USE OF SWAT FOR CLIMATE CHANGE IMPACT AND VULNERABILITY ASSESSMENT AT DISTRICT LEVEL

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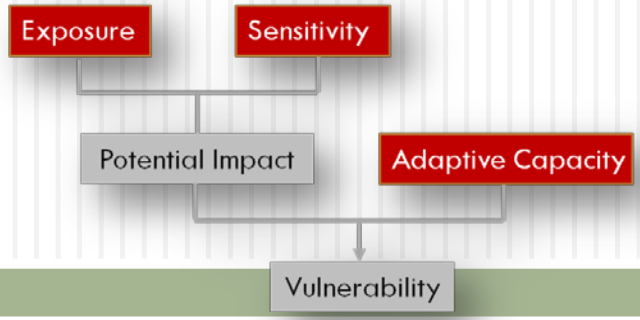
Assessment of vulnerability to climate change

- Assessment of vulnerability to climate variability and change broadly helps in:
  - Understanding current vulnerability
  - Identify the factors that render some districts more vulnerable than others
  - Inform and facilitate the decision-making process
  - Selection of adaptation strategies and practices
- Generating district level Vulnerability Index for Madhya Pradesh
  - VI would facilitate the identification of districts, which are vulnerable to climate change and need special attention towards adaptation
  - A geographically disaggregated map of vulnerability to climate change is helpful for planning adaptation strategies
- Study was supported by GIZ

Concept

- Exposure
  - Exposure is defined as degree of climate stress upon a particular unit analysis; it may be represented as either long-term changes in climate conditions, or by changes in climate variability, including the magnitude and frequency of extreme events (IPCC, 2001).
  - There are two main elements to consider in exposure.
    - Things that can be affected by climate change (populations, resources, property, and so on)
    - The change in climate itself (sea level rise, precipitation and temperature changes, and so on)
- Sensitivity
  - Sensitivity is the degree to which a system will be affected by, or responsive to climate stimuli (Smith et al., 2001).
  - Sensitivity is basically the biophysical effect of climate change; but sensitivity can be altered by socio-economic changes. For example, new crop varieties could be either more or less sensitive to climate change.
- Adaptive Capacity
  - Adaptive capacity refers to the potential or capability of a system to adjust to climate change, including climate variability and extremes, so as to moderate potential damages, to take advantage of opportunities, or to cope with consequences (Smit and Pilifosova, 2001). As the name suggests, adaptive capacity is the capability of a system to adapt to impacts of climate change

Approach



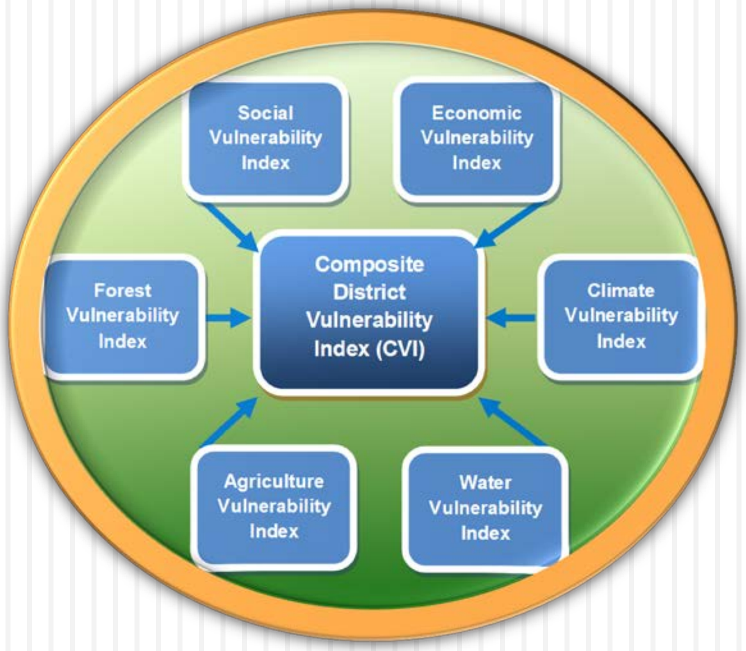
- The IPCC working definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2001) is used as measure to derive the district vulnerability to climate change
- The key components incorporated include socioeconomic and environmental indicators
- A range of indicators under socioeconomic and environmental variables as the drivers of vulnerability have been identified

Methodology

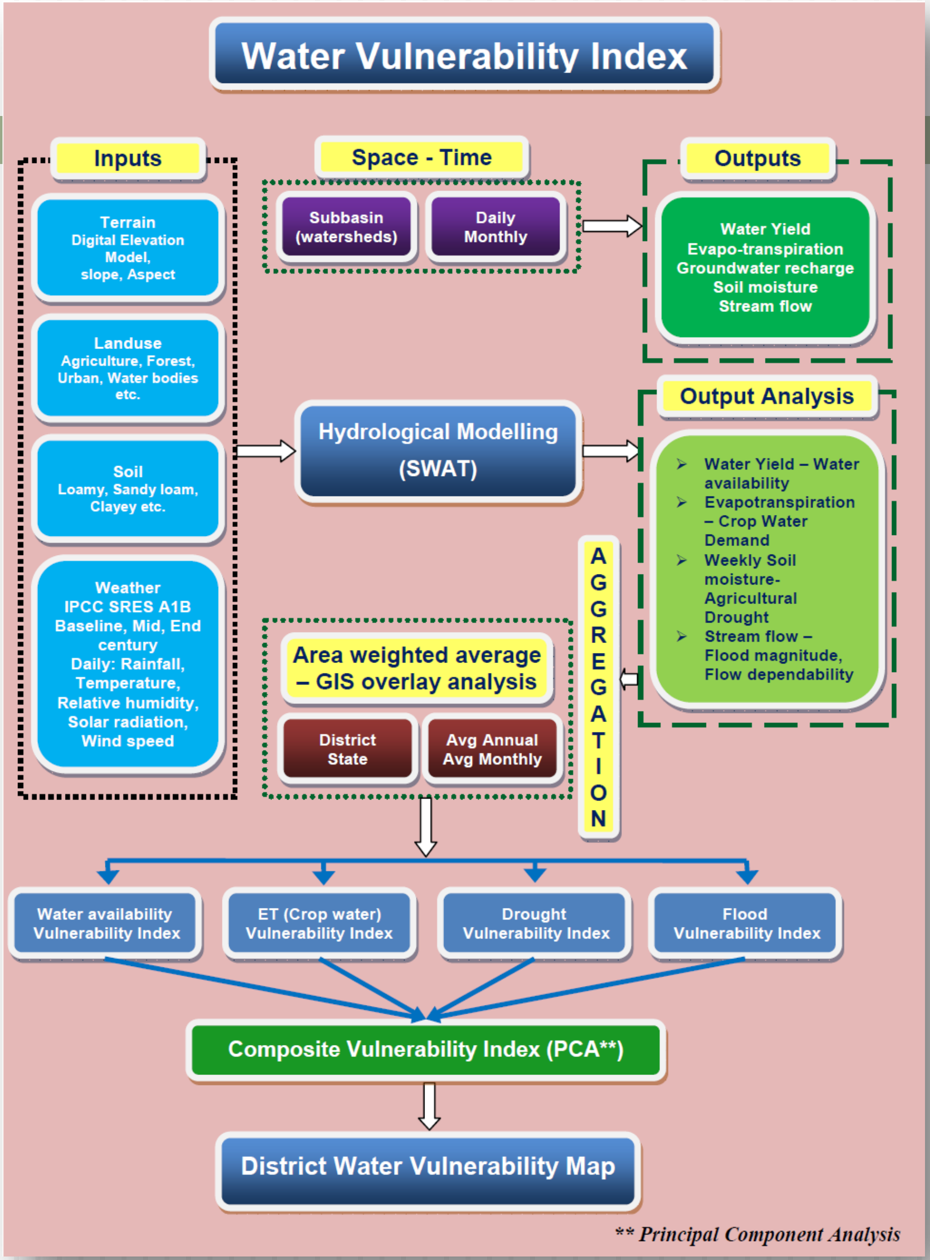
- Socio-economic, environmental, agriculture, water resource and forest indicators of vulnerability are employed and classified into adaptive capacity, sensitivity, and exposure
- Multivariate statistical method of Principal Component Analysis (PCA) is performed on the normalised values of the variables to obtain the component scores
- Component scores are used as weight for the variables before arriving at the vulnerability indices
- Districts are ranked based on the sectoral indices
- Cluster analysis was performed on the indices to group the districts according to their degree of vulnerability using Ward Method of Agglomeration
- Districts are grouped into low, moderate, high and very high categories of vulnerability.
- Outputs are mapped using GIS to visually enhance the spatial variability
- Index is developed for the current climatic conditions and for future projected climatic conditions, using PRECIS simulated weather parameters for IPCC SRES A1B

Drill down Vulnerability Index

- Drill down is performed sectorally along the same concept using the same indicators/variables
- drill down exercise is to help the decision makers to prioritise the development activities in any chosen district by identifying the sector which makes that district vulnerable
- Sectoral vulnerability index for:
  - Social (SVI) - 16 social indicators
  - Economic (ECVI) - 4 economic indicators
    - Combined as Composite Socio-economic (CSEVI)
  - Climate (CLVI) - 10 climate indicators
  - Water (WRVI) - 5 water indicators
  - Agriculture (AGVI) - 8 agriculture indicators
  - Forest (FOVI) - 15 forest indicators
    - Combined as Composite Environment (CENVI)



District Water Vulnerability Index



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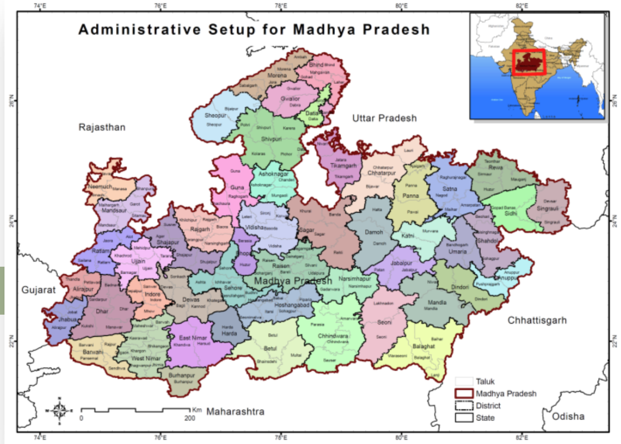
Madhya Pradesh at a glance



- 50 districts, 45903 villages
- Geographical Area:308,252 km^2 Area rank 2nd
- Population (2011): 73 million, Rank 6th, Density 240/ km^2
- 11 Agro-climatic zones
- subtropical climate
  - Hot dry summer extends from April to June followed by monsoon from July to September and winter months (November to February)
  - average rainfall is about 1,370 mm , decreases from east to west
- Major land use is agriculture (52%), Forest (25 %) and about 10 % wasteland
- Agriculture is the primary source of the economy
  - 74% of population living in rural area is dependent on agriculture
  - about 71 % of total working populations are engaged in agriculture
  - rice, maize, millet, wheat, pulses, sugarcane, ginger and oilseeds
- Narmada, Tapi, Ganga, Godavari and Mahi
- annual surface water availability is 8.1 million ham, estimated ground water resources 5 million ham
- developed irrigation potential of 2 million ham

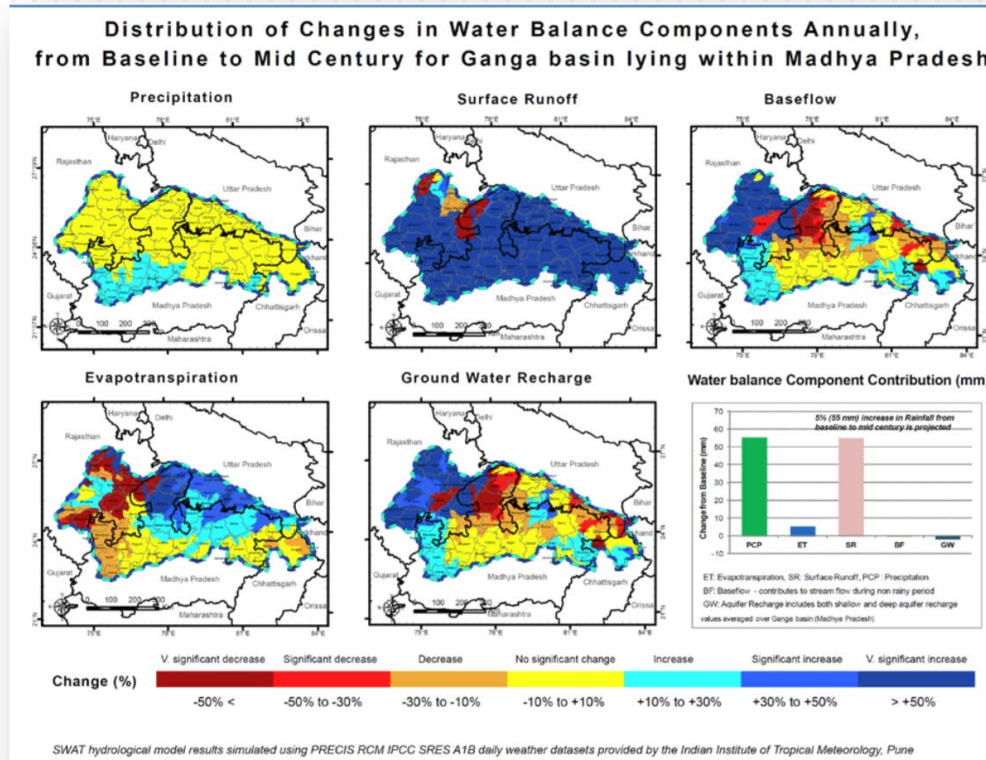
Climate Projections for Madhya Pradesh

- PRECIS simulations for future indicate an all-round warming over Madhya Pradesh associated with increasing greenhouse gas concentrations
  - mean minimum and maximum air temperature rise by mid century ranges from 2.3°C and 1.9°C respectively
  - change for the same towards end century is projected to be around 4.8°C and 3.9°C
  - increase in minimum temperature is projected to be higher than the maximum temperature
  - precipitation is projected to increase by about 11% and 30% towards mid century and end Century respectively
  - climate extremes show significant increasing trend for warm day/night and consecutive dry days and decreasing trend for cool day/night

Weather: IPCC SRES A1B, A2, B2, Hadley Centre U.K. at a resolution of 0.44° X 0.44° latitude by longitude grid points obtained from IITM, Pune

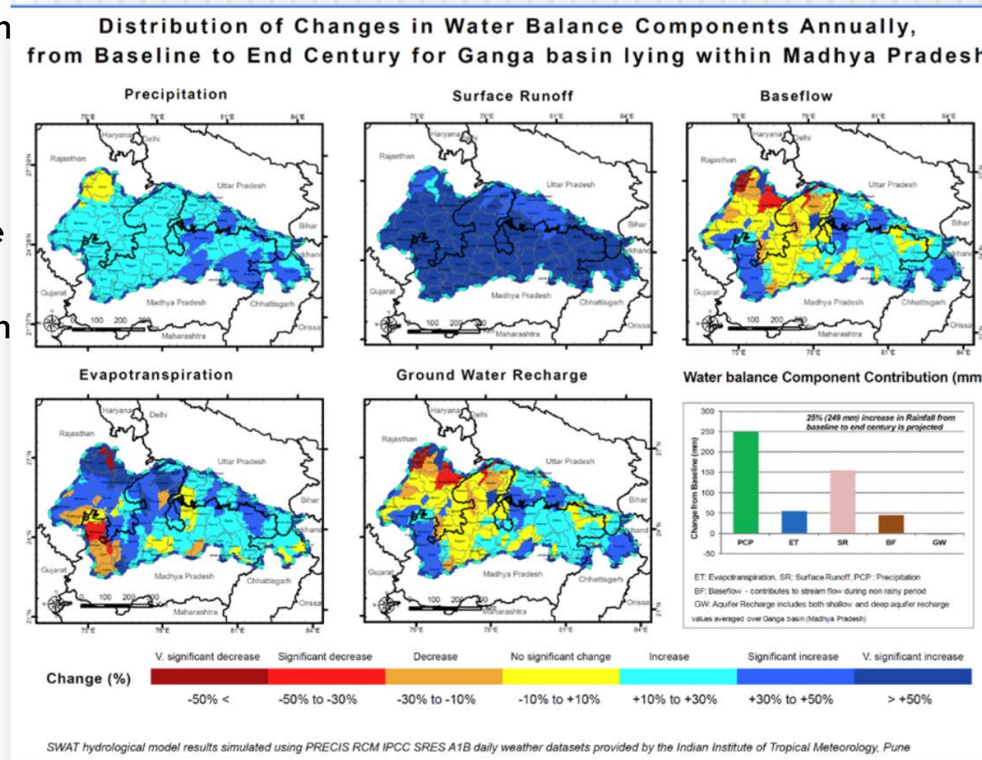
Impact of climate change on water resources of Madhya Pradesh

- Assessment made using SWAT hydrological model, from NATCOM Phase II study of MoEF
- For the Ganga basin lying within Madhya Pradesh
  - Mid century projections
    - increase in annual precipitation of about 5% resulting in increase in runoff, thus contributing to the stream flow and negligible contribution to the ground water recharge, Evapotranspiration is projected to increase
    - during the monsoon months (JJAS) increase in precipitation is projected to be about 8%, 86% of this is contributed to the stream flow and the rest is contributed to the ground water recharge, decrease in evapotranspiration by 1%
    - indication is that in parts of the basin surface runoff would be increased under the A1B mid century scenario
    - during the Rabi season (OND), precipitation is projected to decrease by 4% resulting in 100% decrease in ground water recharge. evapotranspiration is projected to increase and baseflow is projected to decrease

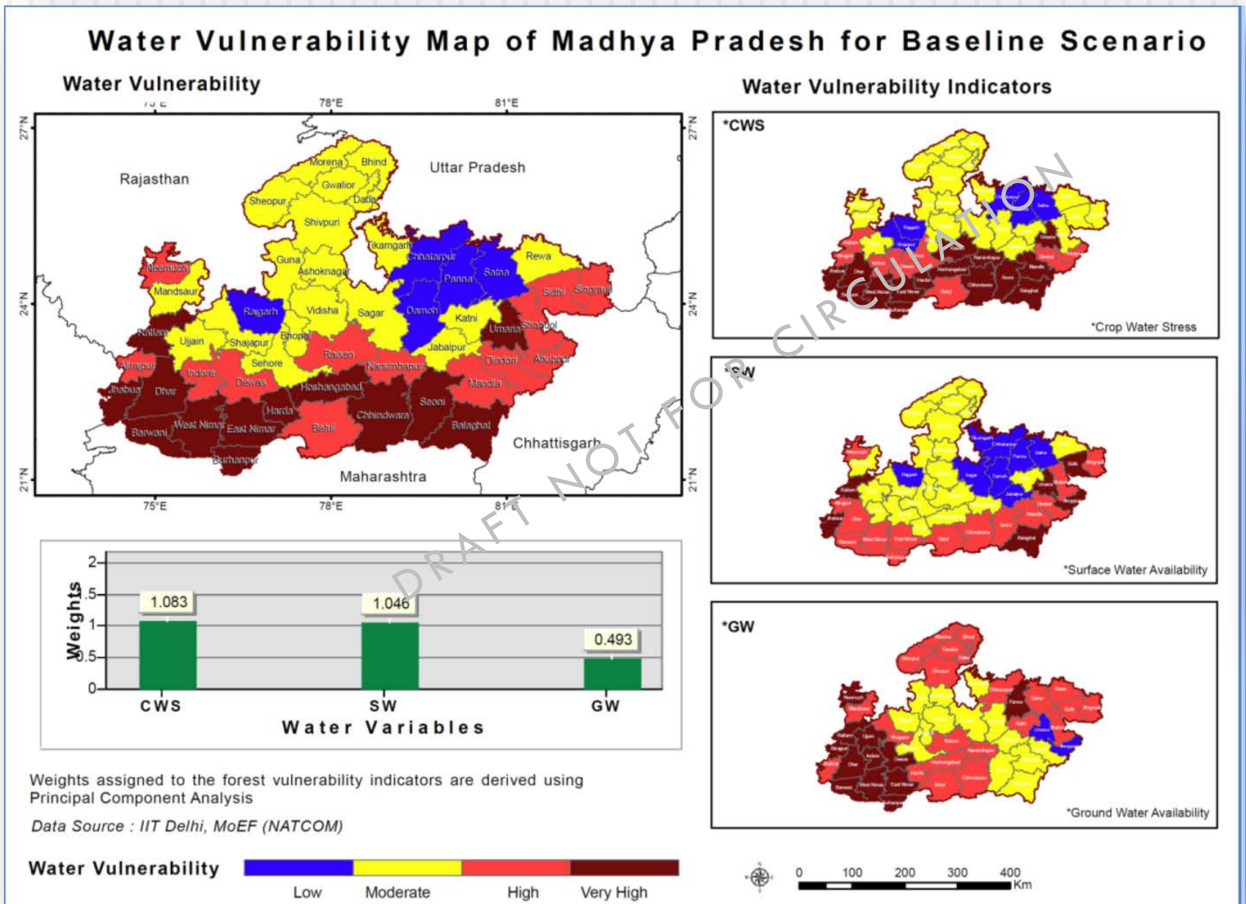


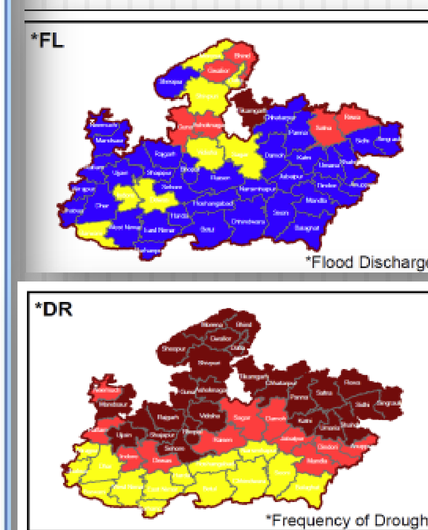
Impact contd …

- End century projections
  - increase in annual precipitation of about 24% by end century is projected, resulting in increase in runoff by almost double, and about 18 % returns to stream as baseflow, evapotranspiration is projected to increase by 22 %. Ground water recharge is projected to be around 18% of the increase in precipitation
  - during the monsoon months (JJAS) increase in precipitation is projected by about 26 %, most of this results in runoff (66%) and baseflow (14%) contributing to the stream flow, 23% of this increase in precipitation is contributed to the ground water recharge and Increase in evapotranspiration is projected by 11 %
  - during the Rabi season (OND), precipitation is projected to increase by 17% resulting in increase in baseflow contribution to the stream flow. Reduction in ground water recharge and substantial increase in evapotranspoitartion is projected



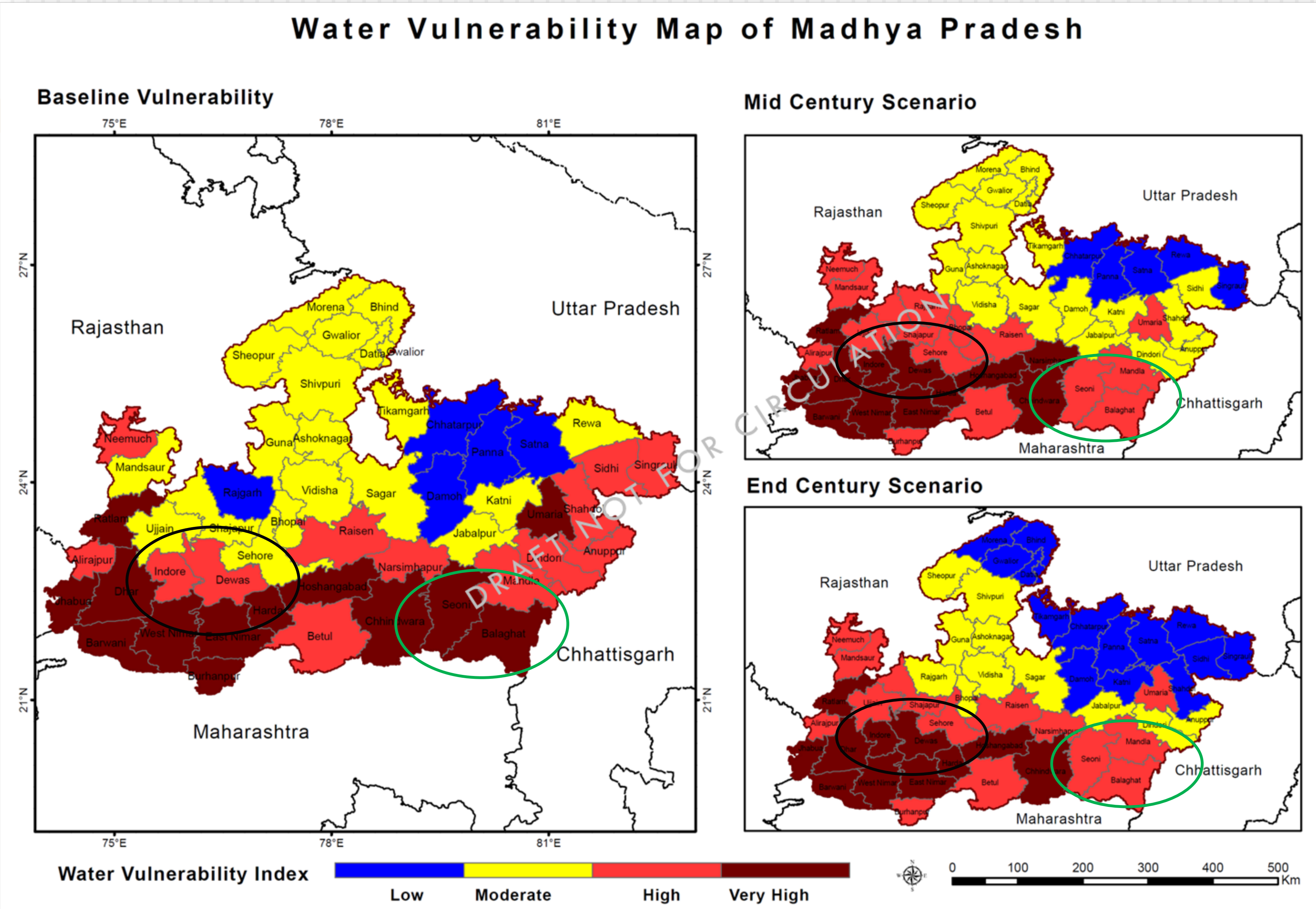
Water vulnerability Indicators (normalised value clustering) used at arriving Water Vulnerability Index/cluster for Baseline scenario



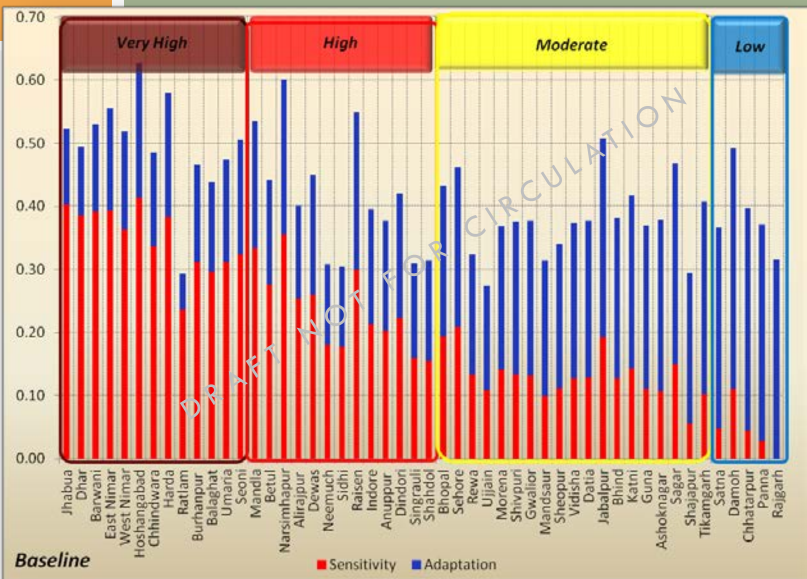


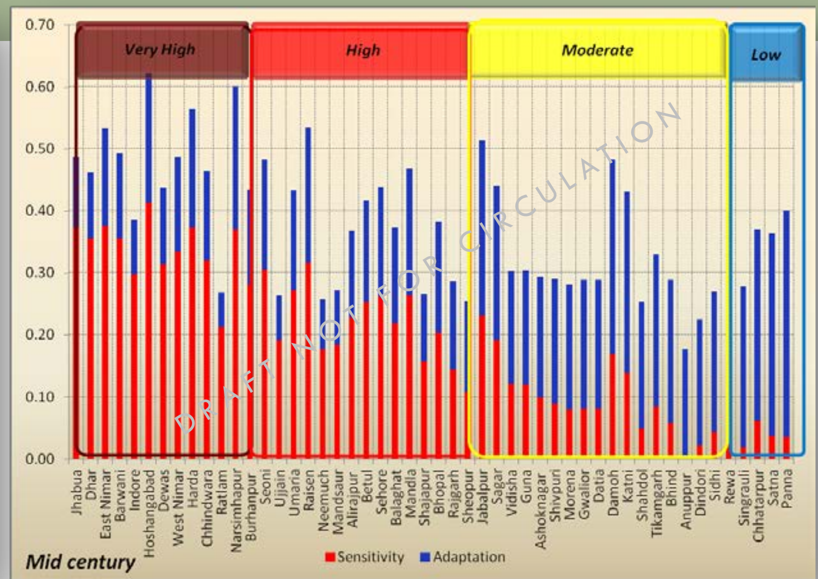
Higher crop water stress which makes Jhabua, Dhar, Barwani, most vulnerable when consider Water Resource Vulnerability Index (WRVI)

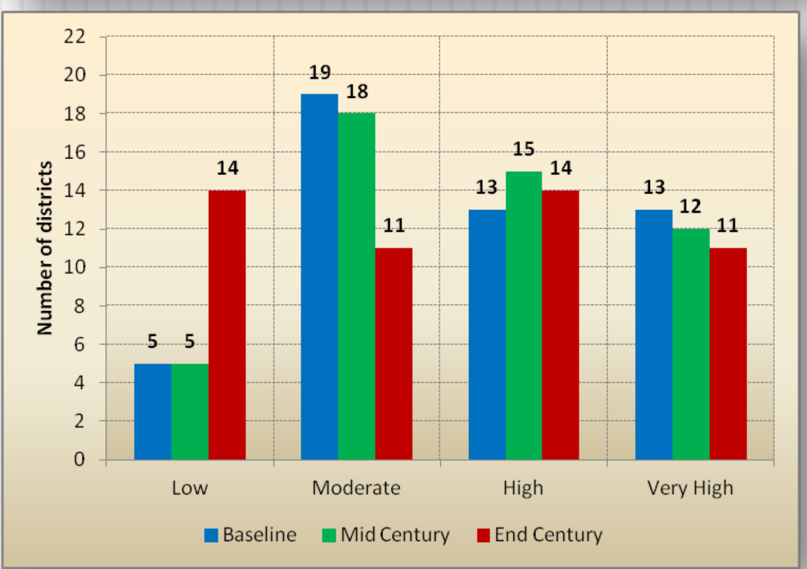
Water vulnerability Map

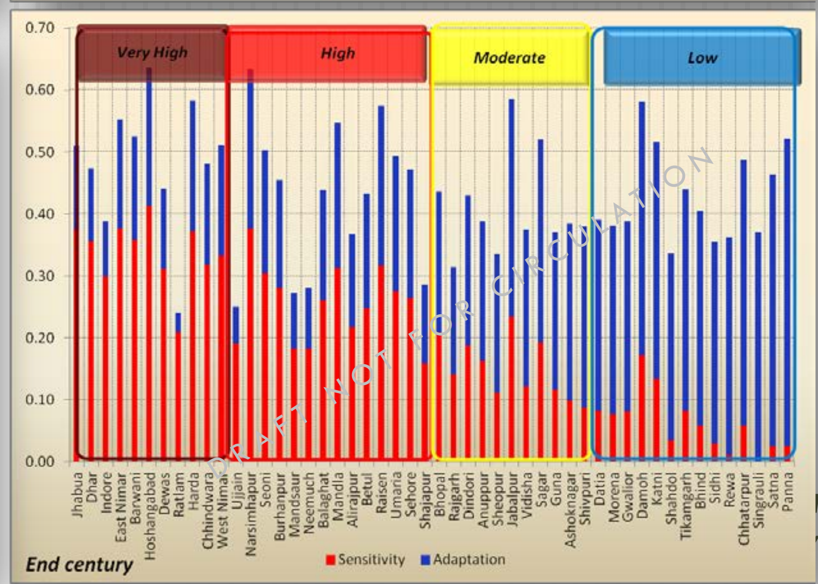


Index values for Sensitivity, exposure and adaptive capacity









- Less Vulnerable
  - Burhanpur, Seoni, Balaghat
  - Singrauli
- More Vulnerable
  - Indore and Dewas
  - Rajgarh

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District Water Vulnerability Index - Cluster, Ranks and Index values

WRVI [(Rank (Cluster, Index)]							
Districts	**Baseline**	**Mid Century**	**End Century**	**Districts**	**Baseline**	**Mid Century**	**End Century**
Alirajpur	34 (3, -0.106)	31 (3, -0.09)	31 (3, -0.07)	Mandla	37 (3, -0.133)	27 (3, -0.059)	32 (3, -0.08)
Anuppur	28 (3, -0.029)	8 (2, 0.177)	22 (2, 0.064)	Mandsaur	17 (2, 0.114)	32 (3, -0.096)	35 (
Ashoknagar	9 (2, 0.165)	18 (2, 0.095)	16 (2, 0.189)	Morena	20 (2, 0.088)	16 (2, 0.124)	12 (
Balaghat	40 (4, -0.154)	28 (3, -0.066)	33 (3, -0.084)	Narsimhapur	35 (3, -0.11)	39 (4, -0.141)	38 (3, -0.12)
Barwani	48 (4, -0.252)	47 (4, -0.218)	46 (4, -0.191)	Neemuch	32 (3, -0.054)	33 (3, -0.097)	33 (3, -0.084)
Betul	36 (3, -0.111)	30 (3, -0.089)	30 (3, -0.063)	Panna	2 (1, 0.313)	1 (1, 0.33)	1 (1, 0.47)
Bhind	12 (2, 0.128)	9 (2, 0.171)	7 (1, 0.287)	Raisen	30 (3, -0.05)	34 (3, -0.099)	29 (3, -0.06)
Bhopal	24 (2, 0.043)	25 (3, -0.025)	25 (2, 0.023)	Rajgarh	1 (1, 0.316)	24 (3, -0.001)	24 (2, 0.032)
Burhanpur	41 (4, -0.157)	38 (3, -0.129)	36 (3, -0.106)	Ratlam	42 (4, -0.18)	40 (4, -0.157)	43 (4, -0.179)
Chhatarpur	3 (1, 0.305)	3 (1, 0.249)	4 (1, 0.369)	Rewa	22 (2, 0.057)	5 (1, 0.232)	5 (1, 0.342)
Chhindwara	44 (4, -0.189)	41 (4, -0.176)	41 (4, -0.157)	Sagar	8 (2, 0.17)	21 (2, 0.057)	18 (2, 0.134)
Damoh	4 (1, 0.273)	13 (2, 0.146)	11 (1, 0.238)	Satna	5 (1, 0.272)	2 (1, 0.29)	2 (1, 0.413)
Datia	14 (2, 0.119)	14 (2, 0.128)	14 (1, 0.225)	Sehore	23 (2, 0.046)	29 (3, -0.085)	27 (3, -0.055)
Dewas	33 (3, -0.069)	44 (4, -0.19)	44 (4, -0.182)	Seoni	38 (4, -0.142)	37 (3, -0.128)	37 (3, -0.107)
Dhar	49 (4, -0.278)	49 (4, -0.25)	49 (4, -0.239)	Shahdol	25 (3, 0.002)	11 (2, 0.155)	9 (1, 0.267)
Dindori	27 (3, -0.026)	7 (2, 0.181)	23 (2, 0.055)	Shajapur	7 (2, 0.184)	26 (3, -0.048)	26 (3, -0.031)
East Nimar	47 (4, -0.234)	48 (4, -0.219)	47 (4, -0.201)	Sheopur	16 (2, 0.116)	23 (2, 0.039)	21 (2, 0.115)
Guna	10 (2, 0.149)	19 (2, 0.064)	17 (2, 0.137)	Shivpuri	19 (2, 0.108)	17 (2, 0.112)	15 (2, 0.204)
Gwalior	18 (2, 0.113)	15 (2, 0.127)	12 (1, 0.226)	Sidhi	31 (3, -0.051)	6 (2, 0.182)	6 (1, 0.296)
Harda	43 (4, -0.186)	42 (4, -0.181)	42 (4, -0.161)	Singrauli	26 (3, -0.009)	4 (1, 0.24)	3 (1, 0.37)
Hoshangabad	45 (4, -0.2)	45 (4, -0.204)	45 (4, -0.19)	Tikamgarh	6 (2, 0.204)	10 (2, 0.161)	8 (1, 0.275)
Indore	29 (3, -0.032)	46 (4, -0.211)	48 (4, -0.211)	Ujjain	21 (2, 0.058)	36 (3, -0.121)	39 (3, -0.132)
Jabalpur	13 (2, 0.121)	22 (2, 0.052)	20 (2, 0.117)	Umaria	39 (4, -0.15)	35 (3, -0.109)	28 (3, -0.058)
Jhabua	50 (4, -0.284)	50 (4, -0.259)	50 (4, -0.24)	Vidisha	14 (2, 0.119)	20 (2, 0.06)	19 (2, 0.13)
Katni	11 (2, 0.129)	12 (2, 0.154)	10 (1, 0.248)	West Nimar	46 (4, -0.21)	43 (4, -0.181)	40 (
Cluster Index values range (minimum, maximum)							
	Baseline	Mid Century	End Century		Baseline	Mid Century	End Century
Low	0.272 ,0.316	0.232 ,0.33	0.225 ,0.47	High	-0.133 ,0.002	-0.129 ,-0.001	-0.132 ,-0.031
Moderate	0.043 ,0.204	0.039 ,0.182	0.023 ,0.204	Very High	-0.284 ,-0.142	-0.259 ,-0.141	-0.24 ,-0.153

37 → 27

36 → 30

4 → 13

29 → 46

14 → 20

A rank value 1 indicates that the district is least vulnerable to climate change rank value 50 indicates that it is the most vulnerable

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Summary

- The analysis of the pattern of vulnerability of districts in Madhya Pradesh to climate change has shown that generally the north, east, south east and south western districts are more vulnerable to climate change
- Vulnerability can result from environmental, social or economic issues
  - this is explained by the greater exposure to drought and climate extremes as well as low levels of technology and socio-economic and infrastructure development
- a single policy for all of the districts would not be appropriate
  - judicious and different combinations of policies for different districts could help them in moving closer to achieving sustainability and climate resilience

Thank You