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Simulated aridity and climate related multi threats to the state of Telangana, south India

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Abstract
Semi-arid areas of India are anticipated to face multitudes of climate change threats. The negative impacts can be felt both on natural and human ecosystems. The present study endeavors to project changes in climate and aridity conditions in the erstwhile Andhra Pradesh, South India under the IPCC high and medium emission scenarios RCP 8.5 and 4.5 respectively. The meteorological parameters such as temperature and precipitations were used to generate De Martonne Aridity Index, for assessing the changes in the spatial distribution of aridity. Model projections generated by HADGEM-ES model at 25 km resolution shows that aridity may be aggravated for the already arid and semi-arid tracks of north west part of Telangana. The city of Hyderabad shows a significant increase in temperatures and rise in drying trends in the mid of 21st century, indicating probability of water and heat related stresses. The drying trend may be attributed to rising single day extreme rainfall events and mean annual temperatures. There were also, extremely wet or flood events in the city. Hyderabad had recorded a Standardized Precipitation Index (SPI) value of +2.75 in the year 1975, marking it as a flood year. The years 1995(+1.95), 2005(+1.5), 2008(+1.61), 2010(+1.26) recorded as severely wet years and 1978, 1981, 1983, 1987, 1989 recorded a moderately wet years in the history of Hyderabad city. The year 2006, 2008, and 2016 have recorded record- breaking single day extreme rainfall of 218mm, 220mm and 215 mm respectively and associated flash floods in the city of Hyderabad in monsoon season. This paper reviews the state government schemes like Mission Kakatiya, Mission Bhageeratha and other river linking projects running in the state. It indicates the need to have robust and resilient action plans to tackle the combined challenge for meeting the water demands of the exponentially growing population. Multi-hazard risk reductions strategies must be envisaged in the state to achieve Intended Nationally Determined Contributions (INDCs) and Sustainable Development Goals (SDGs).

Keywords: climate change; RCP 4.5; warming; aridity; de martonne; semi-arid; adaptations; floods, resilience; sustainability

Introduction

United Nations Convention to Combat Desertification (UNCCD 2016) [36] reports that worsening aridity conditions may raise serious concerns for sustainability and human wellbeing in the context of global climate change. The problem of land degradation and its social implications may continue to exacerbate due to climate change in future (Shifteh *et al*. 2013; IPCC 2012) [31, 15]. At present, climate induced catastrophes are creating record breaking extreme weather events almost every year in India, including 2020-2021. It constantly poses risks to both humans and natural systems. Many studies have been conducted to understand socio economic vulnerability of coastal areas of India, on the basis of exposure, sensitivity and adaptive capacity (Maiti *et al*. 2015; Kumar *et al*. 2010;) [21, 20] Distribution and availability of rainfall will be more variable and could be 25% lower in many semi-arid regions, if average global temperatures rise by 2° C above pre-industrial period. According to De vente *et al*. (2017) [5], management of green water for rain-fed farming is integral for eradicating hunger and achieving food security. Building social resilience for the vulnerable areas deserves special attention in this context.

Sustainable growth is a serious challenge for regions that already reel under physical threats and multiple disasters. Vimal Mishra *et al*. (2017) [37] suggested that India would be more vulnerable to the socio-economic impacts of extreme weather events such as floods, droughts, cyclones, heat waves etc. Additionally, the National Disaster Management (DM) act of 2005 and DM policy of 2009 and the revised National Disaster Management Plan of 2019, released by the National Disaster Management Authority (NDMA) emphasize that developing contemporary forecasting and early warning systems are prerogative for every states in India as a proactive disaster risk reduction strategy. Actions that aim in reducing disaster risks, stand as an efficient response and relief to the vulnerable sections of the society (IPCC 2013b & 2014) in a proactive way.

Scientific studies have already indicated global warming as a major challenge for climate driven economic sectors in India such as water resources, agriculture and allied services, biodiversity and forests (Türkeş and Altan 2013) [34]. As per the latest estimates of climate change for India, there may be an increment of 5–10 days in the consecutive dry days as per Representative Concentration Pathways (RCP) 8.5 emission pathways for the period, 2081–2100 (Chaturvedi *et al*. 2012) [4]. The latest simulation study reported by Chaturvedi *et al*. (2012) [4] indicated a rise in mean annual temperature for India in the range of 2.9°C to 3.3°C under RCP 4.5 and RCP 6 pathways respectively.

According to the Desertification and Land Degradation Atlas of India published by the Space Application Centre in 2007, about 32.07 % of the land is subjected to various forms of degradation and 25 percent of the geographical area is affected by desertification, forcing stressors to preserve land resources. Ramachandran *et al*. (2015) [28] suggested that the aridity conditions for many parts of Tamil Nadu, south India may be increased during the end of 21st century as a result of rise in warming. Simulating the future trajectories of climate change, sea level rise etc enables a state to visualize and prepare short and long term sustainable plan for future developmental processes. There are very few simulation studies reported for India based on future aridity and sea level rise projections as per Representative Concentration Pathways trajectories of IPCC's Fifth Assessment Report. This study is an attempt to understand the climate extremities especially the looming aridity conditions for other parts of peninsular India.

Apart from aridification, heat waves also add risks to the already existing vulnerability for living organisms around the world (Simone 2015) [33]. Simone *et al*. (2015) [33] cautioned that there could be an enhanced probability, magnitude, extent and duration of heat waves. in the coming two decades (2021–2040). A recent World Bank report on South Asia's hotspots has foreseen 8% erosion of the country's GDP by 2050, accompanied by a fall in living standards due to deviations in temperature, rainfall and precipitation patterns. Vimal Misra *et al*. (2018) reported that population exposure to severe heat waves is projected to increase by about 15 and 92 times the current level by the mid and end-21st century respectively under the 2◦ C low-warming target. Limiting global temperatures to 1.5◦ C above pre-industrial would reduce the heat wave exposure by half relative to the RCP 8.5 trajectory by the mid-21st century. Ekardt (2020) has mentioned in a recent publication that the world climate has already become uncertain and unstable. Global warming and rising heat stress enhance challenges for sustainable living, one of the UN's prime Sustainable Development Goals (SDGs).

The journal Lancet countdown on health and climate has reported that India has been particularly affected by the rising frequency of heat wave events and lost about 75 billion hours of work, a significant part of it is in the agricultural sector. An estimated loss of 153 billion hours of labor during 2017 due to rising temperatures around the globe is a reminder to dramatically curb greenhouse gas emissions.

According to the Ministry of Earth Sciences, Government of India, nearly 1,600 people died in the year 2016 due to erratic weather conditions, of which 557 casualties were due to severe heat wave. Records from the central ministry also shows that there were 74 days of severe heat wave on an average between 1961 and 1970 and increased during the 2001-2010 with the number of severe heat wave days peaking to 98 (Murari *et al*. 2015 and Ratnam *et al*. 2016) [25, 29]. The state of Andhra Pradesh and Telangana are faced with severe heat wave conditions every year and it claims many lives. Guleria and Gupta (2018) [12] have reported that severe heat wave conditions with variance more than 6º C is seen in both the states during the summer, 2016, leading to 324 sunstroke deaths in Telangana State. According to EM-DAT9, the international disaster database, the heat wave of 2015 caused deaths of 2248 people in various parts of India. The heat waves over India are projected to be more intense and frequent in future. Alugula *et al*. (2020) [2] reveals that increasing urbanization in Telangana and Tamil Nadu is likely to enhance the amount of rainfall during the heavy rainfall events by 20 per cent to 25 percent.

Materials and Methods

1. Study area

Telangana is located between 12°41' and 22° N latitude and 77° and 84°40' E longitude, and is bordered by Maharashtra, Chhattisgarh and Orissa in the north, the Bay of Bengal in the east, Tamil Nadu to the south and Karnataka to the west. The south-west monsoon accounts for about 67% of the annual rainfall in the State (SAPCC, Andhra Pradesh & Telangana State 2014) [[30] SAPCC, Andhra Pradesh & Telangana Stat30e SAPCC, Andhra Pradesh & Telangana State.The State has a total population of 8,46,65,533(as per the 2011 census of India) and density is 308 persons per sq. km. Erstwhile Andhra Pradesh is popularly referred to as a 'River State'. Nearly 75% of the State is covered by basins of three major rivers - Godavari, Krishna and Pennar and their tributaries. In addition, there are 17 other rivers like Sarada, Nagavali, Musi and other streams. The Godavari, is the longest and the broadest river in South India, with a length of 1464 km length, of which about 772 km lies within the State.Telangana is always faced with variability in rainfall distributions. The rain-fed farming systems in the state is adversely impacted by aberrations in rainfall. The state receives rainfall between 600 mm in the south to 1000 mm in the north. Drought and heat waves are recurrent features in the state.

2. Climate change modeling approach

Abdus Salam International Centre for Theoretical Physics (ICTP), Italy has developed the Regional Climate Models (RCMs) *viz*., RegCM4.0 to simulate future climate scenarios under IPCC fifth assessment report based emission trajectories. The GCM boundaries used to drive the RCMs was Had GEM-ES model. The model simulation was run for 128 years (1971 to 2098) using the latest RCP 4.5 and RCP 8.5 scenarios. The weather variables maximum and minimum temperature are extracted from the RCM output. The future projections are based on a representative CO_2 concentration pathway that generates a radiative forcing of 4.5 Wm^{-2}, and 8.5 Wm^{-2} are chosen for the study. Chaturvedi *et al*. (2012) [4]; Taylor *et al*. (2012) [35] and Kumar *et al*. (2001) have carried out enormous work on climate change simulations for India. RCP 4.5 represents moderate emissions scenario, presuming actions are being under taken to limit greenhouse gas emissions by 2050. Under RCP 4.5 scenario the atmospheric CO_2 concentration in the year 2050 would be 478 ppm, and by 2100, it would be 538 ppm. From the daily outputs of RegCM4, mean annual estimations were made using Perl programme for climate analysis. The annual estimations were done for each grid and then averaged for the state to find the increase or decrease in trend of climate parameters till the end of 21st century.

3. Aridity assessment

Globally, semi-arid lands (SALs) are home to approximately one billion people, including some of the poorest and least food secure regions. In order to calculate Aridity Index, a numerical indicator of the degree of dryness of the climate at a given location. In order to understand Meteorological drought when there is a significant decrease in precipitation from the normal over an area, Standardized Precipitation Index (SPI) developed by McKeee *et al.* (1993) [22] are used in this paper. SPI is computed by considering the precipitation anomaly with respect to the mean value for a given time scale, divided by its standard deviation (Dhanya and Ramachandran 2015b) [7].

"De Martonne" Aridity Index was used to evaluate present and future aridity trends prevailing in Telangana and Andhra Pradesh "De Martonne" Aridity Index was utilized using the simulated climatic output of RegCM under RCP 4.5and RCP 8.5. Aridity is being delineated for yearly time scale values using mean precipitation and air temperature for both the states. The projected aridity was calculated for the near (2010-2040), mid (2041-2070), end century (2071-2098) periods.

De Martonne aridity index (DM_{Ia}) was calculated using the formula (Table 2)

$$DMI_a = \frac{P}{T+10} \quad (1)$$

Where

P - annual precipitation sum [mm];

T - annual mean air temperature [°C]

Table 1: Aridity classes as per De' Martonne Index (DM_I) classification

Climate	Values of DMI
Dry	$DM_I < 10$
Semi- Dry	$10 \le DM_I \le 20$
Mediterranean	$20 \le DM_I < 24$
Semi- Humid	$24 \le DM_I < 28$
Humid	$28 \le DM_I < 35$
Very Humid Extremely Humid	a.$35 \le DM_I \le 55$ b. $DM_I > 55$

Source: Elaborated by the authors

Results and Discussion

1. Aridity assessment

Observed temperature and rainfall of the city of Hyderabad were collected to understand the basic climatology of the place. This indicates a significant increasing trend in mean annual temperature in the study area from 1971 to 2010. With reference to the baseline (1971-2000) simulations, monthly climatology was compared for understanding the actual trends and possible future directions. Mean annual temperature in this study area is likely to increase (Fig.2), as reported by Wiltshire *et al.* (2013) [38] and Shifteh *et al.* (2013) [31]. Similar kind of increased projection pattern for India was also observed by Chaturvedi *et al.* (2012) [4]; Simone *et al.* (2015) [33]; Misra *et al.* (2017). The observed climatology shows no significant trend for rainfall (Fig. 3) with an annual mean rainfall of 832.83 mm, however inter annual variations were noted.

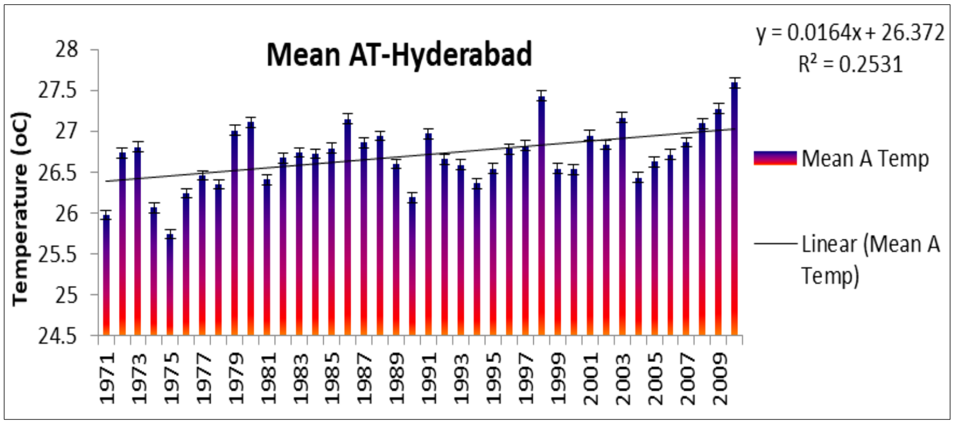

Fig 1: Mean annual temperature for the main city of the study area- Hyderabad for the period 1971- 2010

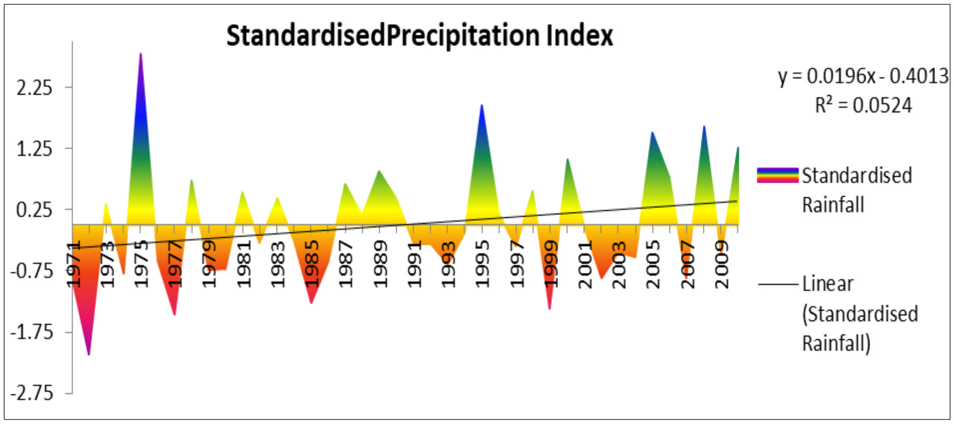

Fig 2: Standardized rainfall for the main city of the study area- Hyderabad for the period 1971- 2010

The meteorological study of drought and flood occurrences shows that there was one extremely severe drought year. SPI-12 is used to evaluate the frequency and severity of drought events across this district in the past. The analysis revealed that the year 1972 with SPI value -2.1, was the extremely severe drought year on record during the period 1970-2011, Fig. 3. The years 1977, 1985 and 1999 were severe dry years and the years 1971, 1974, 1976, 1979, 1980, 1986, 1993, 1997, 2002, 2007 and 2009 were under moderately dry category. It is an alarming situation if a city with an increasing population faces mild to severe drought situations frequently. The city of Hyderabad is already reeling under water crises. There were extremely wet or flood events also in the city in the recent past. The year 1975 has recorded the highest SPI value of +2.75 marking a flood year. The years 1995(+1.95), 2005(+1.5), 2008(+1.61), 2010(+1.26) recorded as severely wet years and 1978, 1981, 1983, 1987 and 1989 were recorded as moderately wet years in the history of Hyderabad city. Recorded breaking single day extreme precipitation events of 218mm, 220 mm and 215 mm respectively and associated flash floods in the city of Hyderabad in August and September months were recorded in the years 2006, 2008, and 2016. Both the extremes such as drought and floods are showing rising trend and can pose critical challenges for the development of Hyderabad city and the wellbeing of its population.

The current climatic classification of Andhra Pradesh and Telangana state and projections of aridity trend using "De Martonne" Aridity Index is presented in the Fig. 4 to Fig.7 respectively under RCP 4.5 and 8.5 scenario. De Martonne" Aridity Index is a widely used index to evaluate the present and future climate and aridity trends prevailing in a region. In the state of Telangana apparently a wetting trend is noted in the near century period (2011-2040) with reference to the baseline period (1971-2000).

Telangana comes under an arid to semi-arid climate. De martonne Aridity Index for Telangana state shows very slight decreasing trend compared to Andhra Pradesh as per as per the model HADGEM2-ES-RCP 4.5 trajectory (Fig. 4& 5). Results shows that north-west part of the state, especially Adilabad, Nizamabad, Karimnagar and Mahabub nagar districts were reeling under an arid climate until 2000. However projections shows that during the near and end century, dry conditions may be improved in Nalgonda, Warangal, and Sangareddy. Eastern side of Mahabubnagar district may experience slight wetting trends during the end century period. The city of Hyderabad may not expect any change in its aridity status as the arid climate will persist in future as well.

Majority of the areas in the state may maintain its aridity status as the index values tend to be between $DM_I < 10$.only in the south eastern part of the state shows a slight wetting trend.

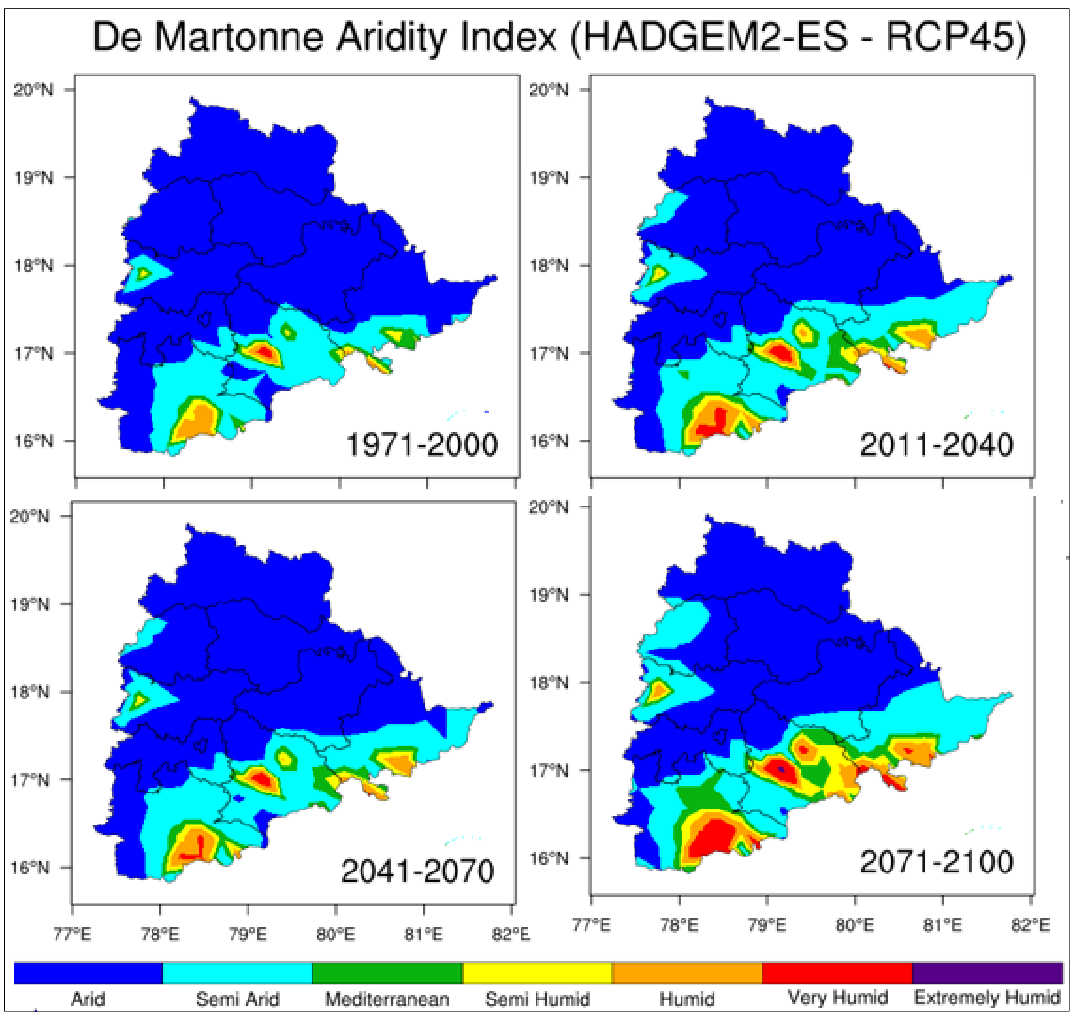

Fig 3: Projected De martonne Aridity Index for Telangana spanning three continuous four time slices (near- 2010-2040, mid-,2041-2070, End-2071-2100) under RCP 4.5.

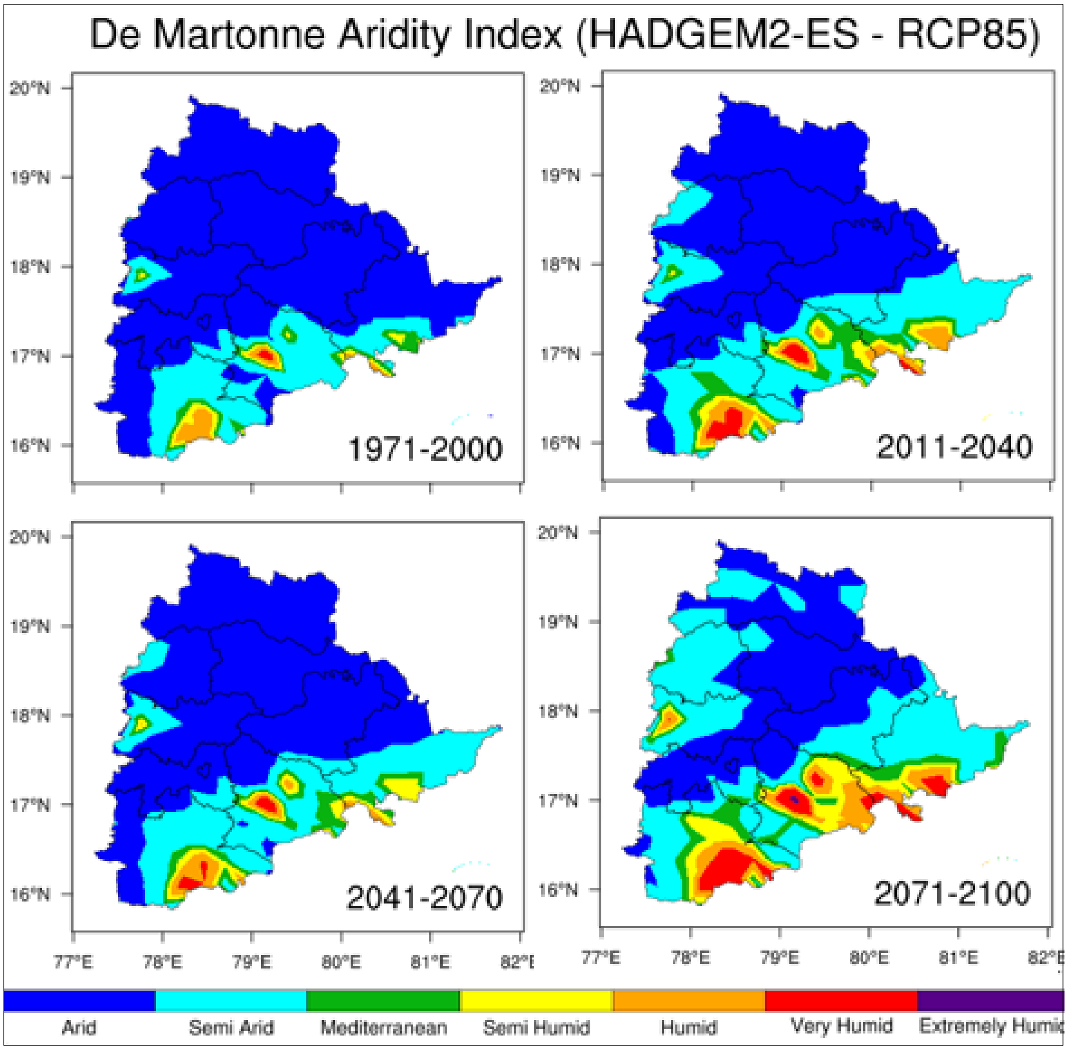

Fig 4: Projected De martonne Aridity Index for Telangana spanning three continuous four time slices (near- 2010-2040, mid-,2041-2070, End-2071-2100) under RCP 8.5.

A comparatively higher level of warming conditions was observed in the north western part of both the states. The likely fall in aridity was observed in Nagarkurnool, Nalgonda and Suryapet areas as the IDM values shown were in the range of 35 $\leq DM_I \leq 55$.

Way forward for resilience for the state

The National Disaster Management Authority (NDMA) mentioned that in recent years, climate change is causing the day and night time temperatures higher than normal and also the frequency and severity of heat waves and heat island effects in cities (Pattanaik *et al*. 2017) [27]. The NDMA held two planning workshops in 2017 and 2018 in Telangana and Andhra Pradesh, respectively to address the problems. Training and capacity building are integral part of preparedness action plans to safeguard the communities from any disasters. Many researchers around the world have appreciated the critical role of social networks in appraising adaptive capacity (Adger 2003; Folke *et al*. 2005) [1].

There should be a combination of proactive and reactive activities to attain resilience (Fig.8). Dhanya *et al*. (2015a) [6] has mentioned various kinds of adaptation to achieve resilience such as proactive, reactive, passive and active. Reactive responses are driven by actual perceived climate induced disasters and proactive strategies can be drawn based on the risk assessments, forewarnings and forecasting future scenarios. Land degradation causes serious implications for biodiversity loss, the most critical global environmental threat (Dhanya *et al*.2016) [8]. More than a third of the global species are facing extinction and an estimated 60 % of the earth's ecosystems have been degraded in the past 50years, posing adverse consequences for the services that depend on them (Joppa.*et al*. 2016) [18].

Discussions

As scientific evidence shows, decision-makers are faced with multi challenges of mitigating multiple environmental risks (Komendantova *et al*. 2016) [19]. The planning commission of India has declared nine districts of Telangana as chronically drought-hit areas, posing critical challenges for sustainability. The government of Telangana has undertaken two ambitious projects for addressing problems of drinking water and irrigation water supply namely Mission Bhageeratha and Mission Kakatiya respectively. As far as the newly formed state of Telangana is concerned, Mission Kakatiya (Our Village - Our Tank) may play a vital role in the revival & restoration of a chain of Tanks system was an aspiration for people during the Telangana Movement (Mission Kakatiya GoTS, report, 2018) [23]. According to the mission, groundwater table will be improved in this water-scarce region, and bore wells, hand pumps in the village will be operational uninterruptedly with additional land will be under tube well irrigation. 70 % of agriculture in Telangana is under tube wells, hence renovating a tank in a village would sustain tube well irrigation. It is planned to restore all the 46,531 minor irrigation sources in the state in the next five years. With community participation, this mission ensures sustainable water security in Telangana State. Under the Mission Bhageeratha, the policy of the Government is to provide drinking water in all the rural and urban areas by integrating the existing water supply systems in the rural and urban areas with the Grid. It is also planned to develop sewerage systems and treatment plants in rural areas of the state (Mohanty *et al*. 2009) [25]. This plan is anticipated to be a sustainable one, however a huge financial layout is required to accomplish it. Environment Protection Training & Research Institute (EPTRI) is preparing the project State Specific Action Plan (SSAPW) for the water sector for Telangana State in accordance with directions issued by Government of Telangana State & National Water Mission, Ministry of Water Resources, River Development & Ganga Rejuvenation, Government of India. Under this scheme, an open source comprehensive water database in public domain is planned along with impact assessment of climate change on water resources. This assessment aims to enhance water use efficiency by 20%, and promotion of basin level integrated water resources management in the state. The inter-linking of Godavari and Krishna rivers are also proposed, to benefit drought-prone areas in Telangana and Andhra Pradesh. It is aimed at sustainable management of water resources and its applications in vulnerable districts of erstwhile Mahabubnagar, Nalgonda districts in Telangana state and Prakasam, Nellore, Rayalseema districts in Andhra Pradesh governed by Krishna and Godavari river development board.

Conclusions

There are uncertainties attached to regional and local economic development and the wellbeing of people in the context of climate change. Observed trends and simulation studies show that Telangana is reeling with multi-hazard risks with respect to intensifying temperatures and aridity, etc. The evaluation of model predictions provided a more robust regional evaluation of the probable impacts of drying trends and sea-level rise. De Martonne" Aridity Index was used to evaluate the present and future climate and aridity trends prevailing in a region. In Telangana and apparently a slight wetting trend is noted for southeastern parts in the near-century period (2011-2040) with reference to the baseline period (1971-2000). Irrespective of which RCP scenario is considered, aridity trends are similar in future i.e. in the near and end century there is a wetting trend for South east part of the states, but in the midcentury period, the trend is reversed. Enhanced research is required to understand how emerging cities and communities behave in the future scenario. Micro-level studies are the essential prerequisites for any developmental planning process as there exist spatial variability in climatic conditions. A research review carried out on the state government's ambitious programmes like Mission Kakatiya, Mission Bhageeratha and river linking projects indicates its huge potential in bringing water resilience to the state. Robust action plans, envisioned to tackle multi hazard risk reductions strategies may meet the water demands of the state.

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References

1. Adger WN. Social capital, collective action, and adaptation to climate Change. *Economic Geography*,2003:79:387-404. http://dx.doi.org/10.1111/j.1944-8287.2003.tb00220.x development geography. Erdkunde 66, 185-195. http://dx.doi.org/10.3112/erdkunde.2012.03.01
2. Alugula Boyaj, Hari Prasad, Dasari Ibrahim, Hoteit, Karumuri Ashok. Increasing heavy rainfall events in South India due to changing land use land cover. Quarterly Journal of Royal Meteorological, 2020. *Society*.https://doi.org/10.1002/qj.3826
3. Census of India. accessed from, 2011. http://censusindia.gov.in/
4. Chaturvedi RK, Joshi J, Jayaraman M, Bala G, Ravindranath NH. Multi model climate change projections for India under representative concentration pathways (RCPs):a preliminary analysis. *Curr Sci*,2012:103:791-802.
5. De Vente JJL, Chotte M, Bernoux G, Kust MJ, Sanz I, Ruiz M, *et al*. Sustainable Land Management contribution to successful land-based climate change adaptation and mitigation. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany, 2017.
6. Dhanya P, Ramachandran A. Farmers' perceptions of climate change and the proposed agriculture adaptation strategies in a semi-arid region of South India. *Journal of Integrative Environmental Sciences*, 2015a, 131. https://doi.org /10.1080/1943815X.2015.1062031
7. Dhanya P, Ramachandran A. Projected Warming and Occurrence of Meteorological Droughts—Insights from the Coasts of South India. American Journal of Climate Change,2015b:4:173-179. http://dx.doi.org/10.4236/ajcc.2015.42013
8. Dhanya P, Ramachandran A, Palanivelu K. The urgent call for land degradation vulnerability assessment for conserving land quality in the purview of climate change: Perspective from South Indian Coast. Land Management Practices for Soil Conservation in Climate Change Scenarios, AIMS Agriculture and Food, 2016:1(3):330-341. doi: 10.3934/agrfood.2016.3.330
9. EM-DAT9, the international disaster database, accessed from, 2019. https://www.emdat.be/ on Deceember.
10. Folke C. Resilience: the emergence of a perspective for social-ecological systems analyses. *Global Environmental Change*,2006:16:253-267. http://dx.doi.org/10.1016/j.gloenvcha.2006.04.002

11. Folke C, Carpenter SR, Walker B, Scheffer M, Chapin T, Rockström J. Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society* [online],2010:15(4)-20. URL: http://www.ecologyandsociety.org/vol15/iss4/art20/
12. Guleria S, Gupta AK, Heat wave in India documentation of state of Telangana and Odisha (2016). New Delhi: National Institute of Disaster Management,2018. 978-93-82571-24-7. (p. 124).
13. IMD Data obtained through https://www.imdtvm. gov.in /index.php? option=com_content& task=view&id= 29&Itemid=43
14. IPCC. Climate Change 2007. The physical science basis, contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK, 2007, 167.
15. IPCC. *Emergent Risks and Key Vulnerabilities*, Final Draft, Chapter 19 [online], 2012. http://ipccwg2.agov /AR5/images/uploads/WGIIAR5-Chap19_FGDall.pdf.
16. IPCC. *Terrestrial and Inland Water Systems*, Final Draft, Chapter 4 (online), 2013. http://ipccwg2
17. IPCC. Climate Change 2014: Impacts, Adaptation, and Vulnerability. In: Field, C., Barros, V., Mach, K., Mastrandrea, M., (Eds.), Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: University Press, Cambridge, United Kingdom and New York, USA, 2014.
18. Joppa LN, O' Connor B, Visconti P, Smith C, Geldmann J, Hoff-mann M, *et al*. Filling in biodiversity threat gaps. *Science*,2016:352:416-418
19. Komendantova, Nadejda, Scolobig, Anna, Garcia-Aristizabal, Alexander, *et al*. Multi-risk approach and urban resilience. International Journal of Disaster Resilience in the Built Environment,2016:7:114-132. 10.1108/IJDRBE-03-2015-0013.
20. Kumar TS, Mahendra RS, Nayak S, Radhakrishnan K, Sahu KC. Coastal vulnerability assessment for Orissa State, East coast of India. J Coast Res,2010:26:523-534.
21. Maiti S, Jha SK, Garai S, *et al*. Assessment of social vulnerability to climate change in the eastern coast of India. *Climatic Change*,2015:131:287-306. https://doi.org/ 10.1007/s10584-015-1379-1
22. McKee TB, Doesken NJ, Kleist J. Relationship of Drought Frequency and Duration to Time Scale. 8th Conference on Applied Climatology, 17-22 January 1993, Anaheim, 1993, 179-184.
23. Mission Kakatiya Report. Accessed from, 2018. https://missionkakatiya.cgg.gov.in/ https://tweb.telangana.gov.in /initiatives/mission-kakatiya/
24. Misra V, Bhardwaj A, Mishra A. Local onset and demise of the Indian summer monsoon. *Clim Dyn*,2018:51:1609-1622. https://doi.org/10.1007/s00382-017-3924-2
25. Mohanty AK, Kumar GAK, Singh BB, Meera SN. Developing multidimensional scale for effective measurement of rural leadership. Indian Res J Ext Educ, 2009:9(2):57-63.
26. Murari KK, Ghosh S, Patwardhan A, Daly E, Salvi K. Intensification of future severe heat waves in India and their effect on heat stress and mortality. *Reg. Environ Change*,2015:15:569-579. 10.1007/s10113-014-0660-6
27. Pattanaik DR, Mohapatra M, Srivastava AK, Kumar Arun. Heat wave over India during summer 2015: an assessment of real time extended range forecast. *Meteorology and Atmospheric Physics*, 2017:129:375-393. https://doi.org/ 10.1007/s00703-016-0469-6.
28. Ramachandran A, Dhanya Praveen, Jaganathan R, Palanivelu K. Projected and Observed Aridity and Climate Change in the East Coast of South India under RCP 4.5. The Scientific World Journal, vol. 2015, Article ID 169761, 2015, 11. 2015. doi:10.1155/2015/169761
29. Ratnam JV, Swadhin K, Behera, Satyaban, Ratna B, Rajeevan M, *et al*. Anatomy of Indian heat waves. *Scientific Reports*,2016:6:24395. https://doi.org/10.1038/srep24395.
30. SAPCC, Telangana State, & Andhra Pradesh. Accessed on 30th August, 2017, State Action Plan on Climate Change, Andhra Pradesh, 2014. http://moef.gov.in/wp-content/uploads/2017/08/Andhra-pradesh.pdf
31. Shifteh Some'e B, Azadeh Ezani, Hossein Tabari. Spatiotemporal trends of aridity index in arid and semi-arid regions of Iran. *Theoretical and Applied Climatology*, 2013: 111:149-160. doi: 10.1007/s00704-012-0650-x.
32. Simone Russo, Dosio A, Graversen RG, Sillmann J, Carrao H, *et al*. Magnitude of extreme heat waves in present climate and their projection in a warming world, J. Geo-phys. Res. Atmos,2014:119:12:500-12,512. doi:10.1002/2014JD022098
33. Simone Russo, *et al*. Top ten European heat waves since 1950 and their occurrence in the coming decades, *Environ. Res. Lett.*, 10 124003, 2015. https://iopscience.iop.org/ article/10.1088/1748-9326/10/12/124003
34. Türkeş M, Altan G. An ecological biogeography analysis of the impacts of climatic variations and forest fires on the natural environment, nature protection areas and biota in the Muğla district. *EgeCoğrafyaDergisi*,2013:22(2):57-76.
35. Taylor KE, Stouffer RJ, Meehl GA. An overview of CMIP5 and the experiment design. *Bull. Am. Meteorol. Soc*, 2012, 93(1). doi: 10.1175/BAMS-D-11-00094.1
36. United Nations Convention to Combat Desertification, UNCCD-SPI. Land in Balance. The Scientific Conceptual Framework for Land Degradation Neutrality. Science-Policy Brief 02. United Nations Convention to Combat Desertification, Science-Policy Interface (UNCCD-SPI), 2016.(www.unccd.int/Lists/SiteDocumentLibrary/Publicati ons /10_2016_spi_pb_ multipage_eng.pdf).
37. Vimal Mishra, *et al*. Heat wave exposure in India in current, 1.5 °C, and 2.0 °C worlds, *Environ. Res. Lett.*, 2017:12:124012. https://doi.org/10.1088/1748-9326/aa9388
38. Wiltshire A, Kay G, Gornall J, Betts R. The impact of climate, CO_2 and population on regional food and water resources in the 2050s. *Sustainability*,2013:5(5):2129-21.