International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

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IJBSM March 2022, 13(3):317-325 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR2721

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2022.2721

Geospatial and Temporal Studies on Climatic Parameters and Their Impact on Inland Fish Production: A Case Study

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ABSTRACT

Climate change threatening the word food security including fisheries production. The current study aimed to find the relationship between different climatic variables and fish production by generating spatial maps. The climatic parameters data viz., mean maximum temperature; mean minimum temperature; total rainfall, and mean wind speed were plotted in GIS (Geographical Information System) platform and thematic mapping of it's for all the districts of Maharashtra for the year 1975 and 2017 on quarter basis was done using QGIS 3.6.1. The thematic maps of the percentage change in parameters of all the quarters of the year 2017 and 1975 were done for all the zone of Maharashtra. In addition, the thematic maps of the percentage change in parameters along with fish production of all the quarters of the year 2017–18 for the year 2012 were done for all the zone. The sensitivity analysis of climatic parameters with inland fish production for Maharashtra state and all the seven zones were done using GAM (Generalized Additive Model). The mean maximum temperature (MMAX) and total monthly rainfall (TMRF) were found to the most significant factors in the prediction of inland fish production. The average increase in MMAX during the 2nd and 3rd quarters (April to September) was less than the average increase in MMAX during the 1st and 4th quarters, whereas, in case of rainfall an average decrease was estimated during the 2nd and 3rd quarter. The current study found that Nagpur and Pune were the two highest fish-producing regions, and Konkan and Aurangabad were the two least productive regions.

KEYWORDS: Climatic parameters, Maharashtra, fish production potential, thematic map

Citation* (VANCOUVER)*: Yadav et al., Geospatial and Temporal Studies on Climatic Parameters and Their Impact on Inland Fish Production: A Case Study. *International Journal of Bio-resource and Stress Management,* 2022; 13(3), 317-325. HTTPS://DOI.ORG/10.23910/1.2022.2721.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 09th November 2021 RECEIVED in revised form on 02nd March 2022 ACCEPTED in final form on 24th March 2022 PUBLISHED on 31st March 2022

1. INTRODUCTION

Climate change has emerged as one of the most multifaceted manifestations of global change (Bearden and Karlsgodt, 2021; Arbabi et al., 2010; Daw et al., 2009; Anonymous, 2020; Loaiciga et al., 1996;). However, there are very limited studies has been found regarding the exact prediction of different climatic variables as well its impact on the food production system, including fisheries and aquaculture (George and Athira, 2020; Mitra et al., 2009; Vivekanandan and Krishnakumar, 2010; Mukherjee et al., 2022). The agricultural sector, including fisheries, has received maximum attention from climate modelers due to its high dependence on several climatic variables like air temperature, salinity, rainfall, pH, acidification rate, sea surface temperature, etc. (Meghwal et al., 2018; Das et al., 2016; Dash et al., 2007; Dubey et al., 2017; Koya et al., 2017). Fisheries dependence, especially in developing countries, shows an important role in debates about its adaptation towards impacts of climate change (Allison et al., 2009; Lal et al., 2018; Lehodey et al., 2003). Climate define as weather of a place which have seasonal variance, it is the change in the statistical distribution of weather over periods of time that range from decades to millions of years (Alare et al., 2022; Bishnoi et al., 2017). It can be a change in the average weather or a change in the distribution of weather events around an average (Honda et al., 2014; McCarthy et al., 2001). Climate change may be limited to a specific region or may occur across the world (Janssens et al., 2020; Cheng et al., 2019; Karmakar et al., 2018; Viner, 2002). The global climate change impact studies show a negative impact on agriculture in long run, which is not true in fisheries domain. For instance, if the water temperature rises, as most fishes tend to be poikilothermic hence it may be beneficial to a certain extent (Kaur et al., 2016; Moyle and Cech, 2004; Vivekanandan, 2013). However, climate change is one of crucial factor in global production including fisheries, so it is important to understand the scale of these impacts in relation to other changes such as improvements in technology and farming systems. Forecasting fisheries production is an integral part of fisheries management because it allows policymakers to develop a strategy and enact management decisions that can achieve goals in light of uncontrollable events (Kizhakudan, 2014; Vivekanandan and Krishnakumar, 2010). Time series modeling and forecasting have fundamental importance in various practical domains.

India ranked second in global inland fisheries production (Anonymous, 2020) and the inland sector contributes most in total fisheries production (Anonymous, 2020). The inland fisheries resources comprise rivers, streams, lakes, reservoirs with a combined riverine length of 8253 km, and 41 600 ha of sprawling lakes and reservoirs. (Anonymous, 2020). Maharashtra is one of the leading state in fisheries production in India. It ranked 5th in total marine landing and total inland fisheries production in the year 2019-20 was 1.18 lakh tonnes (Anonymous, 2020). This state has huge potential for improvising its freshwater production but simultaneously climate change issues greatly affecting the total fish production. Therefore, future forecasting of different climatic variables and understanding the relationship between the climatic variables and the fisheries production for this state is very essential and relevant for recent times.

A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data (Vilela et al., 2021; Fisher, 2013; Meaden, 2001). GIS and remote sensing have been widely applied to marine fisheries, there have been fewer applications of these technologies in inland fisheries management and planning (Shaari and Mustapha, 2018; Goswami and Zade, 2015).

The current study aims to generate thematic maps of different climatic variables i.e. mean maximum temperature; mean minimum temperature; total rainfall, and mean wind speed along with their percentage change. The present study also tries to show the changing pattern of the total inland production by generating a thematic map and trying to correlate the relationship between the different climatic variables with the fisheries' production.

2. MATERIALS AND METHODS

2.1. Collection of meteorological data

Collection of meteorological parameters data has done from Indian Metrological department (IMD) Pune and collection of Inland fish production for different zone of Maharashtra was done from Maharashtra state fisheries department. The metrological parameter included mean maximum temperature; mean minimum temperature, lowest minimum temperature, highest maximum temperature total rainfall, and mean wind speed.

2.2. Processing of the data and preparation of spatial map

The metrological data have been collected for all the districts of Maharashtra and also for all seven zones i.e. Konkan, Nashik, Pune, Aurangabad, Latur, Amravati, and Nagpur. The data were obtained for monthly temporal resolution and it has been converted into quarterly temporal resolution. All the metrological data were plotted in the GIS (Geographical Information System) platform and thematic mapping of it for all the districts of Maharashtra for the year 1975 and the year 2017 were done using open source GIS software QGIS 3.6.1. The thematic maps with the percentage change in parameters for all the quarters of the year 2017 for the year 1975 (base year) have been done for all seven zones. In addition, the thematic maps of percentage change in parameters along with fish production of all the quarters of the year 2017 for the year 2012 have been done for all the zone of Maharashtra.

2.3. Methods for sensitivity analysis of climatic parameters with inland fish production

The sensitivity analysis of climatic parameters with inland fish production for the Maharashtra state and all the seven zone of Maharashtra were done using GAM (Generalized Additive Model). GAMs are semi-parametric extensions of Generalized Linear Model (GLM); the only underlying assumption made is that the functions are additive and that the components are smooth (Yadav et al., 2020). A GAM, like a GLM, uses a link function to establish a relationship between the mean of the response variable and a 'smoothed' function of the explanatory variable(s). The strength of GAMs is their ability to deal with highly non-linear and non-monotonic relationships between the response and the set of explanatory variables (Maunder and Punt, 2004). The analysis under GAM was done using R software. The detailed about GAM is beyond the scope of this paper, and the same can be seen in other studies (Guisan et al., 2002).

3. RESULTS AND DISCUSSION

Thematic mapping showed the quarterly metrological data district-wise of Maharashtra of the years 1975 and 2017 (Figure 1 and Figure 2). The visual representation/interpretation will help in finding the distribution of all the metrological data in all districts of Maharashtra in all four quarters of the year 1975 and the year 2017. In addition, the percent change in parameters of all the four quarters for the year 2017 with respect to the base year 1975 was shown in Figure 3 - Figure 6. The summary of percentage change in parameters in the year 2017 to 1975 for the Maharashtra State and different regions has shown in table 1 and table 2. The current study found that the average increase in MMAX during the 2nd and 3rd quarters (April to September) was less than the average increase in MMAX during the 1st and 4th quarters. The study also revealed that there was an average decrease in rainfall during the 2nd and 3rd quarters.

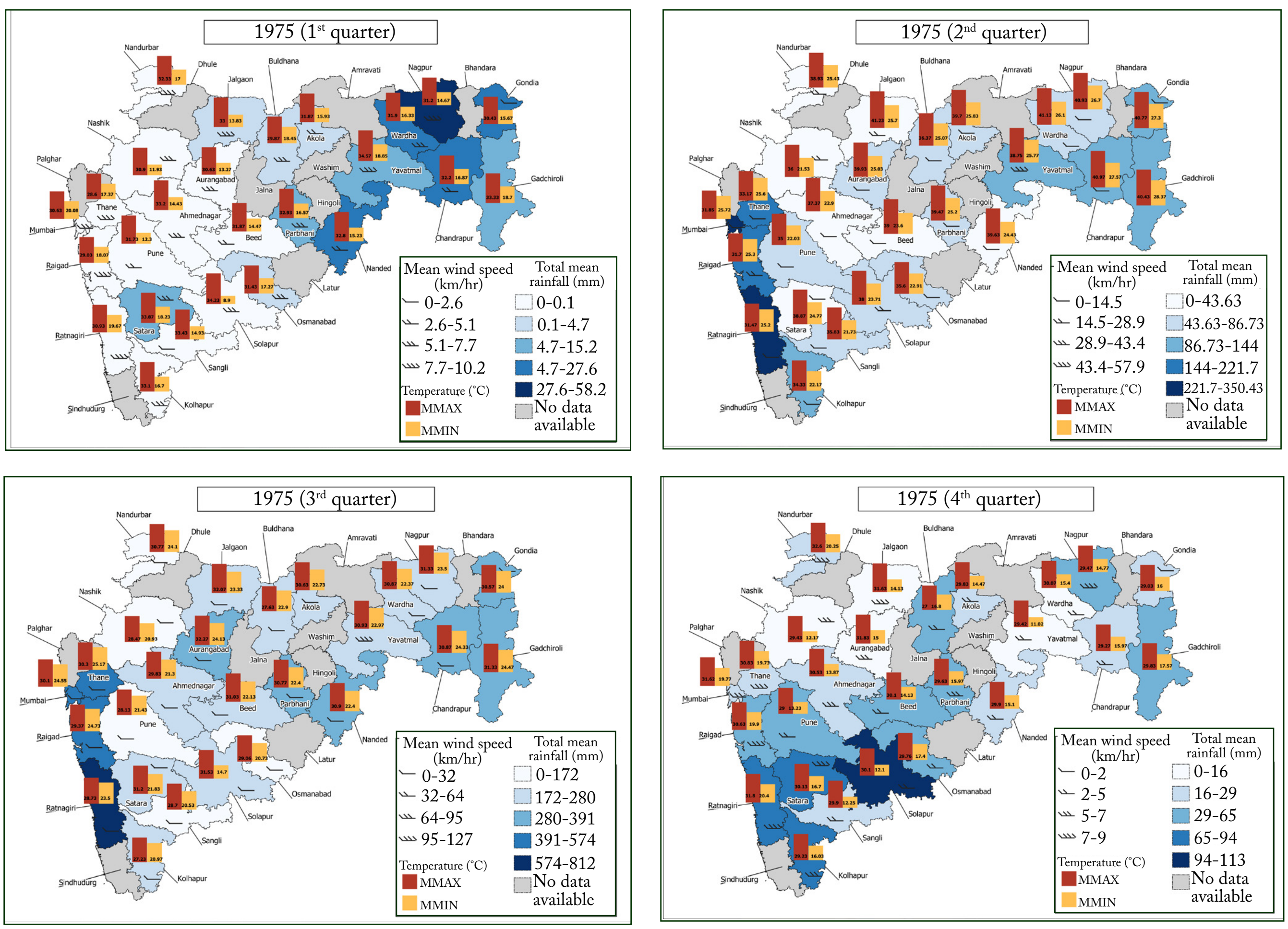

Figure 1: Thematic mapping of the district-wise quarterly meteorological data for the year 1975

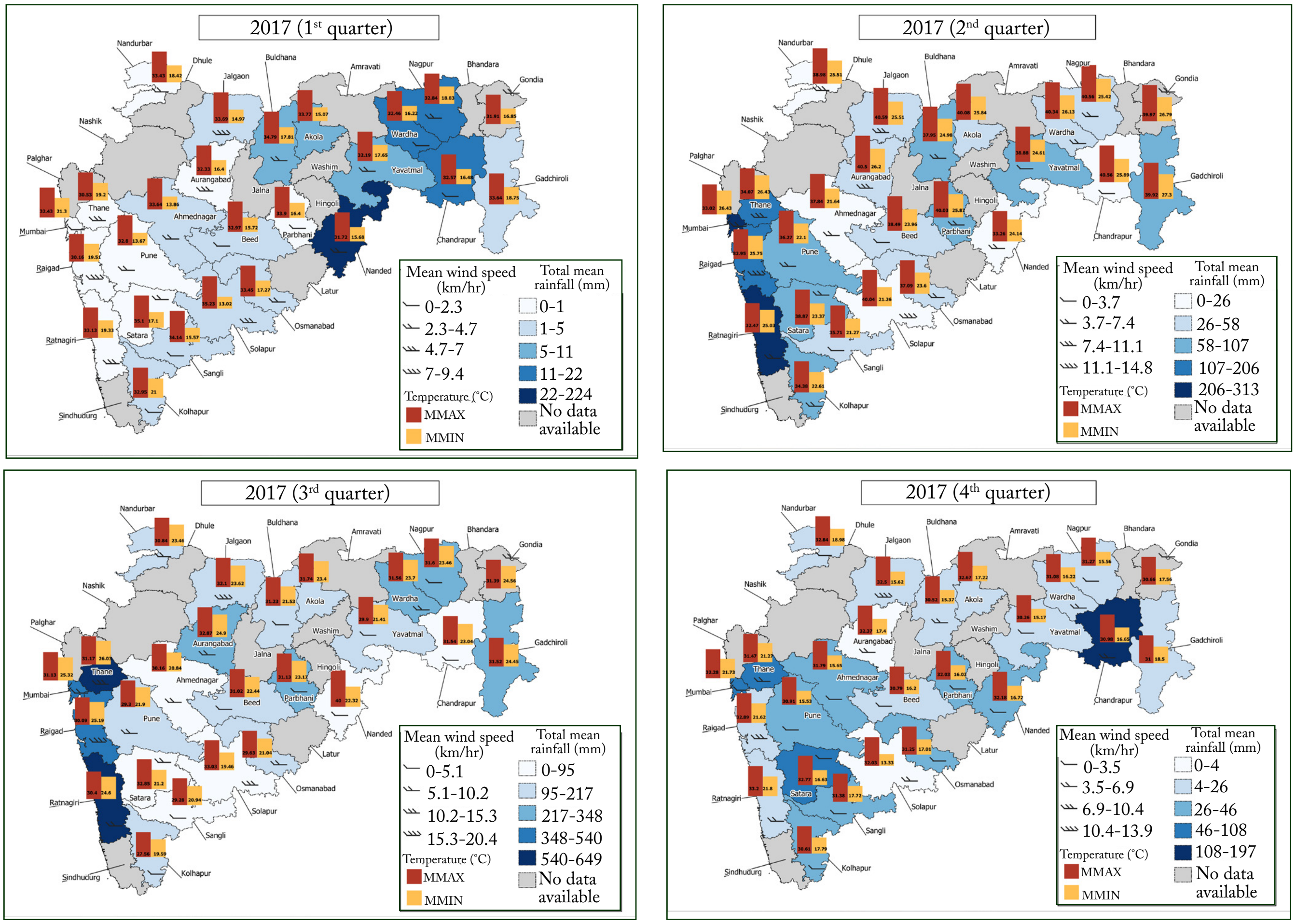

Figure 2: Thematic mapping of the district-wise quarterly meteorological data for the year 2017

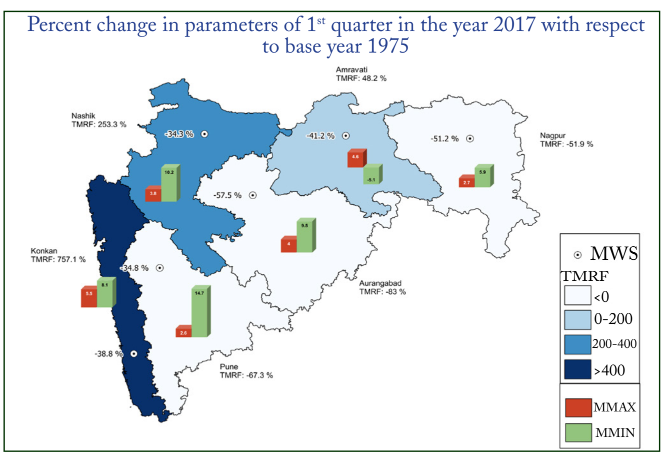

Figure 3: Thematic mapping showing the percent change in parameters of 1st quarter in the year 2017 concerning the base year 1975

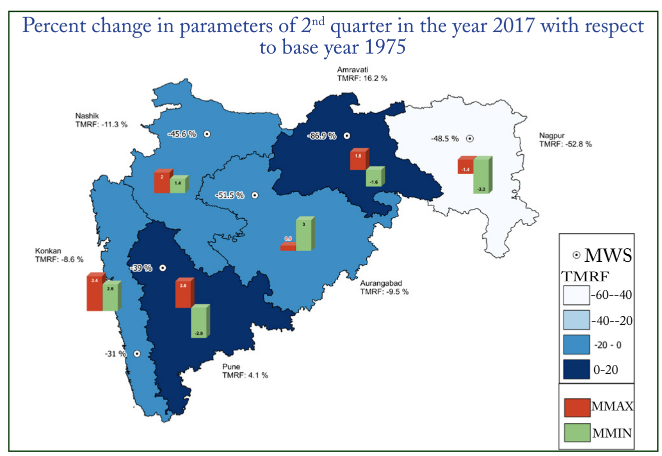

Figure 4: Thematic mapping showing the percent change in parameters of 2nd quarter in the year 2017 concerning the base year 1975

Similar kinds of studies for the Ganga region, West Bengal (Das et al., 2016) also revealed the same, which supports the current study.

Thematic maps showing the percent changes in parameters and fish production of all the four quarters in the year 2017–18 with respect to the base year 2012–13 has shown in Figure 7 to Figure 10.

The GAM analysis of fish production data of Maharashtra with respect to climatic data has shown in Figure 11. and the distribution of inland fish production (in ton) of all the

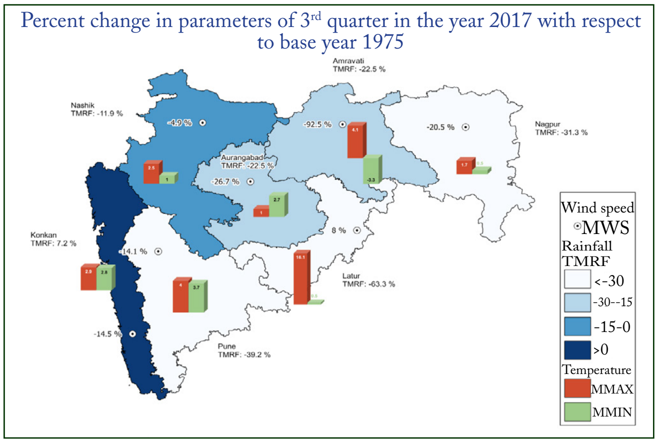

Figure 5: Thematic map showing the percent change in parameters of 3rd quarter in the year 2017 concerning the base year 1975

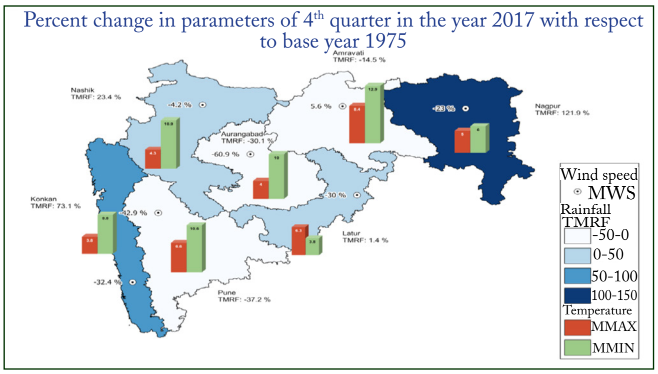

Figure 6: Thematic mapping showing the percent change in parameters of 4th quarter in the year 2017 with respect to the base year 1975

Table 1: Percentage change in climatic parameters in the year 2017 with respect to 1975 for the Maharashtra State

Parameter→ Quarter↓	MMAX	MMIN	TMRF	Wind speed
1st	3.49	5.96	143.58	-40.52
2nd	0.25	-0.02	-13.30	-53.33
3rd	4.58	1.10	-21.87	-50.57
4th	5.43	8.86	8.79	-27.09

Table 2: Region-wise percentage change in parameters in the year 2017 with respect to 1975

Region	Parameter→ Quarter↓	M max	M min	T MRF	Wind speed
Amravati	1st	4.61	-5.06	48.22	-41.17
	2nd	1.81	-1.61	16.17	-86.93
	3rd	4.12	-3.28	-22.48	-92.45
	4th	8.95	12.92	-14.52	5.64
Aurang-abad	1st	3.95	9.50	-83.00	-57.52
	2nd	0.52	2.98	-9.45	-51.53
	3rd	1.01	2.69	-22.49	-26.66
	4th	3.96	10.04	-30.11	-60.88
Kankan	1st	5.5	8.09	757.14	-38.78
	2nd	3.43	2.60	-8.58	-31.04
	3rd	2.92	2.81	7.17	-14.50
	4th	3.82	8.79	73.10	-32.44
Latur	1st	1.47	1.39	601.97	-28.03
	2nd	-6.48	0.84	-22.41	-11.61
	3rd	16.12	0.54	-63.34	7.97
	4th	6.32	3.79	1.37	-30.00
Nagpur	1st	2.74	5.95	-51.92	-51.17
	2nd	-1.41	-3.32	-52.82	-48.45
	3rd	1.70	0.46	-31.27	-20.53
	4th	4.96	6.00	121.86	-22.99
Nasik	1st	3.80	10.16	253.33	-34.28
	2nd	1.96	1.38	-11.27	-45.64
	3rd	2.47	1.00	-11.86	-4.86
	4th	4.28	10.89	23.44	-4.24
Pune	1st	2.56	14.65	-67.28	-34.80
	2nd	2.55	-2.85	4.07	-38.96
	3rd	3.98	3.67	-39.20	-14.07
	4th	6.62	10.55	-37.24	-42.92

regions of Maharashtra over the period from 2012-13 to 2017-18 was shown as Figure 12. The current study found that MMAX and TMRF were the most significant factor in the prediction of inland fish production in most cases. The average increase in MMAX during the 2nd and 3rd quarters (April to September) is less than the average increase in MMAX during the 1st and 4th quarters. In addition, the current study also estimated that there was an average decrease in rainfall during the 2nd and 3rd quarters. The present study revealed that the maximum fish production for the Maharashtra state as a whole is coming from the MMAX temperature ranges 33–34°C and TMRF ranges from 70–95 mm. Though similar kind of studies for Maharashtra is limited, according to National Innovations in Climate Resilient Agriculture (Sharma et al., 2014) report for the West Bengal region, the MMAX temperature ranges from 30–32°C, which gave an idea about the changes in the inland sector and support the present study.

The current study also reported that (Figure 12) with respect to all seven regions of Maharashtra, Nagpur and Pune were the two most fish-producing regions, and the

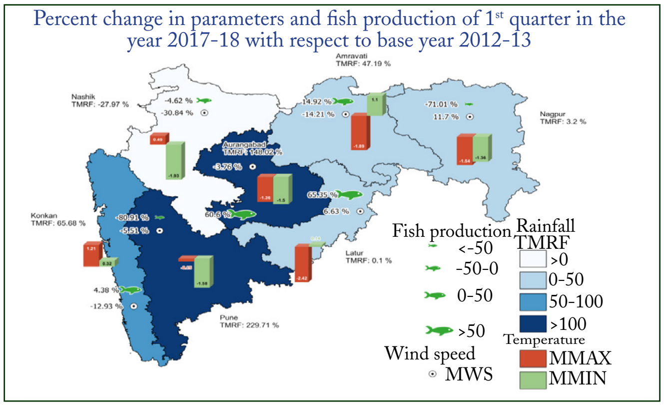

Figure 7: Thematic map showing the percent changes in parameters and fish production of 1st quarter in the year 2017-18 with respect to the base year 2012-13

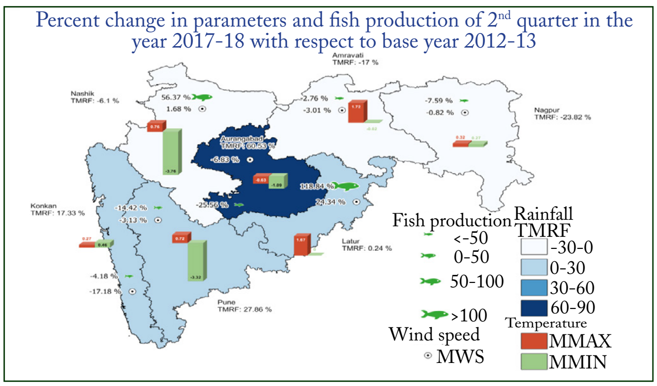

Figure 8: Thematic map showing the percent changes in parameters and fish production of 2nd quarter in the year 2017-18 with respect to the base year 2012-13

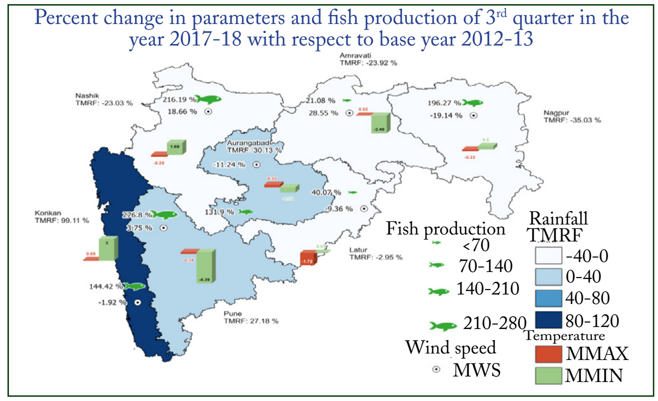

Figure 9: Thematic map showing the percent changes in parameters and fish production of 3rd quarter in the year 2017-18 with respect to the base year 2012-13

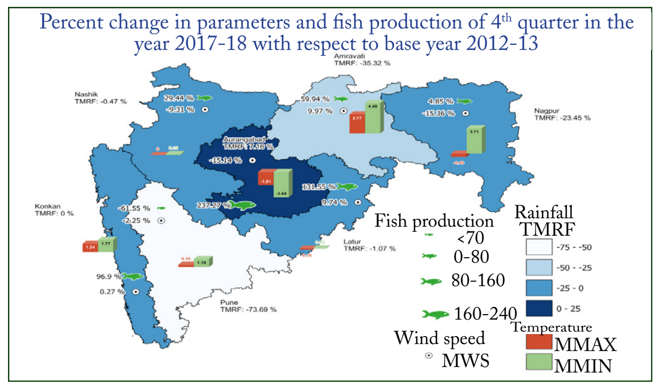

Figure 10: Thematic map showing the percent changes in parameters and fish production of 4th quarter in the year 2017-18 with respect to the base year 2012-13

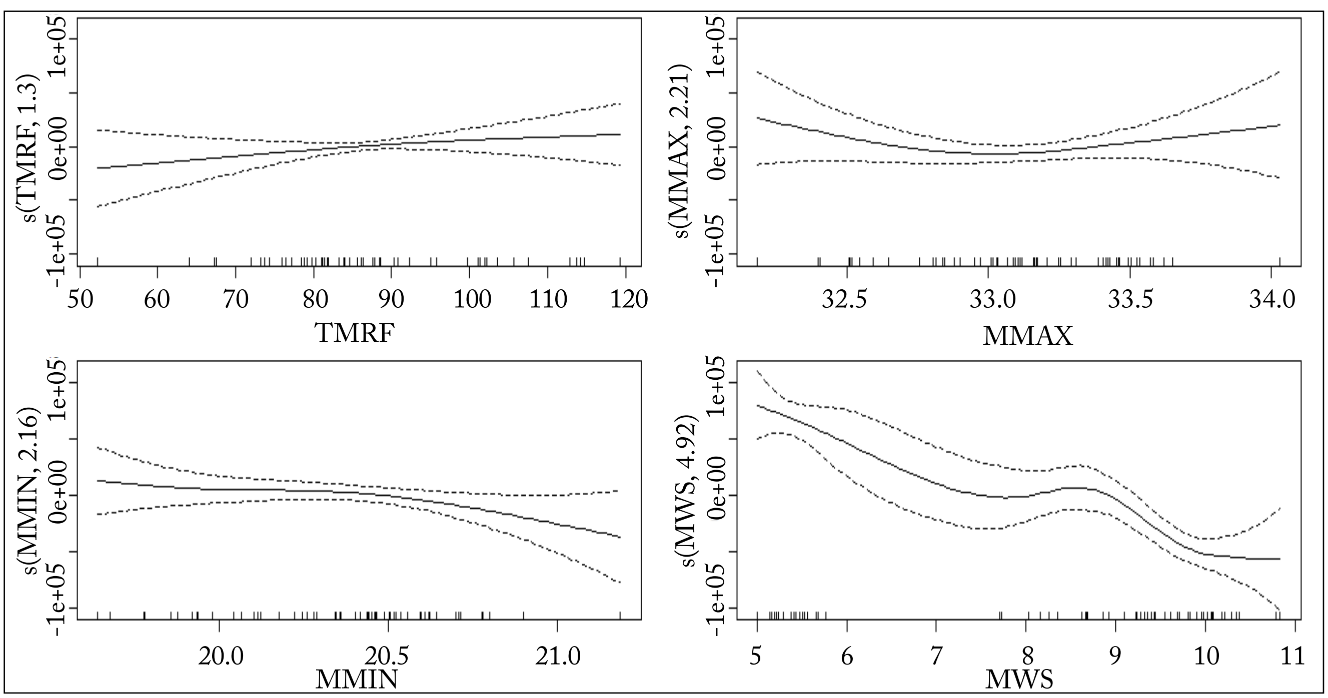

Figure 11: GAM analysis of fish production data of Maharashtra with climatic data

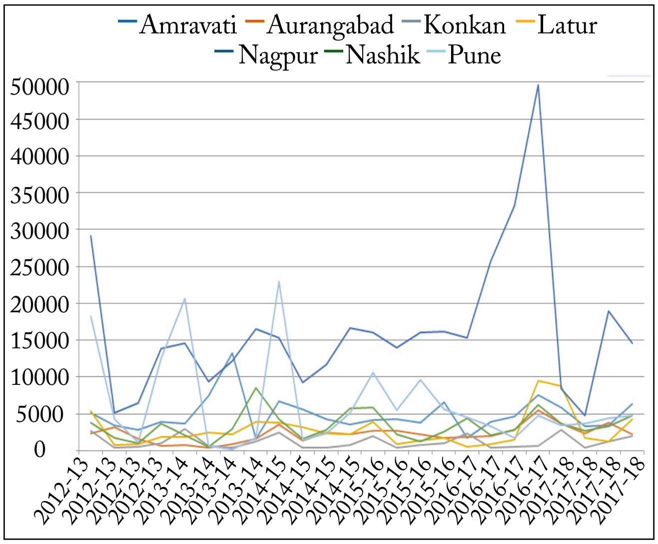

Figure 12: Distribution of inland fish production (in tons) of all the regions of Maharashtra over the period from 2012–13 to 2017–18

Konkan and Aurangabad regions were the two least fish producing region. The GAM plot analysis (not shown here) found, that in the case of the high fish productive region, the MMAX lies between 33–40°C. Whereas, in case of low production zone (Konkan) the MMAX temperature for maximum fish production varies from 31–32.5°C and TMRF ranges between 100–600 mm.

4. CONCLUSION

Increasing trend of different climatic variables will give a serious threat to inland fisheries production in near future. The increased temperature was resulting from several anthropogenic activities like deforestation, growth of industrialization, increasing population density, energy production by burning fossil fuels, etc. The erratic rainfall pattern increased the tendency of flood and drought in this region; also it reduced the availability of water resources for aquaculture and decreased the total production. Area-specific climate adaptations strategies should be developed by using spatial maps.

5. ACKNOWLEDGMENT

The authors are thankful to the ICAR-Central Institute of Fisheries Education, Mumbai, and the Indian Meteorological Department for providing the necessary data, supports, and facilities to carry out the study.

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