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Water Resources Vulnerability Assessment to Climate Change in a Semi-Arid Basin of South India

K. Shimola, M. Krishnaveni

Abstract**—**This paper examines vulnerability assessment of water resources in a semi-arid basin using the 4-step approach. The vulnerability assessment framework is developed to study the water resources vulnerability which includes the creation of GIS-based vulnerability maps. These maps represent the spatial variability of the vulnerability index. This paper introduces the 4-step approach to assess vulnerability that incorporates a new set of indicators. The approach is demonstrated using a framework composed of a precipitation data for (1975–2010) period, temperature data for (1965–2010) period, hydrological model outputs and the water resources GIS data base. The vulnerability assessment is a function of three components such as exposure, sensitivity and adaptive capacity. The current water resources vulnerability is assessed using GIS based spatio-temporal information. Rainfall Coefficient of Variation, monsoon onset and end date, rainy days, seasonality indices, temperature are selected for the criterion 'exposure'. Water yield, ground water recharge, evapotranspiration (ET) are selected for the criterion 'sensitivity'. Type of irrigation and storage structures are selected for the criterion 'Adaptive capacity'. These indicators were mapped and integrated in GIS environment using overlay analysis. The five sub-basins, namely Arjunanadhi, Kousiganadhi, Sindapalli-Uppodai and Vallampatti Odai, fall under medium vulnerability profile, which indicates that the basin is under moderate stress of water resources. The paper also explores prioritization of sub-basinwise adaptation strategies to climate change based on the vulnerability indices.

Keywords**—**Adaptive capacity, exposure, overlay analysis, sensitivity, vulnerability.

I. INTRODUCTION

ARID and semi-arid region water resource systems are aggravated by the impacts of climate change and are considered to be vulnerable. Vulnerability can be defined as the degree to which a component in a system is likely to experience damage due to exposure to unusual change or stress [7]. Vulnerability assessment is a process of evaluating, quantifying and characterizing the exposure, sensitivity and adaptive capacity of watersheds to climate change [2]. Exposure is defined as the degree of climate stress exposed upon a component in a system. It may be denoted either by long-term changes in climate variables or by changes in the magnitude and frequency of extreme events [2]. The two main elements considered in the exposure are things that can be affected by climate change and the changes in climate itself; for example, the resources and changes in climate variables. Sensitivity is the biophysical effect of climate change. Sensitivity is the degree to which an element will be affected by or is reactive to climate inducement [5]; for example, changes in crop ET, water yield, etc. Adaptive capacity is the ability of a system to adapt to climate change impacts. Adaptive capacity refers to the ability of a system to adapt to climate change including climate variability and extremes, or to cope with consequences [5]; for example, a water resources system.

The vulnerability assessment methodology incorporates different physical, social, economic and environmental indicators. The IPCC framework is the most commonly used framework for vulnerability mapping [8]. The vulnerability can be quantified by a 4-step approach [4]. In this approach, spatial vulnerability indices are developed based on spatial data layers representing the vulnerability indicators. Thus, the vulnerability maps can be produced by overlaying the spatial data layers in GIS environment. Identifying the extent and level of vulnerabilities plays an important role in developing the coping capacities to climate change. Assessment of vulnerability to climate change also helps to facilitate the decision-making process and to select appropriate adaptation strategies. The main objective of this study is to identify the vulnerable areas by water resources vulnerability mapping using GIS.

II. STUDY AREA

Vaippar basin is one of the semi-arid basins of Tamil Nadu in India bound by Western Ghats, a mountainous region in the western part, Bay of Bengal in the east, Thamirabarani basin in the south and Gundar basin in the north. It is located in the southern part of Tamil Nadu, situated between latitudes 8°59'N to 9° 49'N and longitudes 77° 15' E to 78° 23' E with drainage area of 5423 km^2. The basin is dominated by cyclonic rainfall, which occurs during northeast monsoon (October–December) and convectional rain also occurs during summer season (March–May); this shows strong seasonality. The basin has a tropical monsoon climate with hot summer and mild winter, which agro-climatically, falls under semi-arid regions. The climate of the basin is dominated by an altitude ranging from 1877 mean sea level in the west to the east. The seasons are classified into winter (January–February), summer (March–May), southwest (June–September) and northeast (October–December) monsoons. Most of the agricultural activities are centered on September to December monsoon seasons. The basin gets its maximum rainfall during northeast monsoon whereas the southwest monsoon also produces a reasonable amount of rainfall, which is quite useful for the rainfed agriculture although the basin falls in the rain shadow area of the Western Ghats. The temperature variation is from

Shimola Kannan (Assoc. Prof. Dr.) is with the Malla Reddy Engineering College, India (e-mail: shimola_jeslin@yahoo.com).

20°C to 30°C in winter and 30°C to 40°C in summer. Irregularities in rainfall, intensified water stress, existence of droughts, limited water availability, over exploitation of ground water, low natural replenishment by rainwater harvesting structures make the basin vulnerable to climate change. Fig. 1 shows the index map of the Vaippar basin.

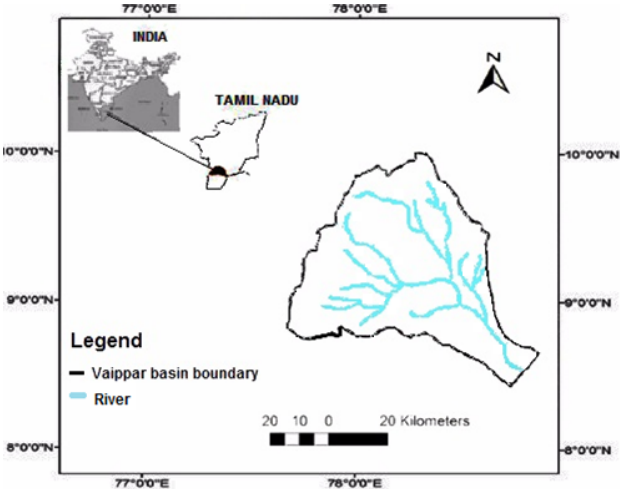

Fig. 1 Index map of the Vaippar basin

III. Methodology

Vulnerability is assessed by three criteria such as exposure, sensitivity and adaptive capacity [2]. Vulnerability indicators are selected based on literature review, major study area characteristics, farmers' perception and consultations with the experts. A new set of indicators precipitation data for (1975–2010) period, temperature data for (1965–2010) period, hydrological model outputs and water resources GIS data base are considered in the vulnerability assessment. Climate change indicators such as seasonality indices, onset and end date of monsoon and rainy days were calculated using the precipitation data. Totally, five indicators (rainfall CV, monsoon onset and end date, rainy days, seasonality indices, temperature) fall into the criterion 'exposure', three indicators (water yield, ground water recharge, ET) fall into the criterion 'sensitivity' and two belong to adaptive capacity (type of irrigation, storage structures).

The selected indicators particularly address the dimension of vulnerability, importance of the indicators and adaptive capacity of water resources system. In order to quantify the vulnerability, a 4-step approach [1] was applied. The 4-step approach of vulnerability assessment is a function of three criteria namely exposure, sensitivity and adaptive capacity which are mapped spatially and shown in Fig. 2. In the fourth step, equal weightage is assigned to the three criteria, and they are overlaid to get the vulnerability profile of the basin in ArcGIS environment.

The vulnerable zones were identified by spatial weighted sum overlay analysis using the spatial rasterised maps. According to [3], the selection and scoring of categorical classes were performed with the help of expert knowledge, considering data availability and coverage. Five classes were assigned for each indicator and the scores varied from one impact to another according to the importance of climate change and presented in Table I. It is assumed that all the indicators attain the same weight within each criterion. Accordingly, the same weight equal to 1 is assigned by default, for all the indicators under each criterion. In order to clearly visualize the vulnerable areas in the vulnerability maps, the vulnerability values ranging from 1 to 10 are categorized into five subclasses (i.e. very high, high, medium, low and very low).

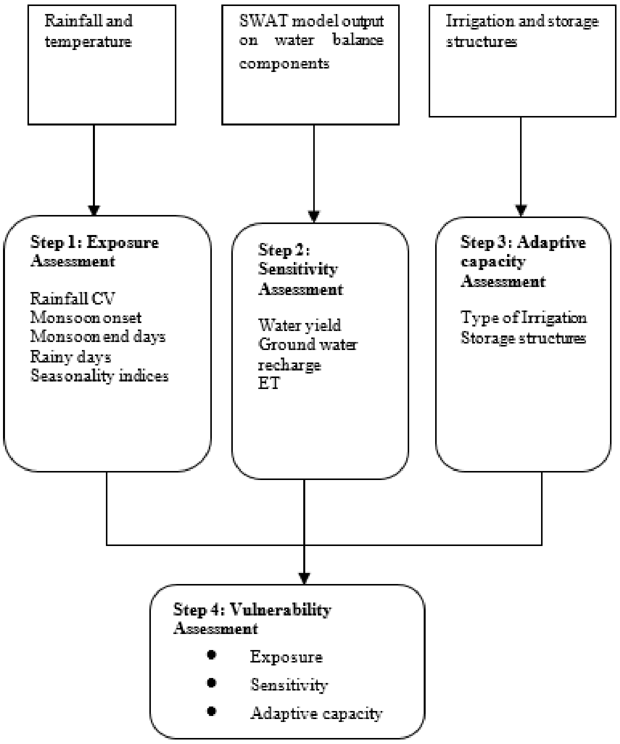

Fig. 2 Vulnerability assessment: A 4-step approach

IV. Results and Discussion

A. Indicators of Water Resources Vulnerability

1. Rainfall CV

The coefficient of variation (CV) is a statistical measure of rainfall which tells how the individual rainfall values vary from the mean value. A smaller value of CV is the indicator of smaller spatial variability and vice versa. In this study, annual rainfall variability was analysed for 10 raingauge stations of the Vaippar basin using rainfall CV. This is a more crucial statistic in agricultural sector where suitable adaptation strategies have been adopted in very dry areas with higher inter-annual variability. The southwest portion of the basin is subjected to high rainfall variability with CV values greater than 0.32. In the central portion of the basin, the CV values are found as 0.26 and 0.27, which confirms that this portion has relatively low rainfall variability. Conversely, the eastern portion experiences relatively high variability with the CV values ranging from 0.29 to 0.32. Fig. 3 (a) also illustrates a westward increase from the central portion. Relatively high rainfall variability is confirmed by its relatively high CV> 0.32. Overall, the relative rainfall variability is proved to be high (CV > 0.26) throughout the basin.

TABLE I
CRITERIA USED IN THE WATER RESOURCES VULNERABILITY ASSESSMENT

CRITERIA	INDICATORS	CLASS	SCORE
Exposure	Rainfall CV	0.26-0.27	1 (Least important class)
		0.27-0.29	2 (Strongly less important class)
		0.29-0.30	3 (Rather less important class)
		0.30-0.32	4 (Weakly less important class)
		0.32-0.34	5 (Most important class)
	Monsoon onset	279-280	1
		281-282	2
		282-283	3
		283-284	4
		284-285	5
	End date	345-346	5
		347-348	4
		349-350	3
		350-351	2
		352-353	1
	Rainy days	27-33	5
		34-39	4
		40-44	3
		45-48	2
		49-52	1
	Seasonality indices	0.92-0.96	1
		0.97-0.99	2
		1-1.02	3
		1.03-1.07	4
		1.08-1.12	5
	Temperature	26-27	1
		27-28	2
		28-29	3
		29-30	4
		30-31	5
Sensitivity	Water yield	73-136	5
		136-215	4
		215-287	3
		287-360	2
		360-449	1
	Groundwater recharge	39-58	5
		58-74	4
		74-87	3
		87-99	2
		99-116	1
	Evapotranspiration (ET)	335-393	5
		393-466	4
		466-512	3
		512-550	2
		550-600	1
Adaptive capacity	Type of Irrigation	Forest	1
		Settlement	5
		Intensively irrigated	2
		Sparsely irrigated	3
		Barren land	4
	Storage structures	Reservoir	3
		Tank	4
		River	5

2. Monsoon Onset

The monsoon onset is a crucial event and it marks the beginning of the rainy season for the country. For the present study, the beginning and ending dates of the northeast monsoon were analysed as the basin gets its maximum rainfall during this season only. The date of the year (DOY) marks the beginning of the monsoon rains as an important event particularly for agricultural planning. Climate change could influence monsoon dynamics, amount of precipitation and a delay in the start of the monsoon season. The average start dates of the northeast monsoon of each raingauge station over the 1975–2010 periods are plotted for the basin as shown in Fig. 3 (b). According to the spatial analysis of monsoon onset, relative to DOY 274 (October 1), the onset date in day of year ranged from 279 (October 6) to 285 (October 12). The basin indicated a clear delayed monsoonal onset with a DOY> 284. However, the monsoon onset starts early in the eastern portion of the basin. The time of delay moves from western to eastern portion of the basin and it is represented by DOY. Thus the delayed monsoon onsets substantially affect the water resources availability and initiation of cultivation practices.

3. Monsoon End Date

To identify the geographic areas where climate change may be relatively large the cessation date of rainfall is a more useful indicator. Later monsoon onsets significantly impacted rice crops in 2009. Many seedlings were lost due to late monsoon onset, and crop yield also affected because of limited duration for plant growth [6]. According to spatial analysis of monsoon end date, the average end date of the northeast monsoon rainfall ranged from DOY 345 (December 10) to DOY 363 (December 28). The analysis of end date of monsoon over the basin showed an early end date in the northern portion of the basin with the DOY>345 during the time period 1975–2010. Fig. 3 (c) illustrates that the end date of the monsoon moves from north to south, and delayed end dates are noticed in the southern parts of the basin. The delayed end dates must be taken into account for planning of proper adaptation strategies. This will enable farmers to better utilise the rains in this period.

4. Seasonality Indices

Generally, rainfall patterns have high intra-seasonal variability and can beexamined by calculating seasonality index of rainfall. The seasonality of rainfall depends on the monthly rainfall variability throughout the year [10]. Studying the changing pattern of rainfall and its variability is useful for agricultural planning. According to spatial analysis of seasonality indices, it varies from 0.92 to 1.12 as shown in Fig. 3 (d). Thus, four rainfall regimes prevailed in the region namely seasonal, markedly seasonal with a long dry season, most rainfall in less than three months and extreme seasonality with almost all rainfall in 1–2 months. The lower seasonality index (SI) value which indicates better distribution of monthly rainfall is for Kousiganadhi sub-basin in the northern portion, which is purely seasonal. The lower seasonality index value which indicates extreme seasonality with almost all rainfall in 1–2 months was observed in the eastern portion of the basin. The SI value varies from 0.9 to1.07 for most rainguage stations, thus confirming that the basin is dominated with markedly seasonal conditions with a long drier season and most rain in three months.

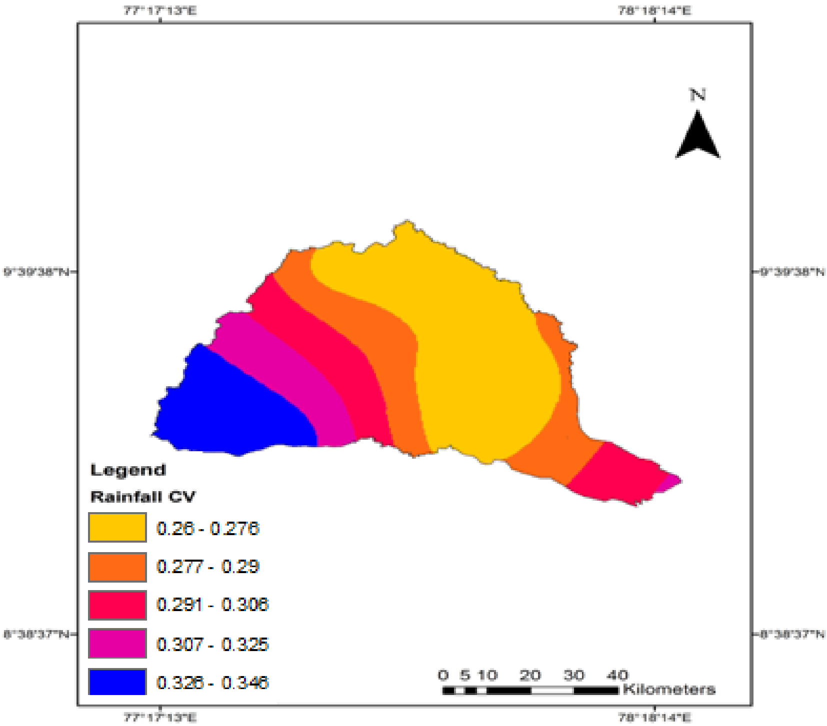

Fig. 3 (a) Spatial mapping of Rainfall CV

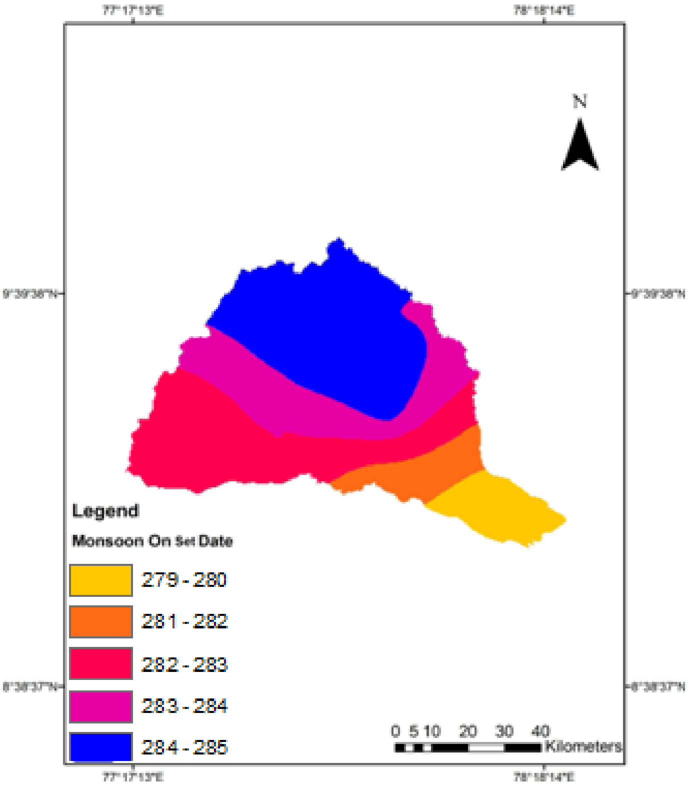

Fig. 3 (b) Spatial mapping of Monsoon onset

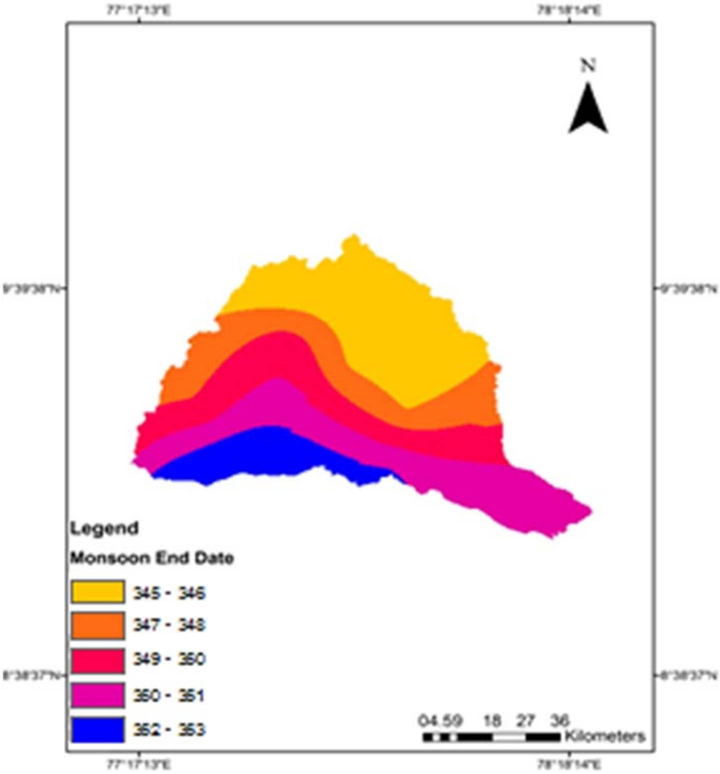

Fig. 3 (c) Spatial mapping of Monsoon End Date

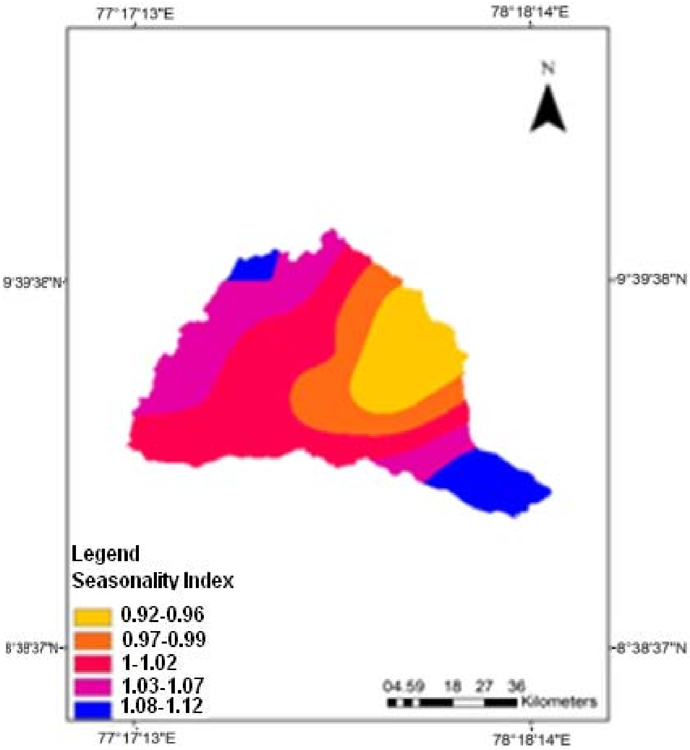

Fig. 3 (d) Spatial mapping of Seasonality Index

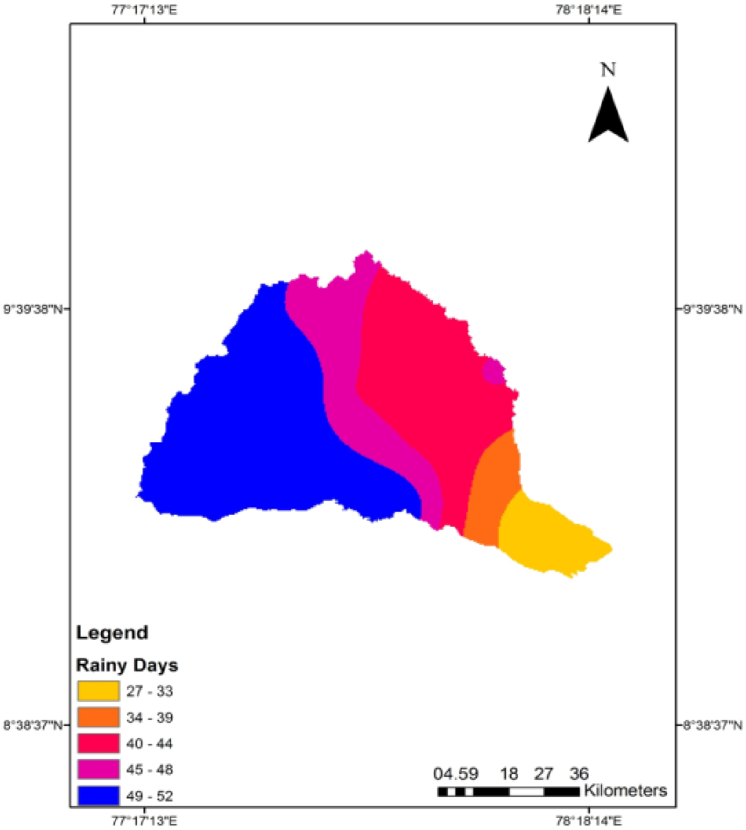

Fig. 3 (e) Spatial mapping of Rainy Days

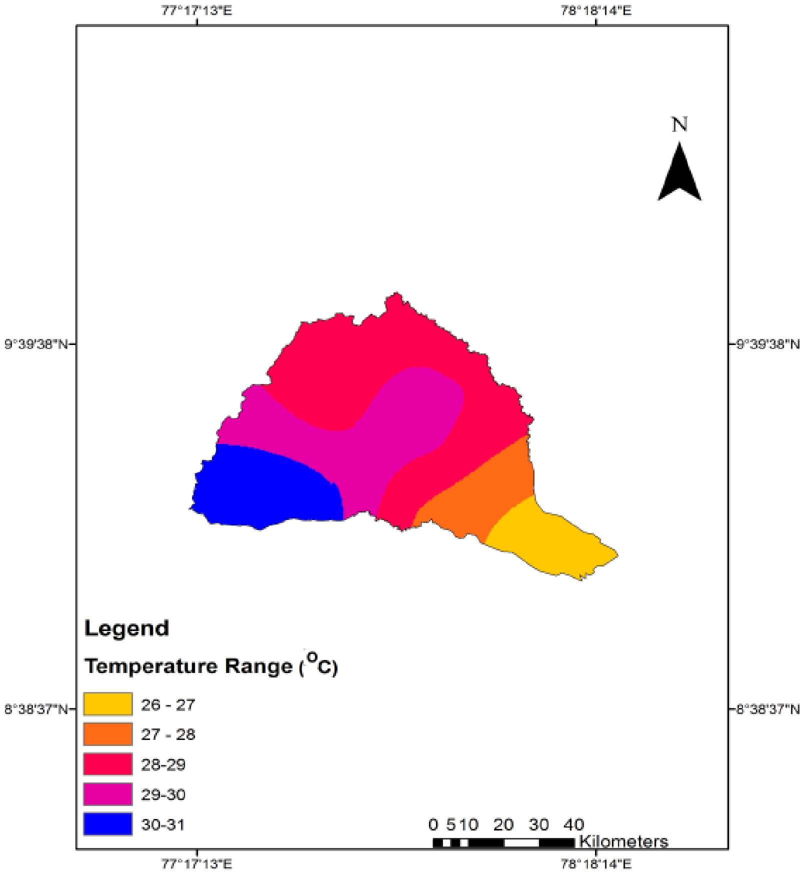

Fig. 3 (f) Spatial mapping of Temperature

5. Rainy Days

The climatic variability is also expressed by the number of rainy days and length of drought period, which result in year-to-year and area-to-area variability of crop production. The number of rainy days and their associated seasonal patterns are critical components of agricultural production. According to spatial analysis of rainy days, the average rainy days vary from 27 days to 52 days. The total number of rainy days is shrinking from west to east, thus revealing the eastern portion of the basin will become drier with a prolonged dry season. The central portion of the basin shows that the rainy days vary from 34 days to 48 days, respectively. The central portion shows larger variations in rainy days. Thus, it has been shown in Fig. 3 (e) that the rainy days resulting from climate change bring about decreased water availability in the eastern portion of the basin.

6. Temperature

Temperature is one of the fundamental physical parameters in the climate as it determines the environmental factors of the particular region such as water availability. The rain shadow region which is the western portion of the basin where the river originates experiences a colder temperature compared to the other parts of the basin. According to spatial analysis of temperature, the average temperature ranges vary from 26°C to 31°C, as shown in Fig. 3 (f). The temperature as recorded by the weather station has shown an increasing trend over the past several decades. Temperature gradually increases from the central portion of the basin and reaches the maximum towards the eastern portion. Rising temperature associated with climate change in the eastern portion will likely result in the emergence of land degradation problems. These changes in the temperature have resulted in the overall decrease in the quantity of available water resulting in the low production of crops.

7. Water Yield

Water yield depends upon rainfall and potential evaporation of a region, which together provide congenial weather for active crop growth. According to spatial analysis of water yield, the average annual water yield ranges vary from 73mm to 449mm, as shown in Fig. 4 (a). Average annual water yield decreases towards the eastern portion with an increase in temperature and a decrease in precipitation. Concurrently, the western portion of the basin experiences an average annual water yield increased with an increase in precipitation. Water yields generally decrease from western to eastern portions of the basin, and thus confirming that the eastern region is more vulnerable to climate change.

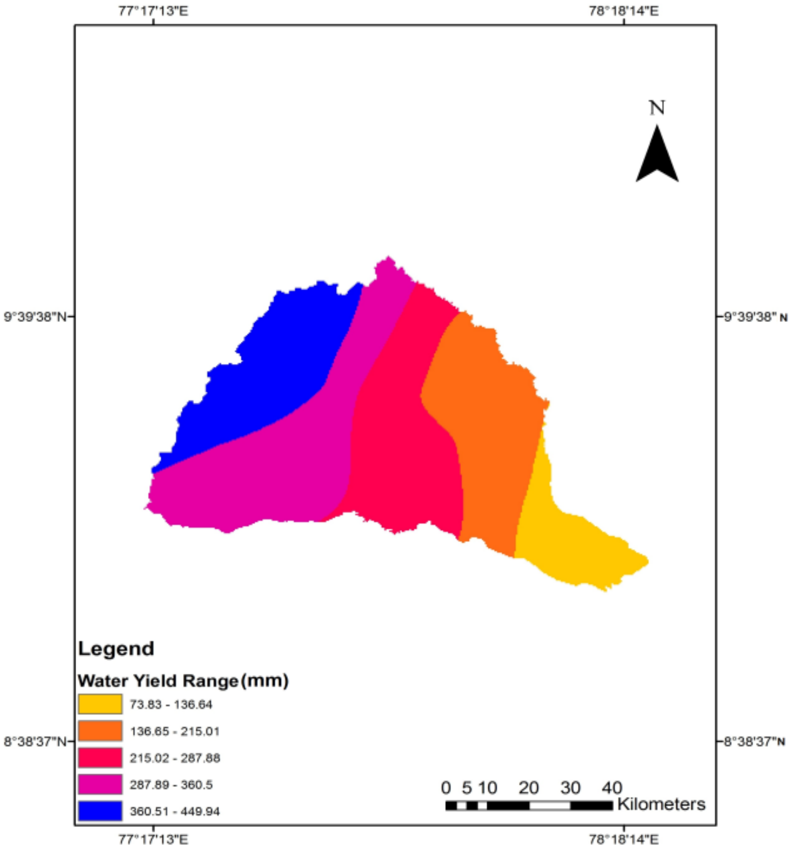

Fig. 4 (a) Spatial mapping of Water yield

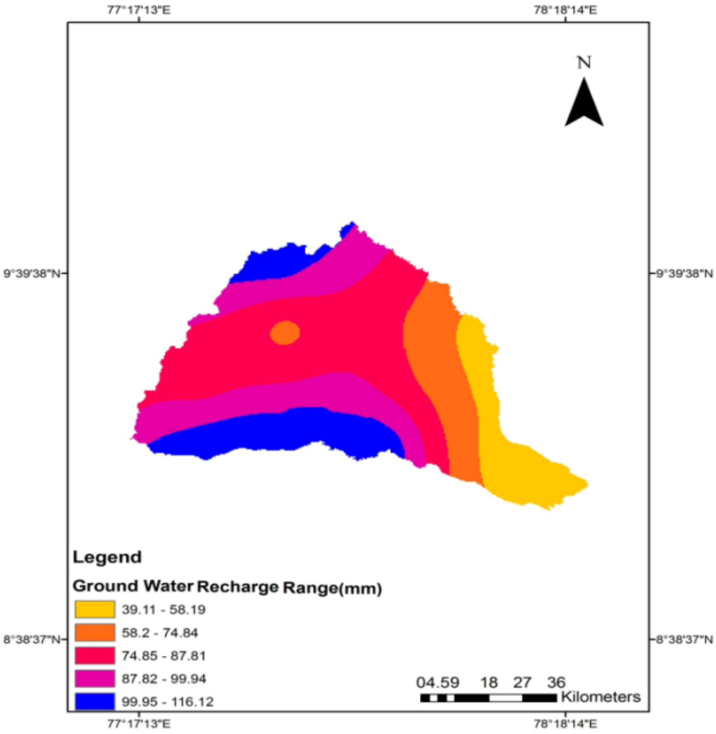

Fig. 4 (b)Spatial mapping of Ground water recharge

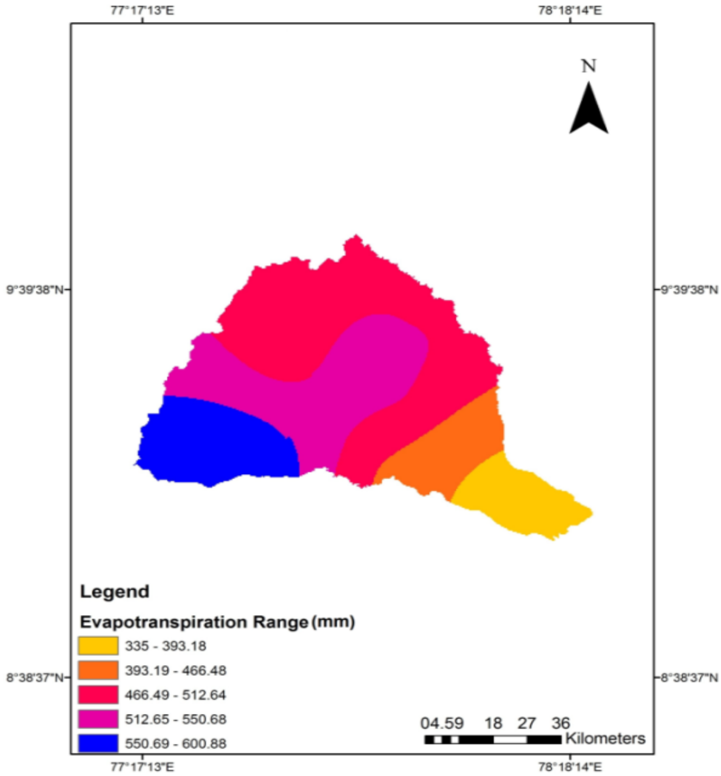

Fig. 4 (c)Spatial mapping of Evapotranspiration

8. Ground Water Recharge

The warming trend and decreasing rainfall in the eastern portion of the basin together with the erratic pattern of rainfall produce a minimal recharge of groundwater resources. Excessive use of groundwater irrigation in particular regions such as Sankarankovil, Kovilpatti Vilathikulam, Rajapalayam and Sedapatti has led to groundwater depletion and is likely to affect crop productivity. According to spatial projections in ground water recharge, it ranges vary from 39mm to 116mm, as shown in Fig. 4 (b). Ground water recharge generally increased in the southern portions and northwest parts of the basin but decreased in the eastern region. Moderate ground water recharge amounts were observed in the central portion of the basin. Thus, the eastern portion experienced the greatest changes in ground water recharge and agricultural production.

9. Evapotranspiration

Evapotranspiration will be increased significantly with this expected temperature rise. According to spatial analysis of temperature, the average annual ground water recharge range varies from 335mm to 600mm, as shown in Fig. 4 (c). An increased evapotranspiration with an increased rainfall was observed in the northwest portion of the basin. The northern portion is experiencing moderate evapotranspiration with values ranging from 466mm to 512mm. In spite of increasing temperatures, the decrease in evapotranspiration in the eastern portion indicates an increase in humidity levels, decrease in available soil moisture, wind speed, change in soil fertility and type of vegetation during the last three decades.

10. Type of Irrigation

Adaptive capacity describes the ability of a system to adapt to changes in climate. The effects of climate change in the irrigation type of this basin are expected to be significant, and likely to have a detrimental effect on the agricultural sector, as shown in Fig. 5 (a). Adaptive capacity is very high for forest areas situated in the Western Ghats. Forest regions situated in the Western Ghats are naturally adapted to withstand extreme and unpredictable climate conditions. Adaptive capacity is high for intensively irrigated areas. Adaptive capacity is medium for sparsely irrigated areas. The lack of management practices are an additional factor strongly limiting the technical adaptation potentials. Adaptive capacity is low for barren land, whereas it is very low for settlements. These barren lands and settlement areas, which are densely populated, are devoid of agricultural practices. Adaptive capacity of settlements is more strongly affected by socio-economic constraints than other irrigation types. The climate change vulnerability of a region can be reduced by both reduction in the exposure to climate stress and an increase in adaptive capacity.

11. Storage Structures

It is defined as the function of infrastructure factors and in this study it is represented by storage structures. The water resources storage structures such as river, tank and reservoir will have a limited adaptive capacity to climate change in a semi-arid region like the Vaippar basin. The ability to respond to increasing temperatures and changes in precipitation is medium for reservoirs. The measurement of adaptive capacity is difficult and these range from medium to very low while responding to climate change. This semi-arid basin storage structures are major constraint to adaptive capacity and they increase the vulnerability of the water resources system. Spatial mapping of indicators of adaptive capacity of storage structures is as shown in Fig. 5 (b).

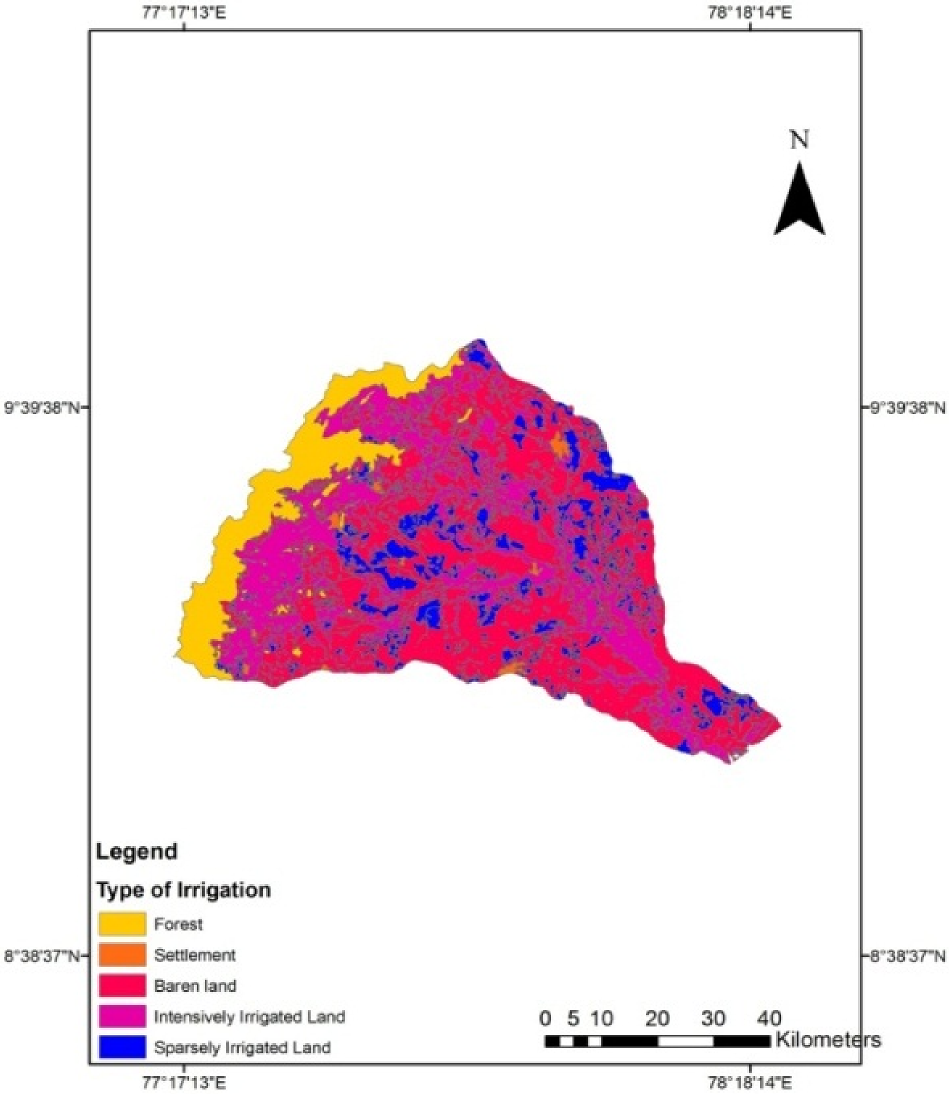

Fig. 5 (a) Spatial mapping of Type of irrigation

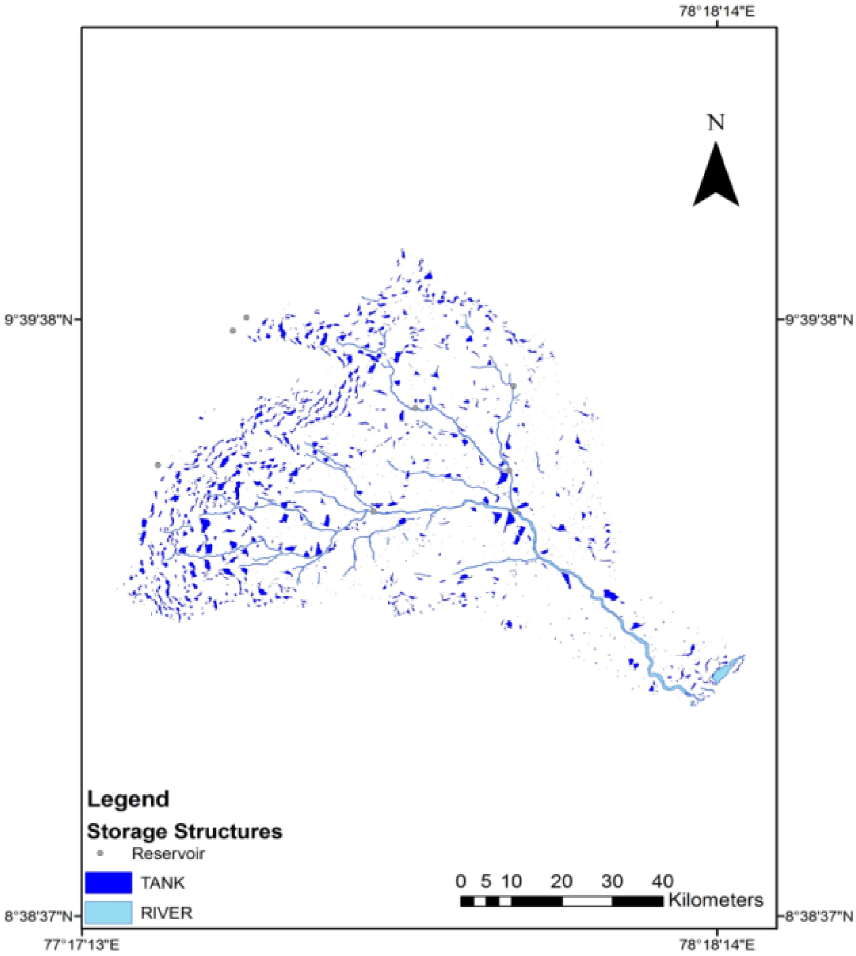

Fig. 5 (b) Spatial mapping of Storage structures

B. Water Resources Vulnerability Mapping

The Vaippar basin is vulnerable to climate change due to the sensitivity of the water resources to climate and its low adaptive capacity. To identify the vulnerable areas to current climate change, sub-basins are divided based on the degree of vulnerability. According to [9], the vulnerability index is classified as very high (0.8–1.0), high (0.6–0.8), moderate (0.4–0.6), low (0.2–0.4) and very low (0.0–0.2). To give the final VI value in a range from 0 to 1.0, the following rules are applied in assigning the weights:

- The total of weights given to each indicator should equal 1.0
- The total of weights given to all components should equal 1.0

From Table II, it is shown that five sub-basins namely Arjunanadhi, Kousiganadhi, Sindapalli-Uppodai and Vallampatti Odai fall under medium vulnerability profile. These sub-basins suffer from environmental and social problems like rapid industrialisation, population concentration, water quality and ground water exploitation from industries. The Lower Vaippar sub-basin remains the most vulnerable sub-basin and is characterised by least water yield with decreased rainfall amounts, frequent drought events and land degradation problems. Although sub-basins like Deviar, Nichabanadhi, Sevalaperiyar and Kayalkudiyar suffer from some environmental and social problems, their relatively high levels of water yields, ground water recharge, seasonal rainfall with more number of rainy days and more tank structures make them less vulnerable. Sub-basins like Upper Vaippar, Uppathurar and Senkottaiyar have high vulnerability to climate change relative to other sub-basins. The major reasons for the high level of vulnerability in this area are less water yield and rainfall, less tank structures, extensive barren land, which impose limits on adaptive capacity. Fig. 6 shows the water resources vulnerability map with regared to climate changes at the Vaippar basin.

Conversely, the Kalingalar and Nagariar sub-basins are assessed as less vulnerable due to hill streams from the eastern slope of the Western Ghats, their forest cover, intensively irrigated areas, high water yield and rainfall events and relatively low temperature. These sub-basins are also in a better position to withstand climate change than others. Thus, the vulnerability map derived based on the integration of the combined exposure, sensitivity and adaptive capacity helps in identifying the geographical areas that need immediate adaptation measures to the current climate vulnerability.

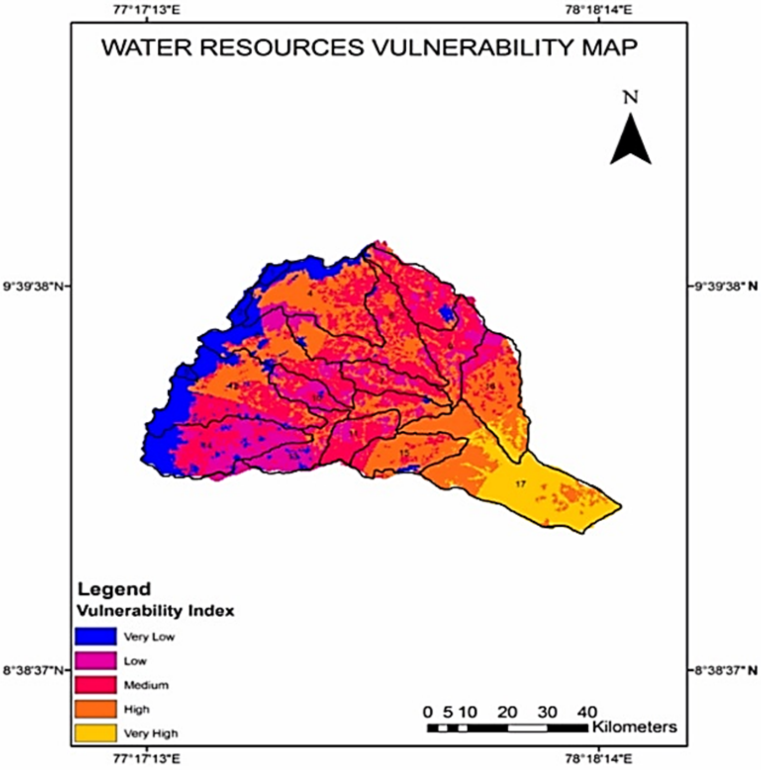

Fig. 6 Water resources vulnerability map in context of climate change

TABLE II
SUB-BASIN WISE VULNERABILITY INDEX

VULNERABILITY INDEX	SUB-BASINS
Very High	Lower Vaippar
High	Upper Vaippar, Uppathurar, Senkottaiyar
Medium	Deviar, Arjunanadhi, Kousiganadhi, Sindapalli-Uppodai, Vallampatti Odai
Medium to low	Nichabanadhi
Low	Kalingalar, Nagariar
Low to very low	Sevalaperiyar, Kayalkudiyar

The vulnerability profile of the basin is divided into four types according to the potential impact (combination of exposure and sensitivity) and adaptive capacity. They are as follows:

Type I. High Impact, High Adaptive Capacity: Effective adaptive capacity to reduce high impact is needed. Uppathurar and Senkottaiyar sub-basins fall under this class. Hence, infrastructural development, improved farming system, irrigation infrastructures, effective water use technologies and enhanced systems for environmental degradation of the highly sensitive sub-basins may help to lower their sensitivity to climate change and increase their adaptive capacity.

Type II. High Impact, Low Adaptive Capacity: The most vulnerable sub-basin lower Vaippar falls under this type, higher priority for adaptation measures which are dependent on vulnerability characteristics such as least water yield and rainfall, frequent drought events and land degradation problems.

Type III. Low Impact, High Adaptive Capacity: High resilience to climate change, the magnitude of impact could be low to the sub-basins such as Kalingalar, Nagariar and Sevalaperiyar, which have low climate change sensitivity (due to higher levels of water resources availability and rainfall), and higher adaptive capacity (forest coverage and more number of storage structures).

Type IV. Low Impact, Low Adaptive Capacity: Exposure to climate and sensitivity to water resources is low. Nichabanadhi sub-basin falls under this class. Medium priority for adaptation measures to improve adaptive capacity is needed.

Thus, the vulnerability mapping helps to highlight the vulnerable areas to high climatic exposure, high sensitivity and low adaptive capacity within the Vaippar basin.

V. CONCLUSIONS

The Vaippar basin is vulnerable to climate variability and change due to the sensitivity of the water resources and its limited adaptive capacity in agricultural sectors. The sub-basin-wise overall vulnerability index showed the degree of vulnerability and it ranges between very high to very low. The results revealed that the majority of the sub-basins namely Arjunanadhi, Kousiganadhi, Sindapalli-Uppodai and

Vallampatti Odai fall under the medium vulnerability profile. The vulnerable areas which are more exposed to adverse events, sensitive to get affected and have lesser adaptive capacity are mapped efficiently. Hence, based on the vulnerability index effective adaptation strategies to climate change of each sub-basin have to be recommended. An indicator based water resources vulnerability mapping identified the vulnerable sub-basins to climate change using GIS. Thus, the vulnerability maps allow the prioritization of sub-basin-wise adaptation strategies to climate change in the agricultural sector according to vulnerability index values. In this way, it is possible to identify the vulnerable and sensitive areas and transfer information to farmers and government agencies in order to support them in the planning of appropriate sustainable adaptation measures. The sub-basin-wise adaptation strategies for combating water resources vulnerability are formulated based on the results of the study. The study raises awareness of the changes in climatic conditions through appropriate communication to the farmers. The results of the study shall be useful for government agencies, meteorological departments and agriculture departments.

REFERENCES

[1] R. Heltberg, and B. M. Osmolovskiy "*Mapping vulnerability to climate change*", *The World Bank Policy Research Working Paper*, 2011, pp. 5554.

[2] IPCC. *Impacts, Adaptation, and Vulnerability Climate change, Third Assessment Report of the IPCC*, Cambridge University Press, 2001, UK.

[3] S. Kienberger, S. Lang, and P. Zeil "*Spatial vulnerability units – expert-based spatial modelling of socio-economic vulnerability in the Salzach catchment, Austria*". *Nat. Hazards Earth Syst. Sci*, 2009, 9, pp. 767-778.

[4] O'Brien, K. Leichenko, R. Kelkar, U. Venema, H. Aandahl, G. Tompkins, H. Javed, A. Bhadwal, S. Barg, L. Nygaard, and J. West, "*Mapping vulnerability to multiple stressors: climate change and globalization in India*", *Global Environ Chang,*2004,14, pp. 303-313.

[5] B. Smit, and O. Pilifosova, "*Adaptation to climate change in the context of sustainable development and equity, Climate Change 2001: impacts, adaptation and vulnerability"*, Chapter 18, 2001, Cambridge: Cambridge University Press.

[6] Subel, B. "*Late monsoon brings fears of food shortages in Nepal*", *The Khaleej times,*2009.

[7] B. L. Turner, R. E. Kasperson, P. A. Matsone, J. J. McCarthy, R. W. Corellg, L. Christensene, N. Eckley, J. X. Kasperson, A. Luers, M. L. Martello, C. Polsky, A. Pulsipher, A. Schiller, "*A Framework for Vulnerability Analysis in Sustainability Science*", Proc. Natl. Acad. Sci. 2003, 100(14), pp.8074-8079.

[8] UNDP. "Mapping climate change vulnerability and impact scenarios: *A guidebook for sub-national planners"*. 2010, New York: UNDP.

[9] UNEP. "Methodologies Guidelines - Vulnerability Assessment of Freshwater Resources to Environmental Change",2009, *United Nations Environment Programme*, Nairobi.

[10] R. P. D Walsh and D. M. Lawer, "Rainfall seasonality: Description, spatial patterns and Change through time", *Weather*, 1981, 36, pp.20-208.