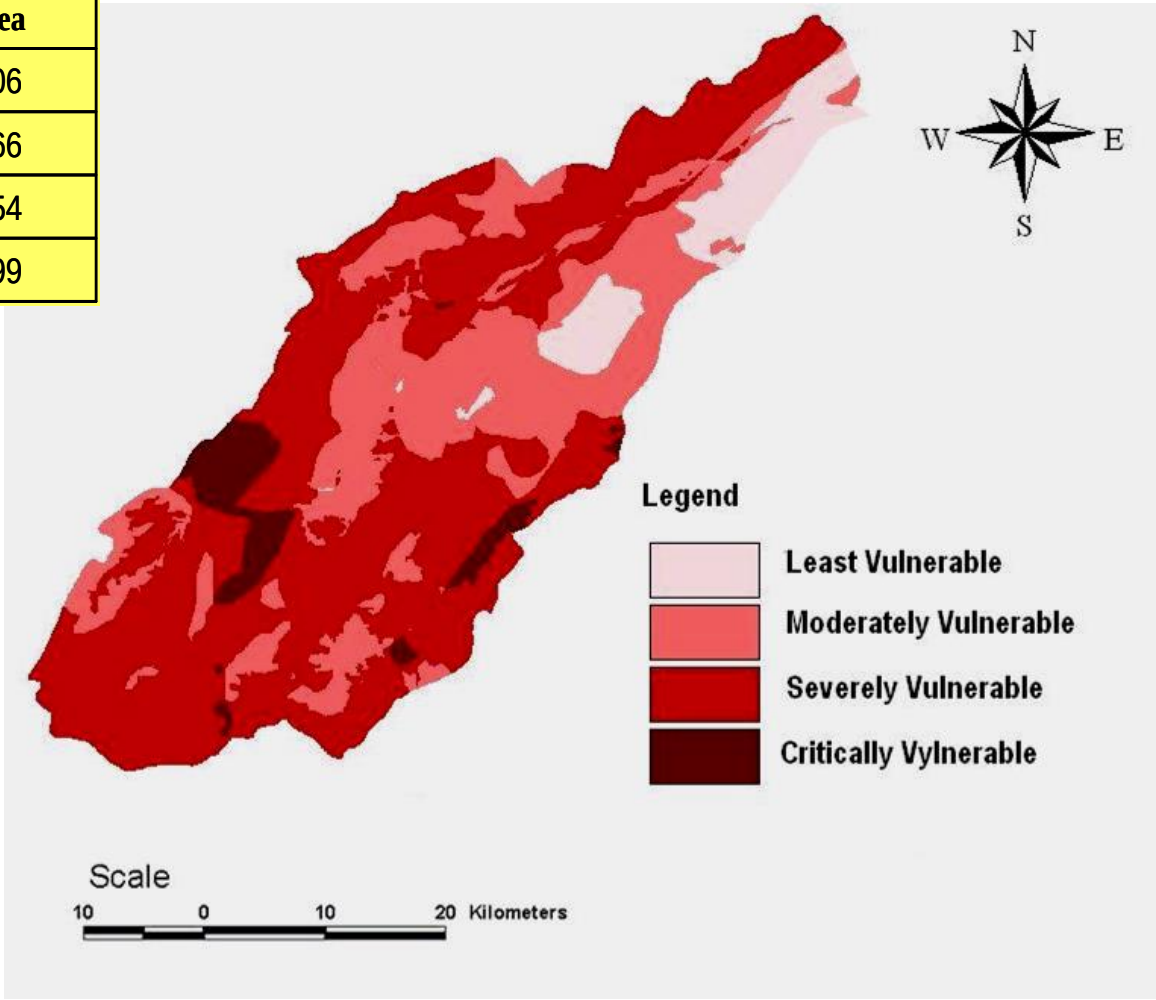




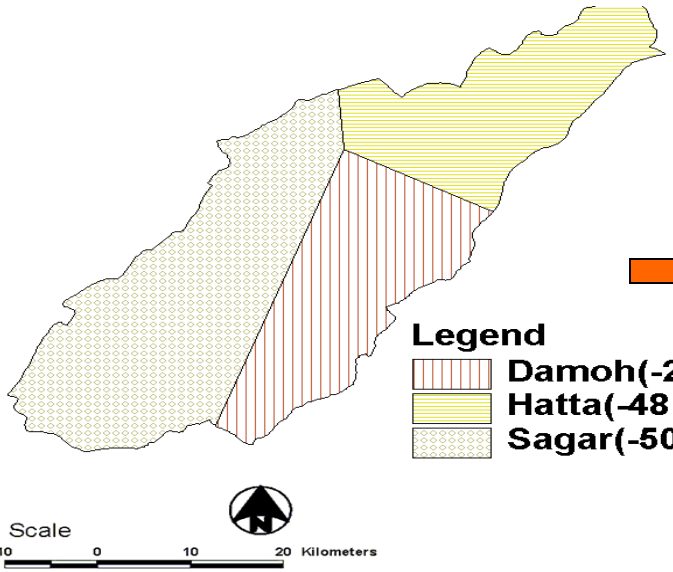


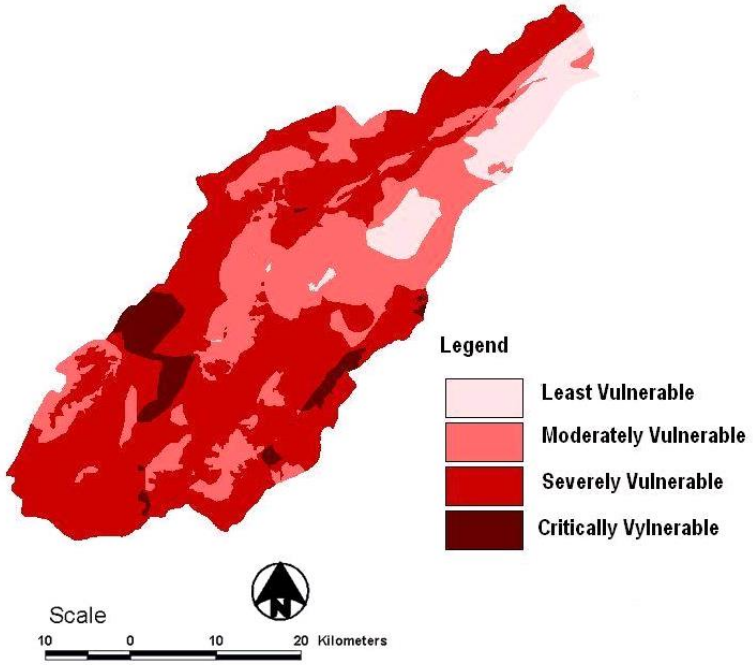
Integration of physiographic factors

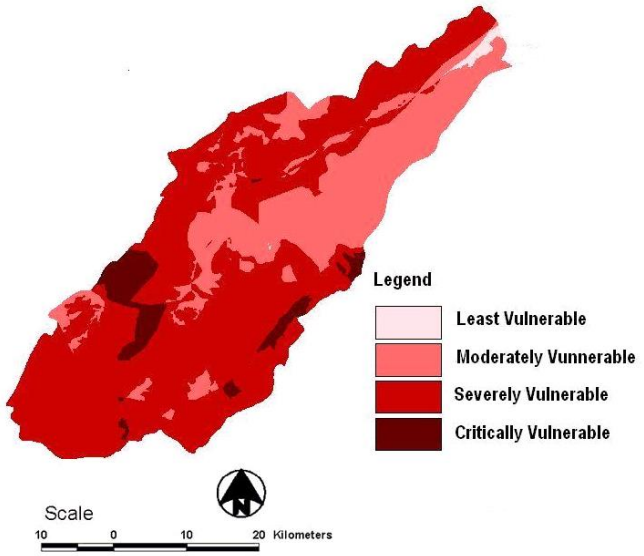
Vulnerability Classes	Area(km2)	% Area
Least	512.290	7.7006
Moderate	1986.840	29.866
Severe	3822.180	57.454
Critical	331.290	4.9799



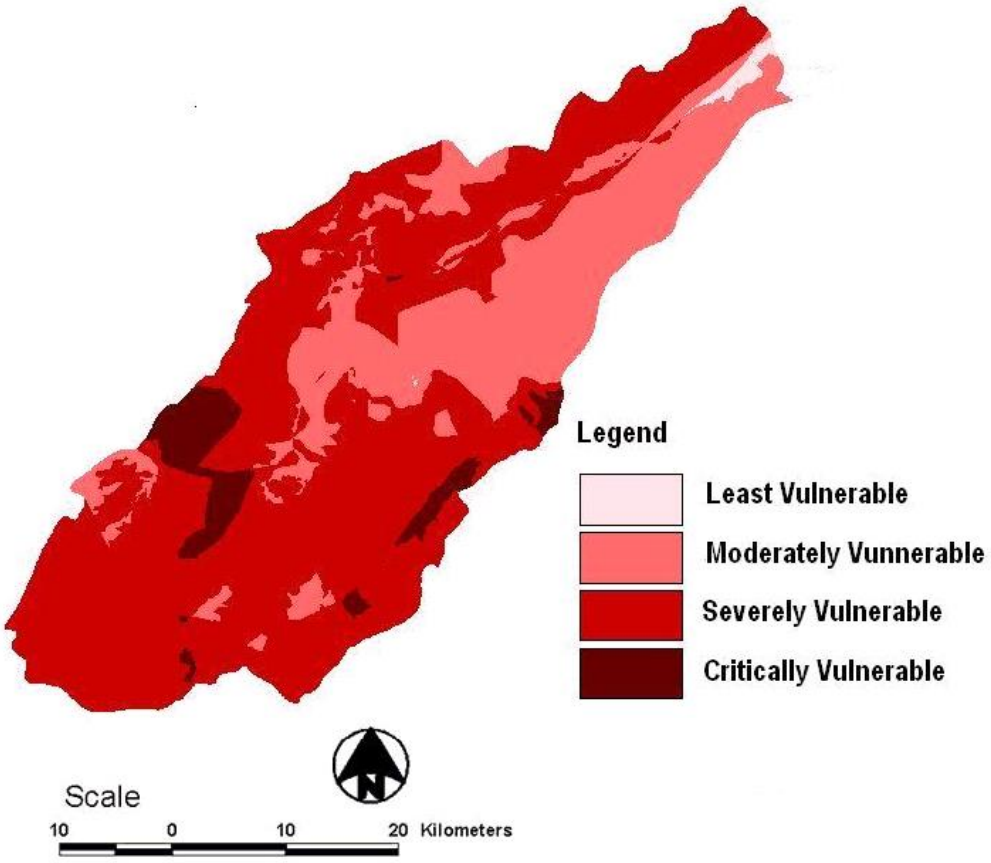
Integration with rainfall departure

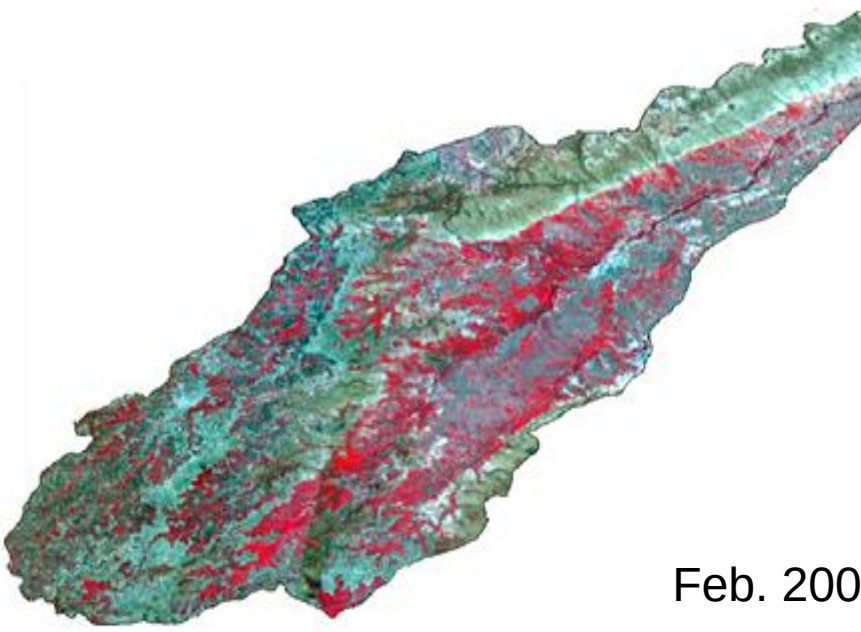






Integrated vulnerability to drought (October-2007)





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Vulnerability Class	Area(k m2)	% Area
Least	51.590	0.78
Moderate	1779.880	26.76
Severe	4516.480	67.89
Critical	304.640	4.58

Assessing vulnerability to Drought (Weighing Scheme)

Vulnerability factor	Vulnerability	Drought Vulnerability class's score (weight)
Reach location	Lower Middle Upper	2 3 4
Probabilities of seasonal crop moisture deficiency(%)	Less than 30 (low) 30-50 (Moderate) 50-70 (high) More than 70 (very high)	2 3 4 5
Soil root zone water holding capacity (mm)	More than 200 150-200 100-150 Less than 100 (low)	1 2 3 4
Land use types	Forestland Grassland Cropland/habitation Water bodies/swamp/wetland	0 2 5 -20 (Masking)
Irrigation Support (canal)	Complete irrigation Tank/Lift irrigation Unirrigated	-20 (Masking) 3 5
Population concentration	Less than average Near average More than average	2 4 5
Status of Groundwater	Safe Semi critical Critical Over exploitation	0 2 4 5
Status of surface water storages in tanks, lakes etc.w.r.t. domestic/cattle and other drinking water demand	Deficit Moderately deficit Surplus	2 3 4

Proposed- Integrated drought vulnerability Index

$$DVI = \frac{\sum w_i}{kN}$$

DVI = Drought Vulnerability Index

N = Number of indicators under consideration

w_i = Weights of drought vulnerability indicators *(where, i= 1,2,……N)*

k = Upper limit of vulnerability weights *(Say, range = 0-k , where, k is highest value of W_i)*

Classification of DVI

Sl. No	Values of DVI	Vulnerability Class
1	0 - 0.2	Least vulnerable
2	0.2 – 0.4	Mild vulnerable
3	0.4 – 0.6	Moderately vulnerable
4	0.6 – 0.8	severely vulnerable
5	>0.8	Critically vulnerable

Example

If a particular pixel/cell has a weight value
2 - on physiographic map,
4 - on soil map,
3- on the surface water deficit map,
3 - on the ground water deficit map,
4 - on the land use map,
5 - on the water demand map, and
3 – on rainfall deficiency map

The composite value weight for given pixel

$$\sum W_i = 2+4+3+3+4+5+3 = 24.$$

$$DVI = \frac{\sum W_i}{kN}$$

Upper limit of weight value of any of the indicator (*K*)= 5
Total no of indicators considered *(N)* = 7

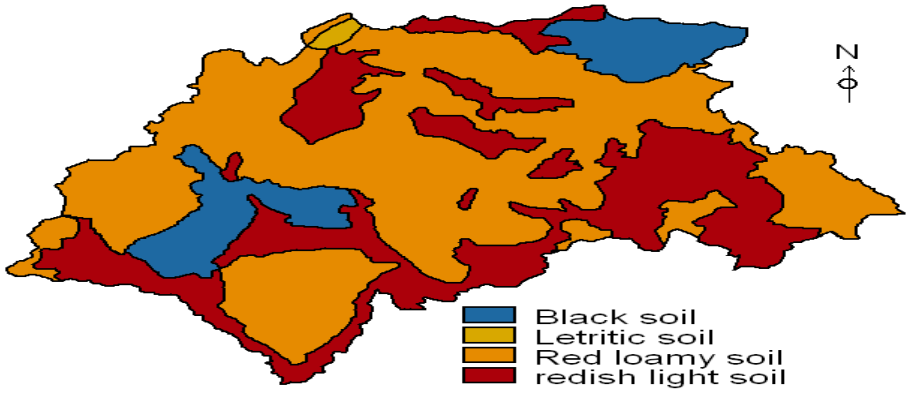
DVI = 24/35 = 0.68

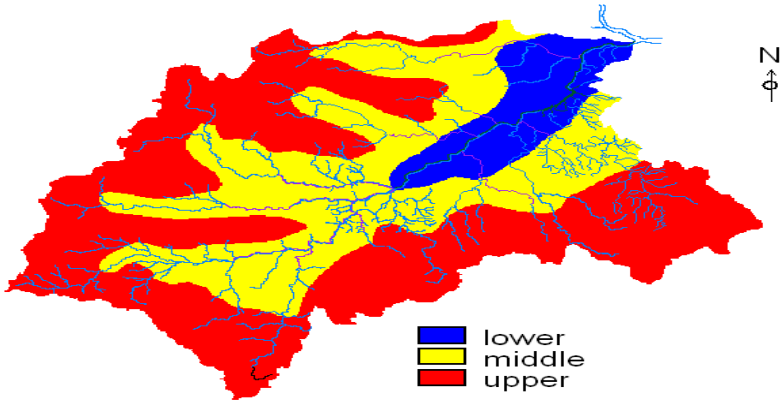
Drought Vulnerability Index :

Least 0 - 0 .20, Mild 0.2- 0.40, Moderately 0.4 - 0.60,
Severe 0.6 - 0.80, Critical 0.8- 1.0

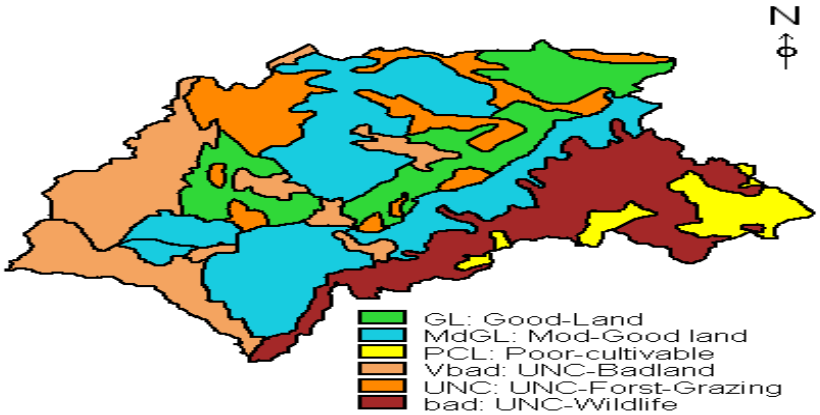
Application of Proposed Method in Another Basin

Soil : Water Holding Capacity

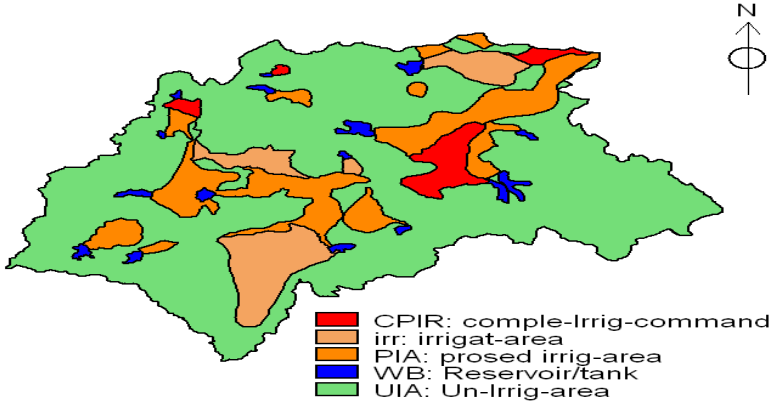




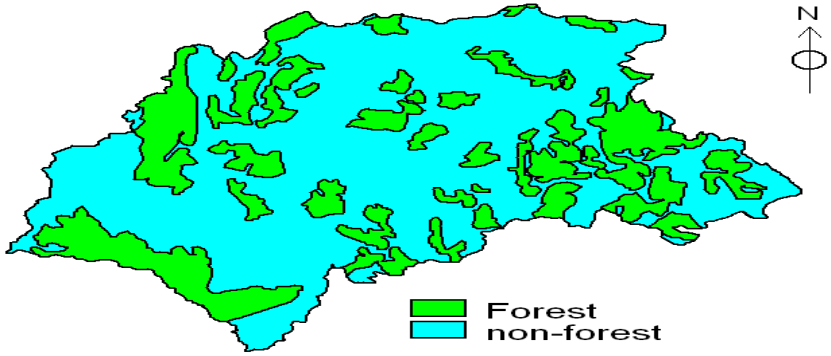
Land Suitability Classes

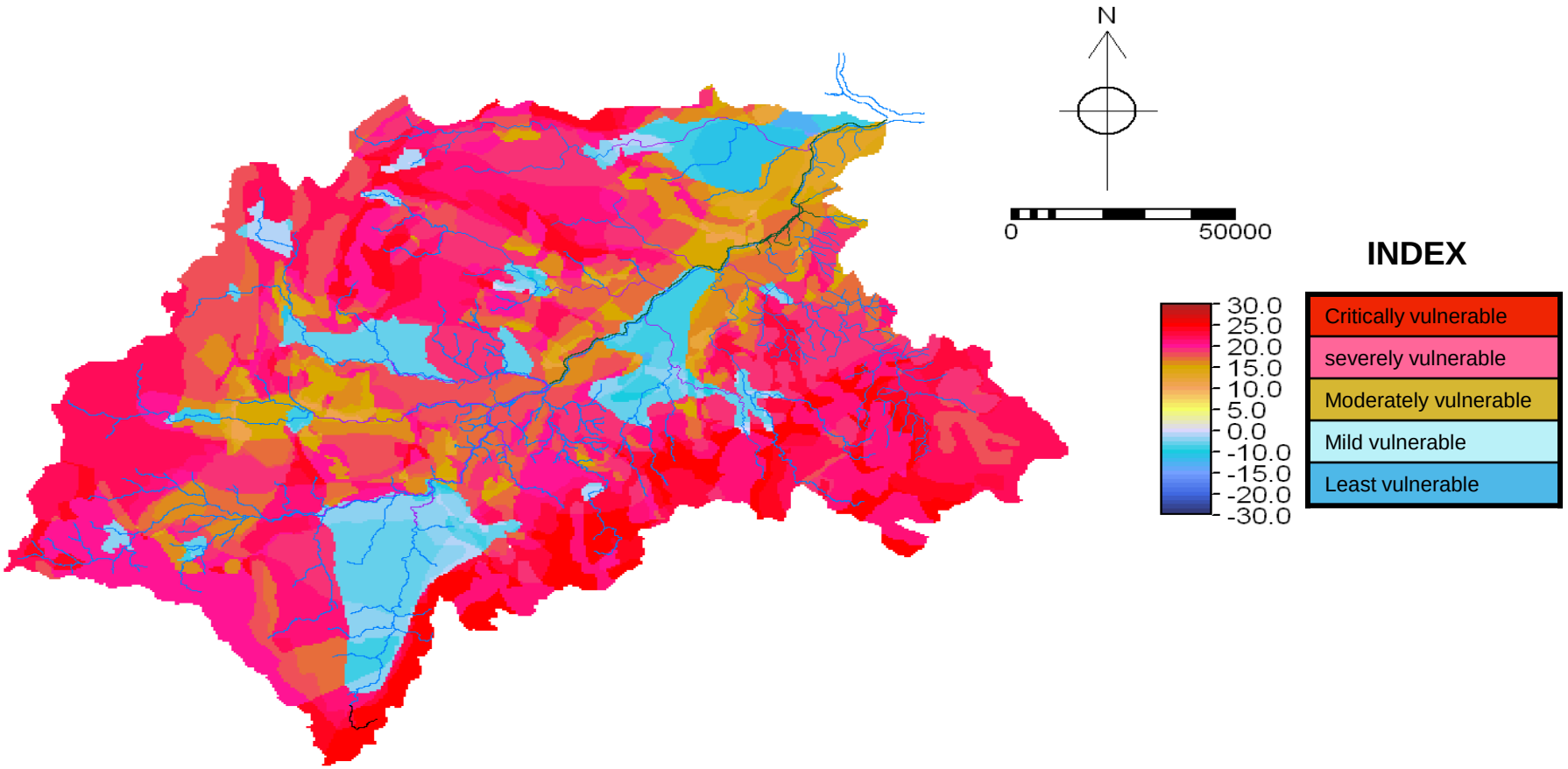


Irrigation Support



Forest Area

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Critically vulnerable
severely vulnerable
Moderately vulnerable
Mild vulnerable
Least vulnerable

OUTCOME OF THE STUDY

Study evolved a methodology for integrated assessment of vulnerability to drought.

Message to Audience

Need to change perception on DROUGHT

Droughts are perceived as extreme events in the climatic system, whereas in reality they need to be recognized as normal occurrences. Drought impacts, therefore, should be handled using risk based approach rather than crisis management, as it is the practice today in many countries

Thank you

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