Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023:
http://dx.doi.org/10.7770/safer-V12N1-art2430

Cotton cultivating marginalised farmers' climate change perceptions, impacts and adaptation strategies in Vidarbha region, Central India.

Percepciones, impactos y estrategias de adaptación del cambio climático de los agricultores marginados que cultivan algodón en la región de Vidarbha, India central.

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ABSTRACT

This study aimed to assess cotton cultivating marginalised farmers' climate change perceptions, impacts, and adaptation strategies in the Vidarbha region of Central India. Purposive sampling was carried out to identify 70 marginalised farmers from the study area in the year 2020. A specially designed and developed questionnaire was used as a tool to elicit information from the respondent. From the identified sample population, 14.28% are illiterate and 34.28% with primary education and 42.85% don't use a cell phone. Climate change perceptions of these farmers are well understood and clear and reported rain pattern change (100%), wind profile change (81.42%) and high atmospheric temperature (75.71%). Of the different causes responsible for climate change crop residue burning is considered as a major (97.14%). Impacts of climate change on agriculture in general is reported as crop production reduced (95.71%) > crop growth reduction (85.71%) > reduction in soil fertility (81.42%) > irrigation water scarcity (65.71%). Impacts on cotton cultivation in particular include increase in insect/pest attack (90%) > production reduced (62.85%) > crop quality deteriorated (32.85%). The cost of insecticide/pesticide use is increased by 21-40% whereas profit received is decreased (71.42%). Heatstroke is identified as a major (66.66%) impact on livestock and death due to it (23.33%). Farmers willingness for adaptation to new methods is in the order of irrigation (82.85%) > harvest (72.85%) > during sowing (67.14%) > crop growth (51.42%). Future climate change adaptation strategies include high yielding crop varieties (100%) > early maturing crop varieties (60%) > use of organic manure (52.85%) > irrigated crops (48.57%) > drought-resistant crop varieties

(45.71%) > crop diversification (37.14%) > water use change (30%). The climate change-induced problems faced by these marginalised farmers are well defined and different from other farmer categories and needs a holistic approach to overcome them. Sustainable adaptation strategies emphasize on climate-smart agriculture is the need of the hour to pave the way for sustainable agriculture and sustainable livelihood. This may be perhaps the first study with this aim from the region.

Keywords: Central India, Chandrapur, climate change, climate smart agriculture, cotton, marginalised farmers, Vidarbha.

RESUMEN

Este estudio tuvo como objetivo evaluar las percepciones, los impactos y las estrategias de adaptación del cambio climático de los agricultores marginados que cultivan algodón en la región de Vidarbha en la India central. Se llevó a cabo un muestreo intencional para identificar a 70 agricultores marginados del área de estudio en el año 2020. Se utilizó un cuestionario especialmente diseñado y desarrollado como herramienta para obtener información del encuestado. De la población muestral identificada, el 14,28% son analfabetos y el 34,28% con estudios primarios y el 42,85% no utiliza celular. Las percepciones del cambio climático de estos agricultores son bien entendidas y claras e informaron cambios en el patrón de lluvia (100 %), cambios en el perfil del viento (81,42 %) y alta temperatura atmosférica (75,71 %). De las diferentes causas responsables del cambio climático, la quema de residuos de cultivos se considera una de las principales (97,14%). Los impactos del cambio climático en la agricultura en general se reportan como reducción de la producción de cultivos (95,71 %) > reducción del crecimiento de los cultivos (85,71 %) > reducción de la fertilidad del suelo (81,42 %) > escasez de agua de riego (65,71 %). Los impactos en el cultivo de algodón en particular incluyen un aumento en el ataque de insectos/plagas (90 %) > reducción de la producción (62,85 %) > deterioro de la calidad del cultivo (32,85 %). El costo del uso de insecticidas/pesticidas aumenta entre un 21 y un 40 %, mientras que las ganancias recibidas disminuyen (71,42 %). El golpe de calor se identifica como un impacto importante (66,66%) en el ganado y la muerte a causa del mismo (23,33%). La disposición de los agricultores para adaptarse a los nuevos métodos es del orden de riego (82,85 %) > cosecha (72,85 %) > durante la siembra (67,14 %) > crecimiento del cultivo (51,42 %). Las futuras estrategias de adaptación al cambio climático incluyen variedades de cultivos de alto rendimiento (100 %) > variedades de cultivos de maduración temprana (60 %) > uso de abono orgánico (52,85 %) > cultivos de regadío (48,57 %) > variedades de cultivos resistentes a la sequía (45,71 %) > diversificación de cultivos (37,14%) > cambio de uso del agua (30%). Los problemas inducidos por el cambio climático que enfrentan estos agricultores marginados están bien definidos y son

diferentes de otras categorías de agricultores y necesitan un enfoque holístico para superarlos. Las estrategias de adaptación sostenible enfatizan que la agricultura climáticamente inteligente es la necesidad del momento para allanar el camino hacia la agricultura sostenible y los medios de vida sostenibles. Este puede ser quizás el primer estudio con este objetivo en la región.
Palabras clave: India central, Chandrapur, cambio climático, agricultura climáticamente inteligente, algodón, agricultores marginados, Vidarbha.

INTRODUCTION

Agriculture plays a key role in the overall economic and social well-being of India. Change in climatic variability plays an important role in ensuring the food security of the world and the Indian economy. Agriculture and allied sectors are found to be most sensitive to climate change and any degree of change in weather parameters, i.e., temperature, rainfall, and relative humidity pose significant impacts. Climate change is likely to affect cotton production both positively and negatively. Temperature influences cotton growth and development by determining rates of fruit production, photosynthesis, and respiration (Hearn and Constable, 1984; Turner *et al*., 1986). Worldwide, cotton is already broadly adapted to growing in temperate, subtropical, and tropical environments, but growth may be challenged by future climate change (Bange *et al*., 2016).

Cotton is the fifth economically important cash crop globally. India is the world's largest producer and the second-largest exporter of cotton and is believed to be the original home of the cotton plant. It is also one of the most important industrial crops of India. As per the report from International Cotton Advisory Committee (ICAC), in October 2020, more than 6 million tonnes of cotton are produced in India. In the coming years, India is expected to expand its total to 6.2 million tonnes. The central zone of India cultivates cotton as a full-season crop, which constitutes states of Gujarat, Maharashtra, and Madhya Pradesh. Maharashtra (98%) and Madhya Pradesh (80%) have been dominated by rainfed cotton cultivation, where climatic conditions are exclusively favourable for the development of superior medium cotton and long-staple cotton (Agarwal, 2008).

Top cotton-producing (in million bales and 1000 metric tons) countries in the world for 2019-20 are presented in Table 1. From the table, it can be seen that India tops the rank with 29.5 million bales (6423 metric tons) followed by China and the USA. In the case of India, cotton cultivation area, production and productivity are presented in Table 2. Provisional cotton cultivation area for 2019-20 is 12.58 million hectare (ha) and production is 36.00 million bales which is about 486 kg/ha. In a comparison of previous data from 2000 to 2015, it can be observed that a steady increase in cotton cultivation area, production, and productivity.

Table 1: Top cotton producing countries in the world (2019-20)

Country	Production (in million bales)	Production (in 1000 metric tons)
India	29.5	6423
China	27.25	5933
USA	19.8	4336
Brazil	13	2918
Pakistan	6.6	1350

Source: United States Department of Agriculture

Table 2: Area, production and productivity of cotton in India

Year	Area in million ha	Production in million bales of 170 kgs	Yield (kg/ha)
2000-01	8.576	14.00	278
2004-05	8.786	24.30	470
2009-10	10.31	30.50	503
2014-15	12.84	38.60	513
2019-20 (P)	12.58	36.00	486

Source: Cotton Advisory Board, P-Provisional

Table 3 presents information about the state-wise area, production, and productivity of cotton in India for 2019-20. It can be seen that Maharashtra has a maximum (4.25 million ha) area under cotton cultivation whereas maximum production is reported from Gujarat (9.5 million bales). Maximum cotton yield is observed from Tamil Nadu (778.63 kg/ha). Cotton cultivation area, production, and productivity in Maharashtra for the last decade (2010-20) is presented in Table 4. From the table, it can be seen that there is a steady increase in cotton cultivation area during the last decade from 3.94 million ha (2010-11) to 4.36 million ha (2019-20). The production and yield have shown fluctuation during the decade.

Maharashtra is the second-largest producer of cotton in India and produced 8.2 million bales of cotton in India (Table 4). Vidarbha region is amongst the maximum cotton-growing region of India. It contributes 30 percent of the crop followed by the Marathwada region. For the past few years, agriculture researchers discovered that extreme climatic events like drought, hailstorms, heat wave, floods, frost, unseasonal and erratic rains have played havoc with cotton cultivation in Maharashtra.

The ability of cotton to survive in elevated temperatures largely depends on water availability and the extremity of weather pattern, even though it can survive in a hot climate. Cotton production is sensitive to frost too. The additional problem will be enhanced due to increased rainfall intensity during the monsoon. Cotton development and fruit formation will be hampered by elevated temperature in hot areas. Maharashtra grows rainfed cotton which will suffer due to increased climatic variability. Rainfed cotton production in Maharashtra may suffer from climatic variability on large scale leading to conditions of drought and flooding (Hebbar *et al*., 2013).

Table 3: State wise area, production and productivity of cotton in India (2019-20)

State	Area (million ha)	Production (million bales)	Yield (kg/ha)
Gujarat	2.65	9.5	556.22
Maharashtra	4.25	8.2	307.71
Telangana	1.82	5.3	437.33
Rajasthan	0.62	2.5	675.68
Haryana	0.70	2.2	552.26
Madhya Pradesh	0.57	2.0	664.50
Karnataka	0.68	1.8	370.64
Punjab	0.26	1.3	729.48
Tamil Nadu	0.13	0.6	778.63
Odisha	0.15	0.4	484.18

Source: Cotton Corporation of India

Table 4: Area, production and productivity of cotton in Maharashtra

	2010-11	2011-12	2012-13	2013-14	2014-15
Area	3.94	4.12	4.14	4.19	4.19
Prod.	8.77	7.60	8.10	8.40	8.00
Yield	378	313	332	341	325
	2015-16	2016-17	2017-18	2018-19	2019-20
Area	4.20	3.80	4.35	4.25	4.36
Prod.	7.60	8.85	8.33	7.55	8.20
Yield	307	396	326	302	319

Source: Cotton Advisory Board, Area in million ha, Prod. in million bales 170 kg, Yield kg/ha

Cotton is considered an important cash crop to small-scale farmers and it contributes to economic growth in developing countries (Mohapatra, 2002). Cotton is known as a water-intensive crop where almost 7,000-29,000 litres of water are required to grow one-kilogram cotton (Soth, 1999). To produce cotton lint, 5019 m^3/ton of blue (irrigation) and 15198 m^3/ton green (rain) water are required, making Indian cotton one of the most water-intensive cotton in the world, using 15% of the water resource of the country (Jasserina, 2007). Cotton needs suitable growing conditions of temperature, sunlight, and soil moisture. Research states that a 1-4^{o}C increase in temperatures causes a decrease in the yield potential of the crop. The period of the dry season is necessary to dehiscence of bolls properly, which is a substantial step of harvesting of cotton (Ton, 2011). In India, alone cotton accounts 54% of the national pesticide use which has been estimated to USD$ 344 million, even though it only takes up 5% of the arable land. Approximately 1 kg of pesticide is applied per hectare of cotton which makes cotton the crop that requires the greatest insecticide usage than any other crop. Indian cotton is one of the most affected by insect infestation, with approximately 50% damage compared to 25% for the rest of the world (Jasserina, 2007).

Print and online literature review revealed that no study was carried out on the climate change impacts on marginalised farmers in the cotton-growing region in India. Thus, this is the identified gap in the subject domain. This study aims to assess cotton cultivating marginalised farmers' perceptions of climate change, impacts, and adaptation strategies adopted and willing to use in the future which has not yet been done in the study region. This study outcome will add a new understanding of climate change impacts on marginalized farmers in the cotton-growing region of Maharashtra state. Furthermore, the initiatives to be taken at crop, local, regional and national level to reduce the vulnerability of these farmers to climate change and pave a way for sustainable adaptation strategies for a secured livelihood and sustainable farming.

MATERIAL AND METHODS

Study Area: To carry out this study three districts of Maharashtra state viz. Amravati, Wardha and Yavatmal were selected (Figure 1). Amravati district is a district of Maharashtra state. The district is situated between 20°32' N to 21°46' N latitudes and 76°37' E to 78°27' E longitudes. The total geographical area of the district is 12,212 sq km. About 75% of the district is covered by the Deccan trap while 25% area is covered by Purna alluvium. The maximum temperature during summer goes up to 47^{o}C while the minimum temperature during winter drops to 5-9^{o}C. The district receives rainfall from the southwest monsoon. The average annual rainfall is 700-800 mm. In the district, 91.50% area is exclusively under rainfed cropping. The total area under Kharif crops is 6,83,700 ha, while 1,06,200 ha is under rabbi crops. The area under irrigation is 80,543 ha, which is 8.5% of the total cultivated area. Cotton is the main cash crop of the district; covering an area of 3,27,901 ha (34.60% of the total cropped area). The district economy is predominantly agro-based.

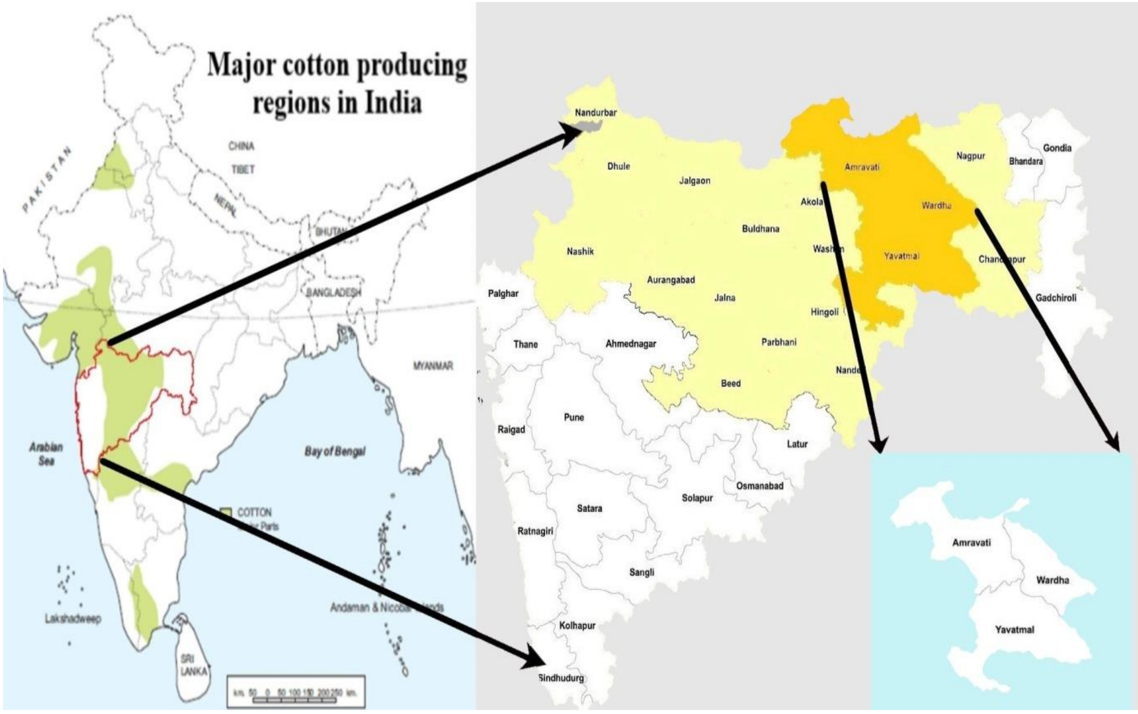

Fig. 1: Study area

Wardha district (20°15′N to 21°21′N and 78°30′E to 79°15′E) is situated in Maharashtra state. The district has an area of 6,309 sq km and the total population is 1.3 million of which 73.70 percent population live in rural areas (Census of India, 2011). The climate is characterised by a hot summer and general dryness throughout the year except during the southwest monsoon season. In summer temperatures can go up to higher than 46°C and in winter the temperature drops to 9^{o}C. The average annual rainfall is 1090.3 mm out of which rainfall during the period from June to September contributes to about 87 percent and July being the wettest month. Black soil is the predominant soil type in this district. Kharif and rabi are the two agricultural seasons of the district, and Kharif has always been the most important season concerning area brought under cultivation. The Kharif season begins in mid-June with the onset of the monsoon and extends up to December depending on the type of crop sown. The rabi season commences in October and extends up to February or March. The important crops grown in the Kharif season are cotton, sorghum, and pulses, and since the mid-1980s, cotton and soybean have become an extremely important Kharif crop in the district. Of the total cropping area, cotton covers an area of 1,48,000 ha. In the rabi season, wheat or gram are cultivated.

Yavatmal district is located between 19^{o}26′ N to 28^{o}42′ N and 77^{o}18′ E to 79^{o}18′ E in the Maharashtra state. The district covers an area of 13,582 sq km. According to the Census of India 2011, the district had a population of 2.77 million. The district is in the southern mountain ranges of Berar, situated on a wide plain surrounded by hilly terrain and mountain ranges running east to west. The central part is a plateau 300 to 600 metres (980 to 1,970 ft) above sea level. The climate of the district is hot and dry. In summer, the maximum temperature of the district goes up to 45.6°C and the temperature drops to minimum 5.6°C in winter. The district receives an average annual rainfall of 911.34 mm. This generally increases from west to east, with 889 mm in the western region of the district and 1,125 mm in the east. Almost all of the rain falls during the southwest monsoon season. More than 75% of rainfall in the district is received in the Kharif season, hence the Kharif cropping system predominates in the zone. In general, all types of soils are observed in this district. Preferably, medium and heavy in texture, fairly high in clay content, alkaline in reaction, high lime reserve with high base saturation of the exchange complex. The soils are severely eroded and shallow. The district has cotton cultivated area of 4,05,000 ha (40.28%) out of 10,05,265 ha of total cultivable land available for agriculture.

The study area was selected based on cotton as the main crop. To assess marginalised farmers' perceptions of climate change, perceived impacts on cotton cultivation, and adaptation behaviour and capacity, marginalised farmers from all the three districts were identified as sample population. The inclusive criterion for the study was those farmers which have agricultural land size ≤ 1.0 ha (≤ 2.5 acres) i.e. marginalised farmers. Three villages from each district and more than 20 marginalised farmers in each district were randomly selected. In total nine villages were selected for data collection through the field survey. The various villages covered under the study include Bhatkuli, Sayat, and Antapur from Amravati district; Sindi, Palasgaon, and Hiwra from Wardha district and Murli, Nukti, and Belora from Yavatmal district. Purposive sampling was used to identify the sample population. A total of 70 sample population were taken for this study. The study was carried out in February and March 2020. The quantitative approach was used for data collection.

Primary data was collected by eliciting the information from these marginalised farmers in a specially designed and developed questionnaire that emphasized climate change perceptions, impacts assessment during sowing, crop growth, post-harvest, livestock, and adaptation strategies used and planned to execute in the future. Likert scale was used for the responses of the questions to get quantitative and comparable responses. The collected data was analysed with the help of Origin pro. Secondary data viz. study area, climate, rainfall, demographic profile, etc. were gathered from government databases such as Census of India, government district data, and India Meteorological Department.

RESULTS AND DISCUSSION

Profile of the sample population: Of the 70 marginalised farmers identified for this study, 94.28% (n = 66) were male and 5.71% (n = 4) female. The major occupation of these farmers is cotton cultivation (100%) and livestock rearing (42.85%). They are engaged in rainfed cotton cultivation (100%) and only 30% had irrigation facility. In the field activities, they receive assistance from their family members, especially from their wife (57.14%) and son (35.71%) and also other farm labourers (28.57%). Maximum farmers (81.42%) carry out crop cultivation activity once a year as cotton is a long period crop (six to eight months). Of the total farmers, 14.28% were illiterate and 34.28% had primary education and stays in a nuclear family (81.42%). Maximum (98.57%) farmers own the agricultural land on which cotton cultivation is being carried out, whereas 1.43% had it on a lease basis. Total 46% of farmers do not have a soil health card and 40% never tested farm soil quality. The cell phone use profile of the farmers indicates, 42.85% of farmers don't use a cell phone and of the remaining (57.14%), 44.28% had a feature phone and only 12.85% had a smartphone. Of the study population, 34.28% belongs to below poverty line (BPL) and all farmers had ration card (food-grain card) and purchase food gains from government outlets. Monthly electricity consumption for domestic purpose is maximum (64.28%) in the range of Rs. 251-500 (US$ 3.25-6.49) and less than Rs. 250 (US$ 3.24) in 14.28%.

Perceptions of climate change

Marginalised farmers' perceptions regarding environmental aspects they have experienced as varying due to climate change are depicted in Figure 2. All farmers reported rain pattern change followed by wind profile change (81.42%) and high atmospheric temperature (75.71%). Due to rain pattern change and high temperature, an increase in drought incidents (55.71%) has been reported. Prolonged summer (75.71%) and winds getting warmer (67.14%) are perceived climate change impacts in summer (Figure 3). In the rainy season (Figure 4) uneven rainfall (98.57%) followed by the late onset of rain (87.14%) is reported. A short period of winter (90%) and a decrease in cold severity (80%) are important changes reported by farmers (Figure 5). Forest vegetation cover decreased (61.42%) in the last ten years is another observation reported by them (Figure 6). Of the different causes responsible for climate change, crop residue burning (97.14%) is perceived as a major agricultural activity responsible for it (Figure 7). Destruction of the cotton crop by climate change is reported by 62.85% of farmers whereas 60% reported partially (Figure 8).

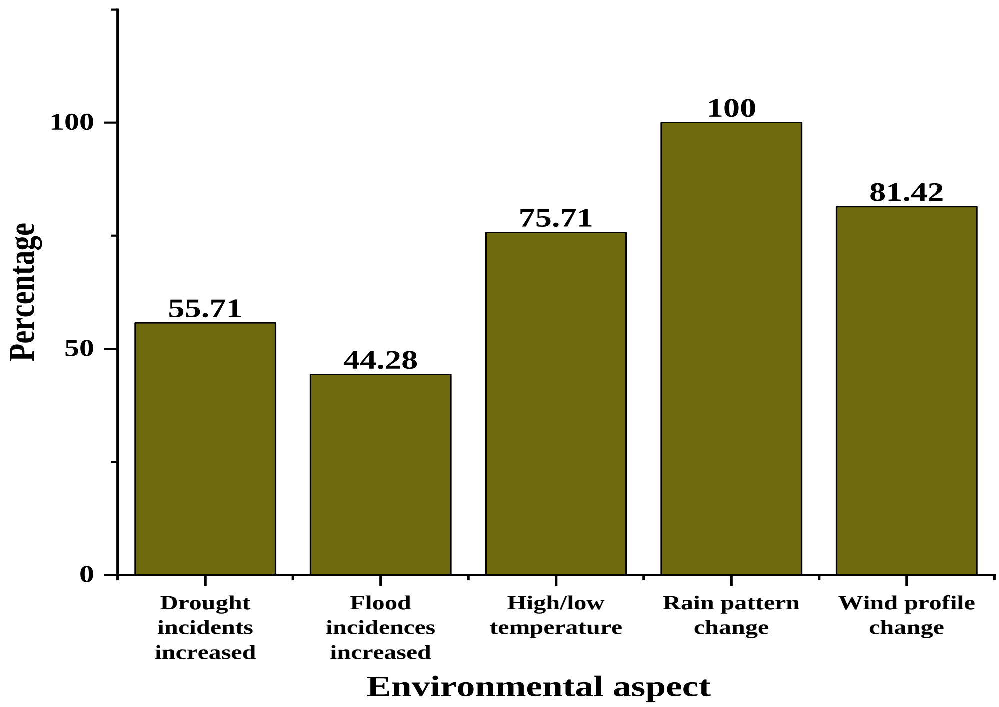

Fig. 2: Climate change perceptions in various environmental aspects

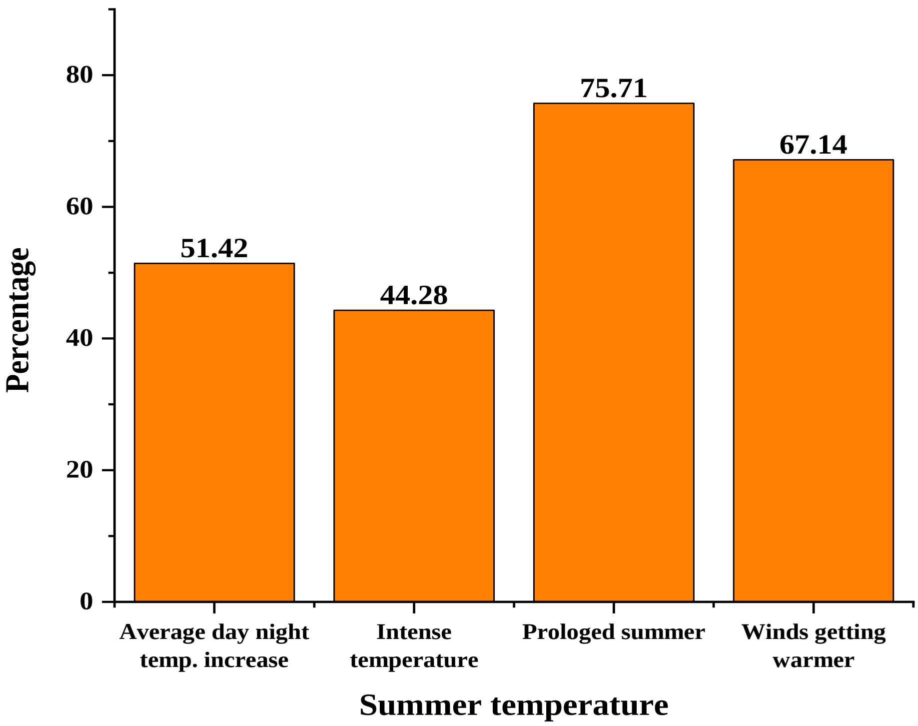

Fig. 3: Climate change perceptions for the summer season

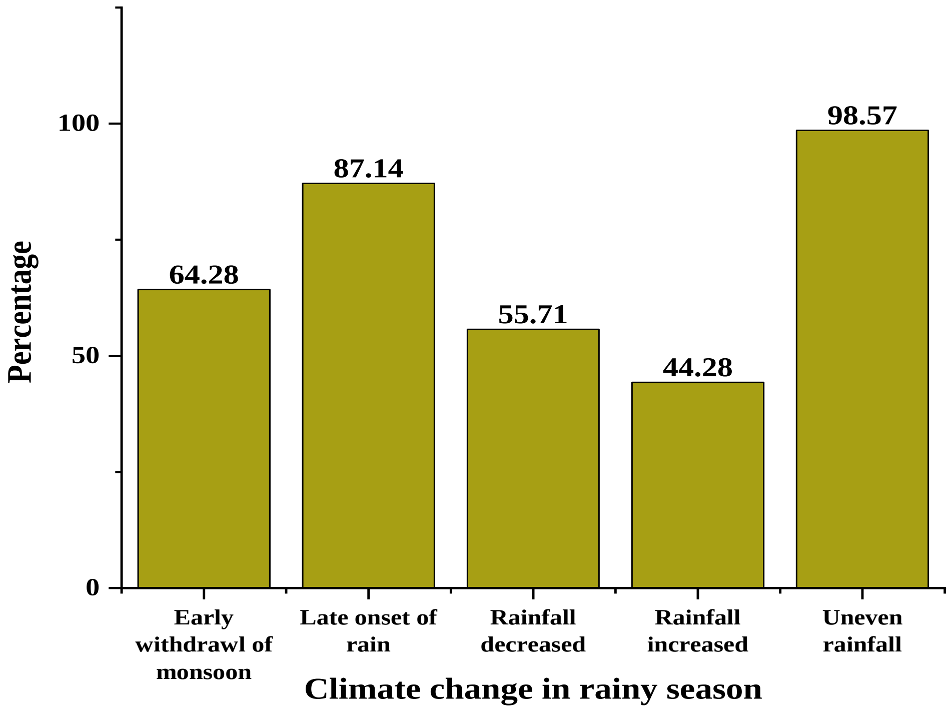

Fig. 4: Climate change perceptions for the rainy season

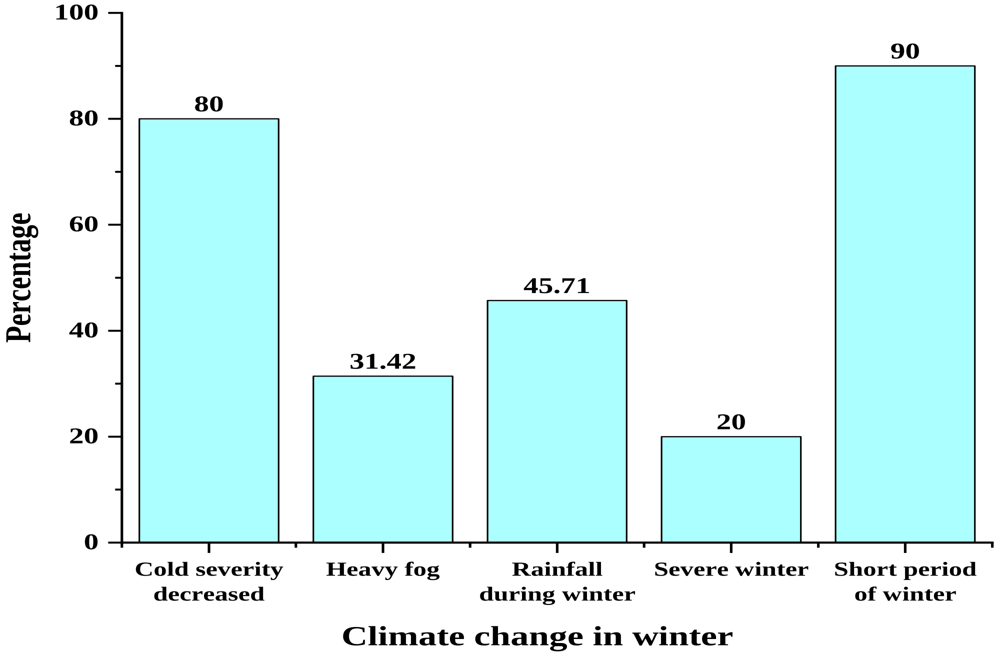

Fig. 5: Climate change perception for the winter season

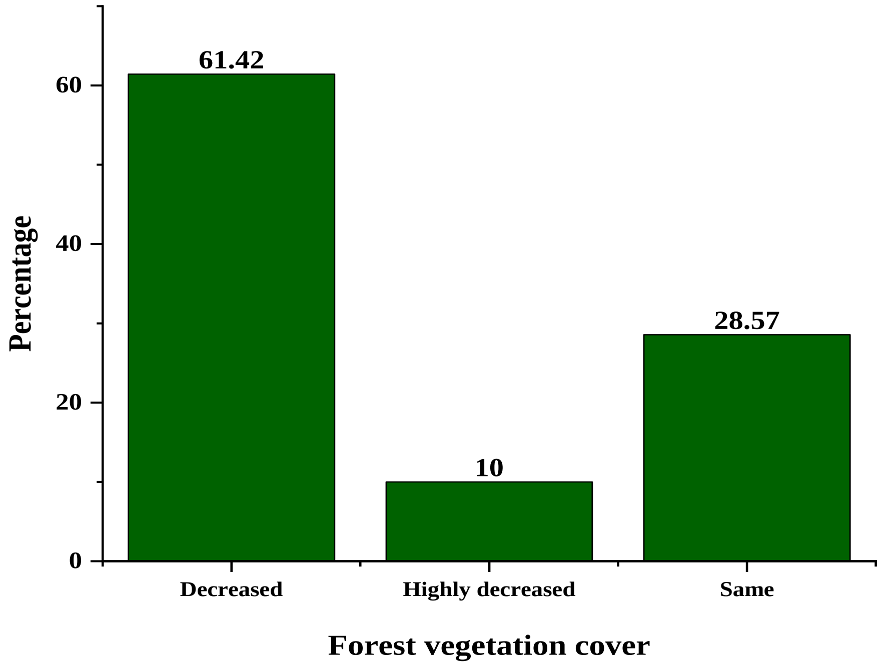

Fig. 6: Climate change perception for forest vegetation cover

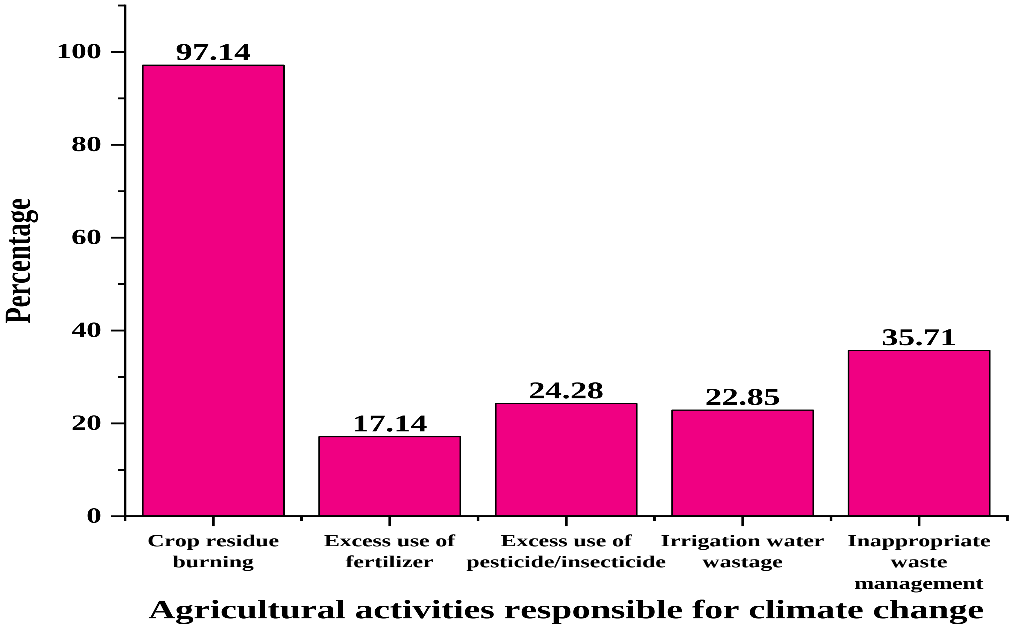

Fig. 7: Agricultural activities responsible for climate change

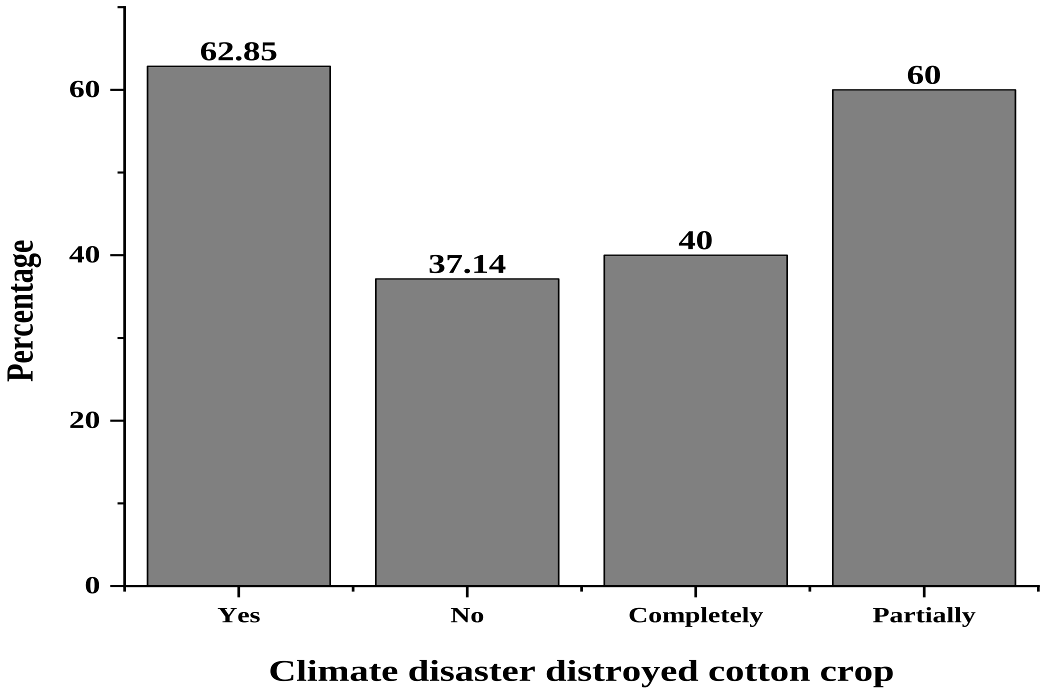

Fig. 8: Climate change destroyed the cotton crop

Perceived impacts of climate change on cotton cultivation: Impacts of climate change on various cotton cultivation related agricultural activities revealed, soil moisture reduction (52.85%) followed by increased soil erosion (15.71%) (Figure 9). In the case of impacts on irrigation, the quantity of surface water decreased (61.42%) and quality deteriorated (52.85%) are reported. On the contrary, groundwater quality and quantity are marginally affected (Figure 10). Figure 11 depicts the effects of less irrigation water on cotton cultivation. From the figure, it can be seen that insect/pest attacks increased (91.42%) and poor quality of yields (44.28%). Impacts of climate change on agriculture (Figure 12) reported crop production reduced (95.71%), crop growth reduction (85.71%), reduction in soil fertility (81.42), and irrigation water scarcity (65.71%). Figure 13 presents impacts of climate change on cotton production with 90% reporting insect/pest attack increased, production reduced (62.85%) and quality deteriorated (32.85%). Cotton yield per acre in the last five years is presented in Figure 14. Farmers have reported a decrease (71.42%) in cotton yield and this is in the range of 0-20% (55.71%), whereas 21-40% is reported by 28.57%.

Cost of insecticide/pesticide use during cotton cultivation is increased in the range of 21-40% (50%) and 0-20% (40%) (Figure 15). In the case of profit received from cotton cultivation (Figure 16) 71.42% of farmers reported a decrease in profit in the range of 0-20% (34.28%) and 21-40% (28.57%) and 41-60% (14.28%). Impacts of climate change on livestock are reported as heatstroke (66.66%) and death due to it

(23.33%). Monsoon season has adverse impacts on livestock (96.66%). Vector-borne diseases increased (80%) and production loss is reported by 66.66% farmers (Figure 17). To manage the challenges posed by climate change farmers had availed loans from various sources (Figure 18). Government banks were the main source for agriculture loans (68.57%) followed by a loan against the mortgage of gold jewellery (71.42%) and a loan from a moneylender (22.85%).

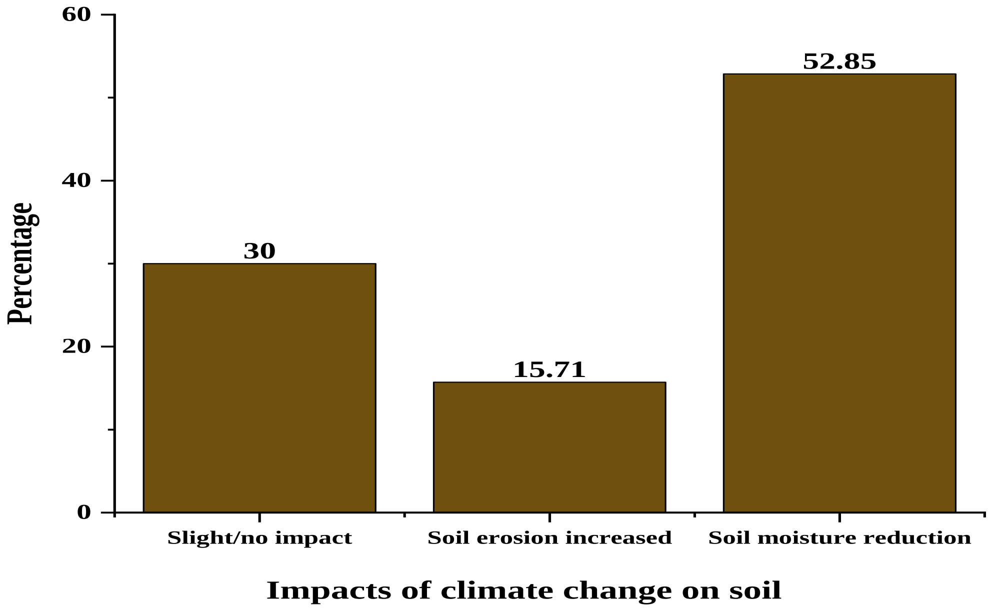

Fig. 9: Impacts of climate change on soil

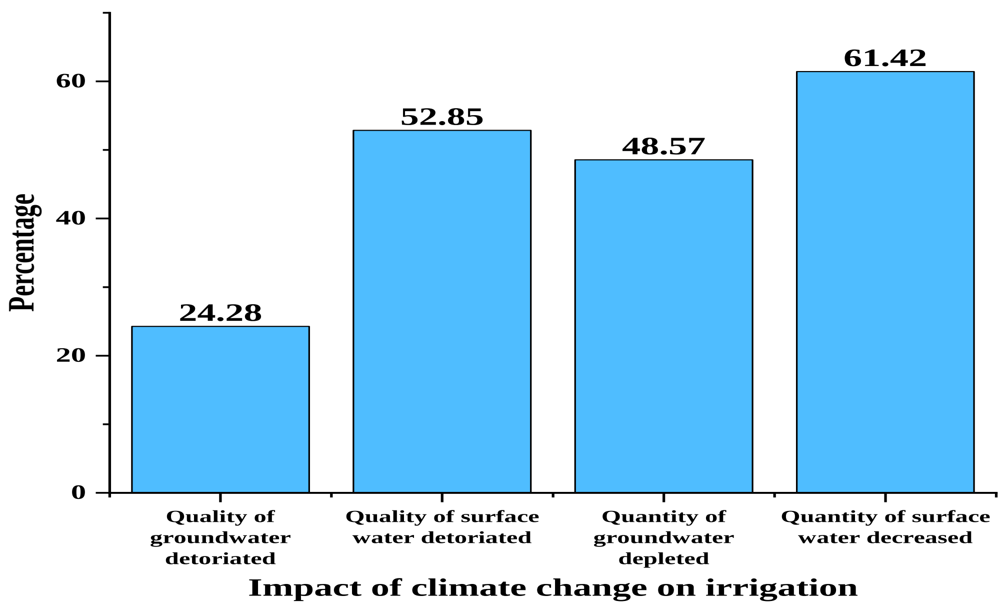

Fig. 10: Impacts of climate change on irrigation

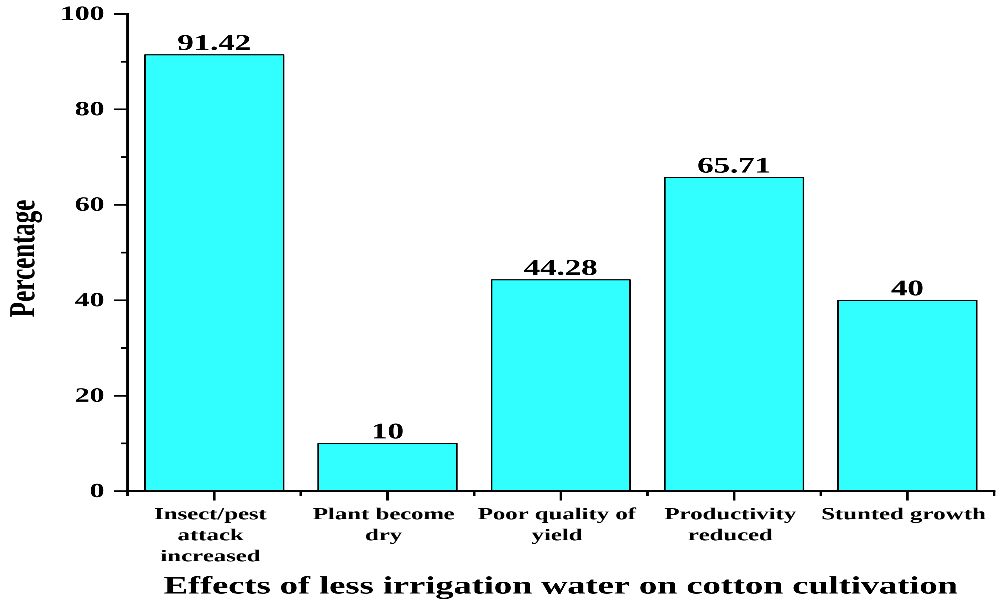

Fig. 11: Effects of less irrigation water on cotton cultivation

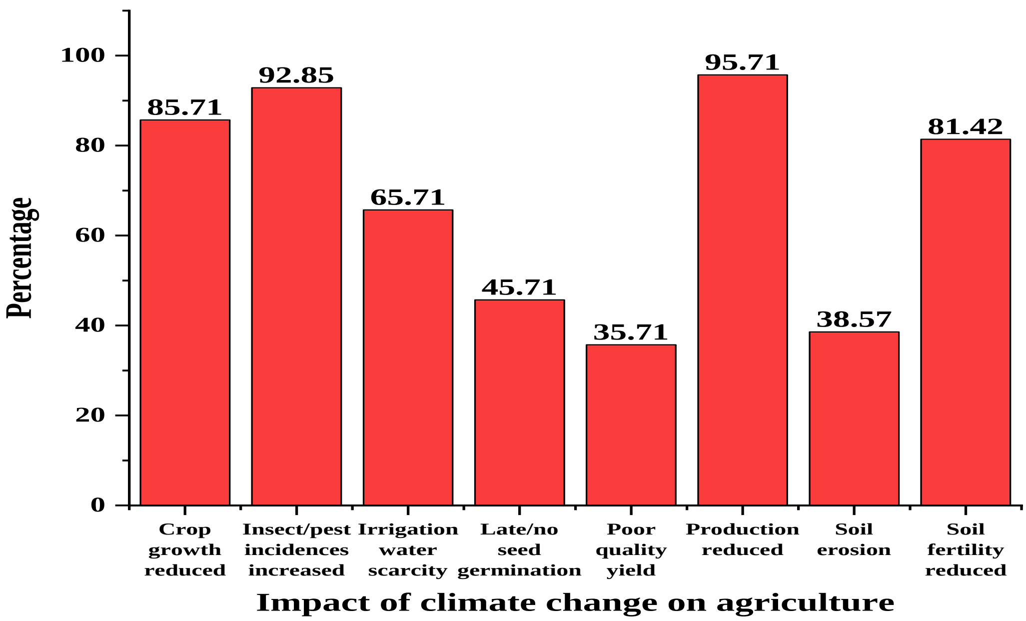

Fig. 12: Impacts of climate change on cotton

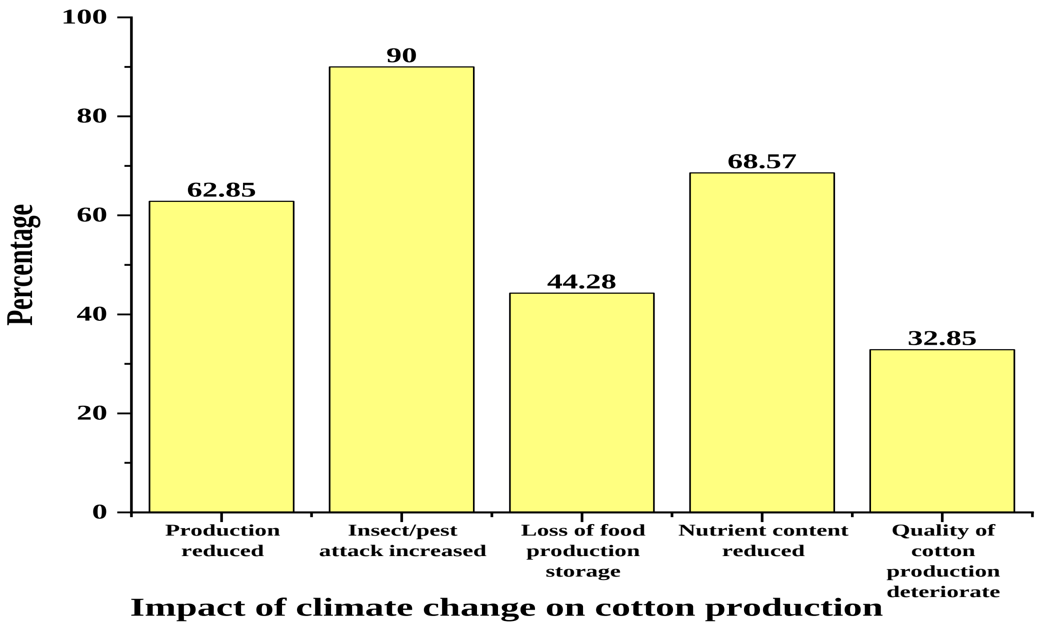

Fig. 13: Impacts of climate change on cotton production

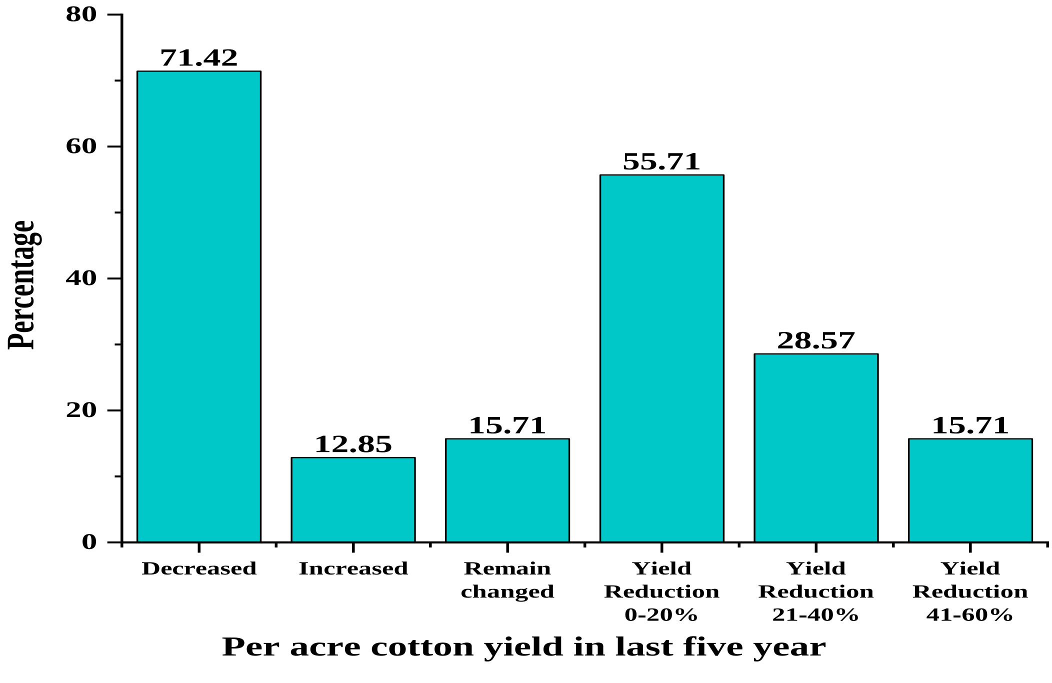

Fig. 14: Per acre cotton yield in last five years

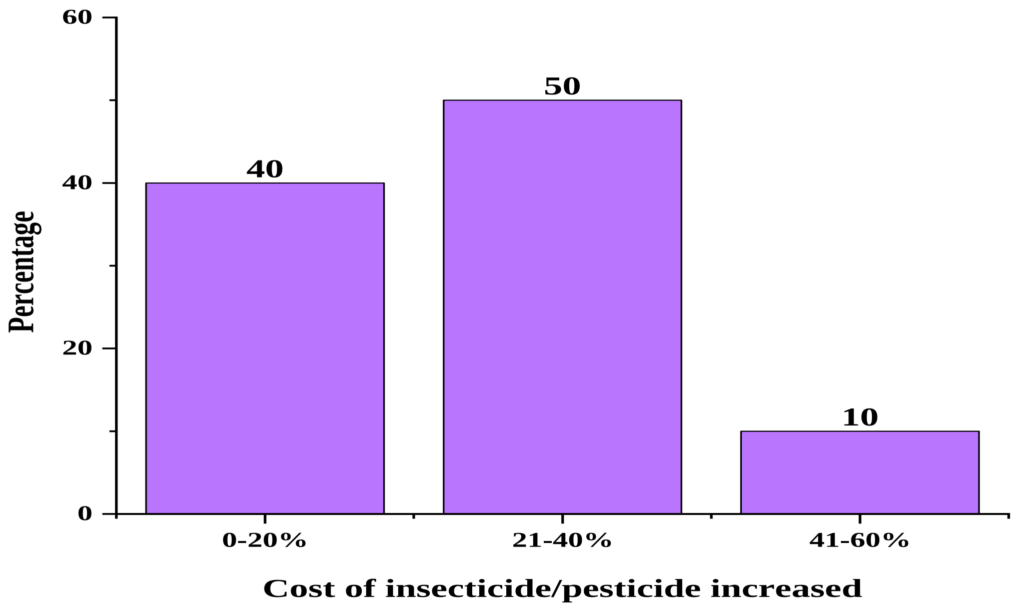

Fig.15: Cost of insecticide/pesticide in cotton cultivation

Fig. 16: Profit received from cotton cultivation

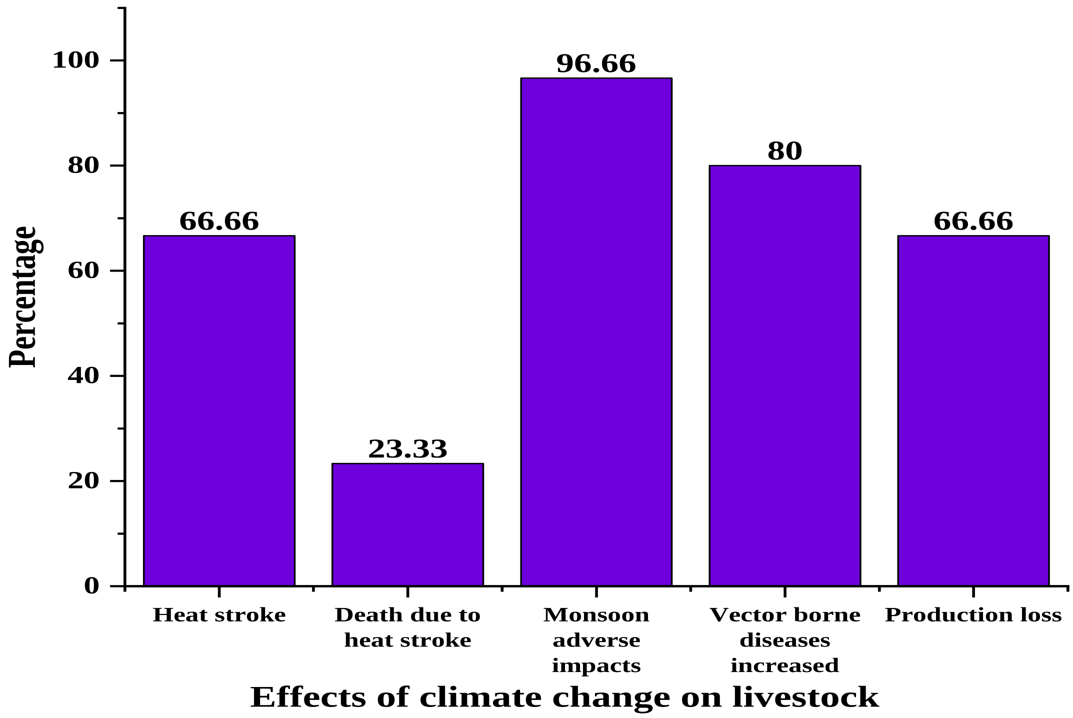

Fig. 17: Impacts of climate change on livestock with cotton producer

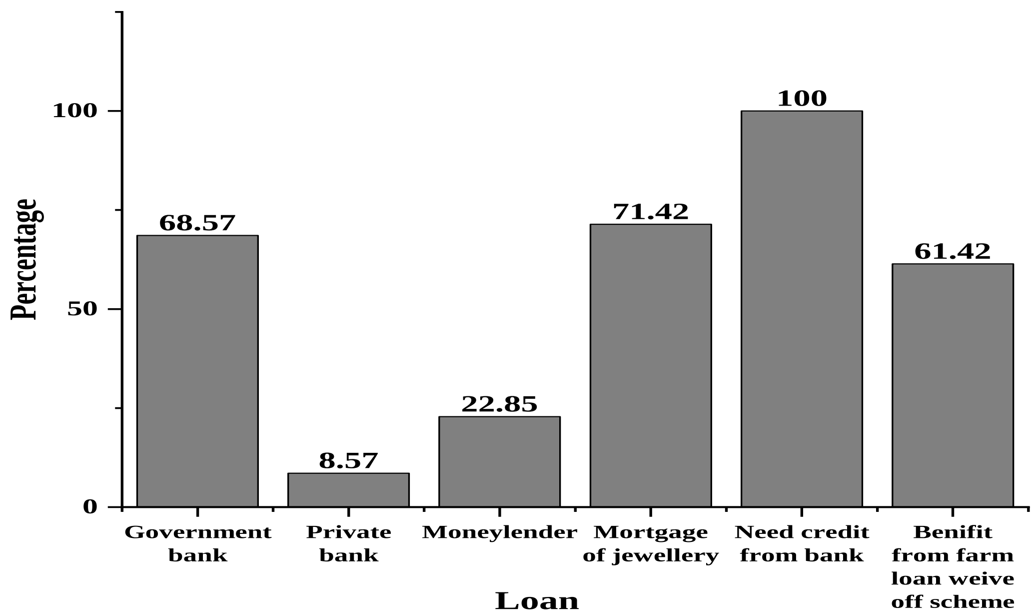

Fig. 18: Loan facility availed by farmers

Adaptation behaviour and capacity: Farmers' willingness for adaptation to climate change is reported by 90% (Figure 19). This willingness is in the order of irrigation (82.85%) > harvest (72.85%) > during sowing (67.14%) > crop growth (51.42%). To cope up with climate variability (Figure 20) farmers have a desire for a better weather forecast (100%) and they have shown poor response to adopting new cropping technology (51.42%) followed by a change in cropping pattern/crop management (41.42%). Measures to be taken for effective irrigation water management during climate change (Figure 21) includes an adaptation of a rainfed crop (81.42%) followed by mulch for decreasing evaporation of water from the soil (74.28%). No response was recorded in favour of the use of modern rainwater harvesting technology. To manage the water demand during non-availability season (Figure 22) is most relied on nearby river or canal (25.71%) followed by borewells/pump well (17.14%) and farm pond (15.71%). Future adaptation strategies for climate change are depicted in Figure 23. From the figure it can be seen that it is in the order of high yielding crop varieties (100%) > early maturing crop varieties (60%) > organic manure (52.85%) > irrigated crops (48.57%) > drought-resistant crop varieties (45.71%) > crop diversification (37.14%) > water use change (30%).

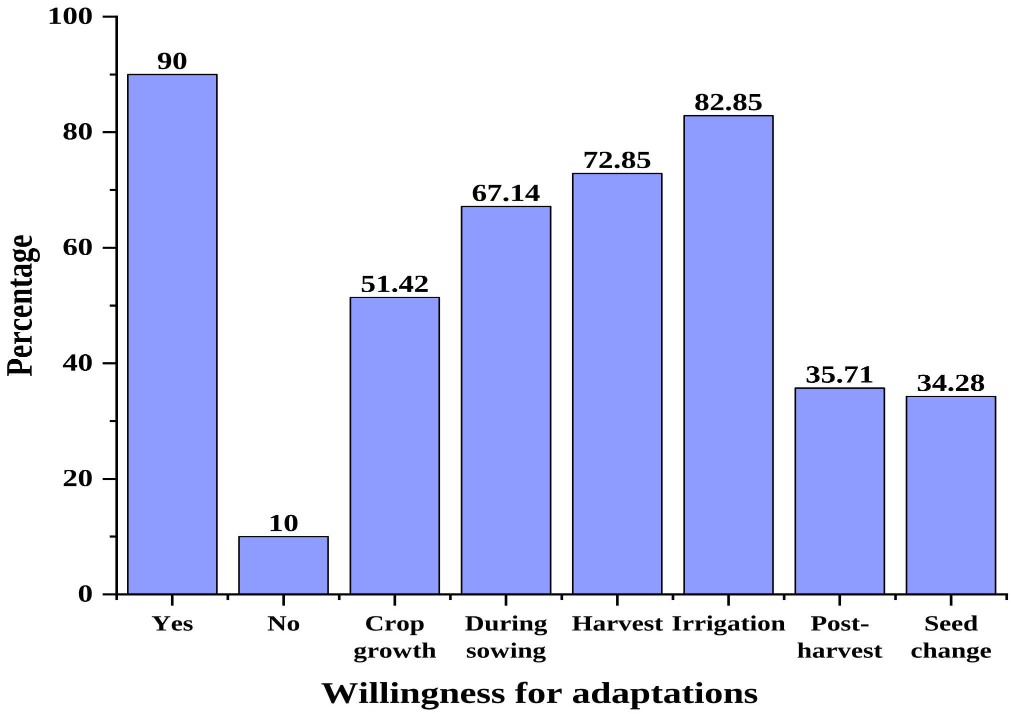

Fig. 19: Farmers willingness for climate change adaptation

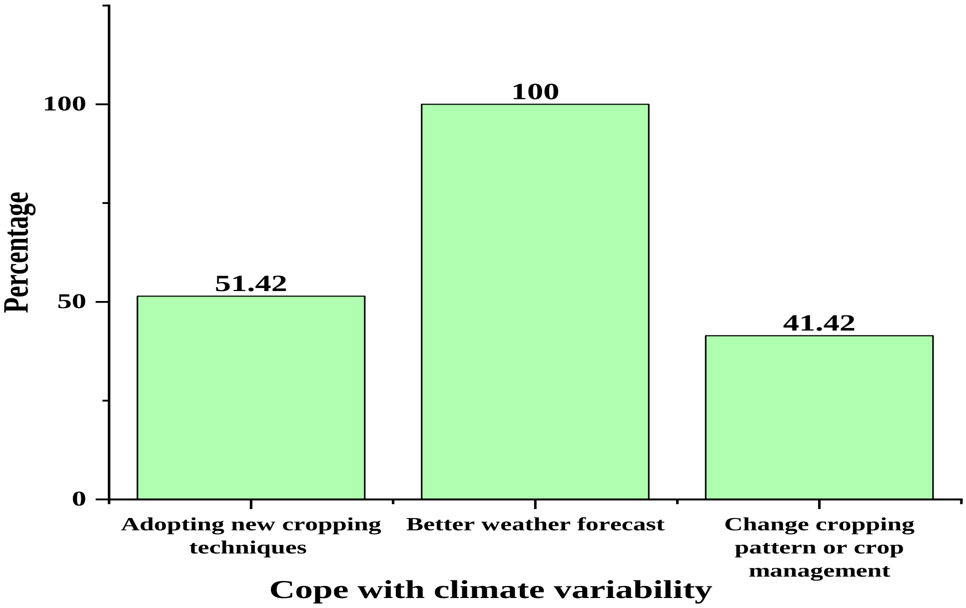

Fig. 20: Cotton cultivator's coping with climate change

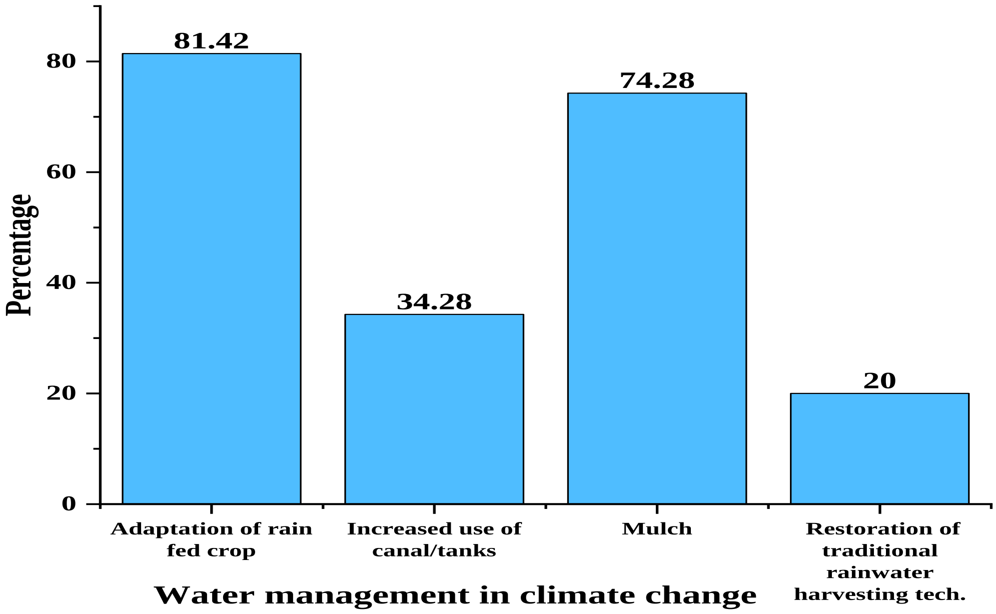

Fig. 21: Water management strategies for climate change

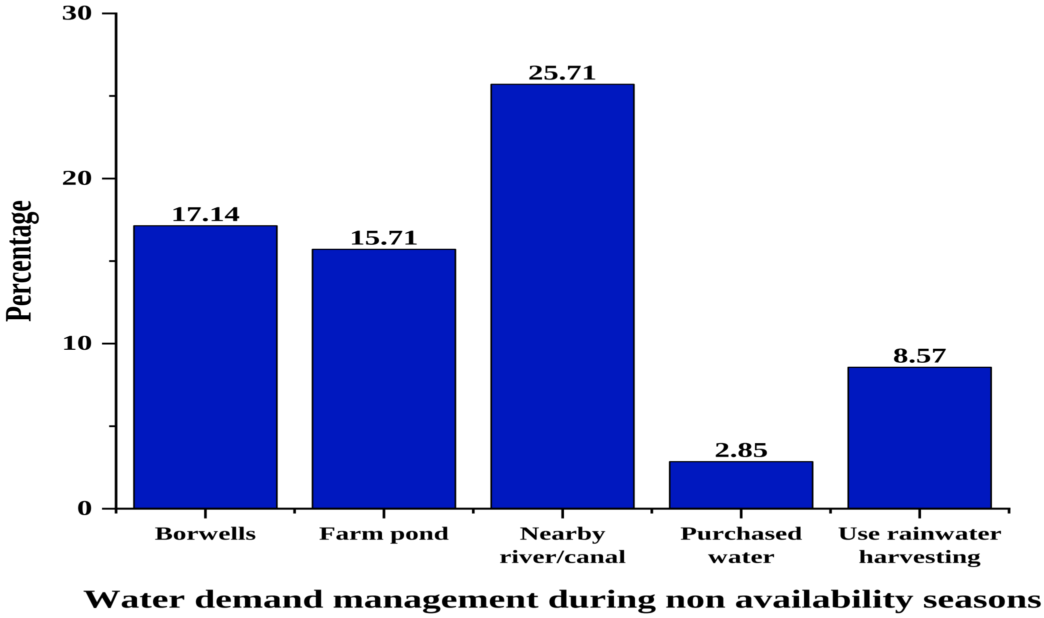

Fig. 22: Water demand management during non-availability season

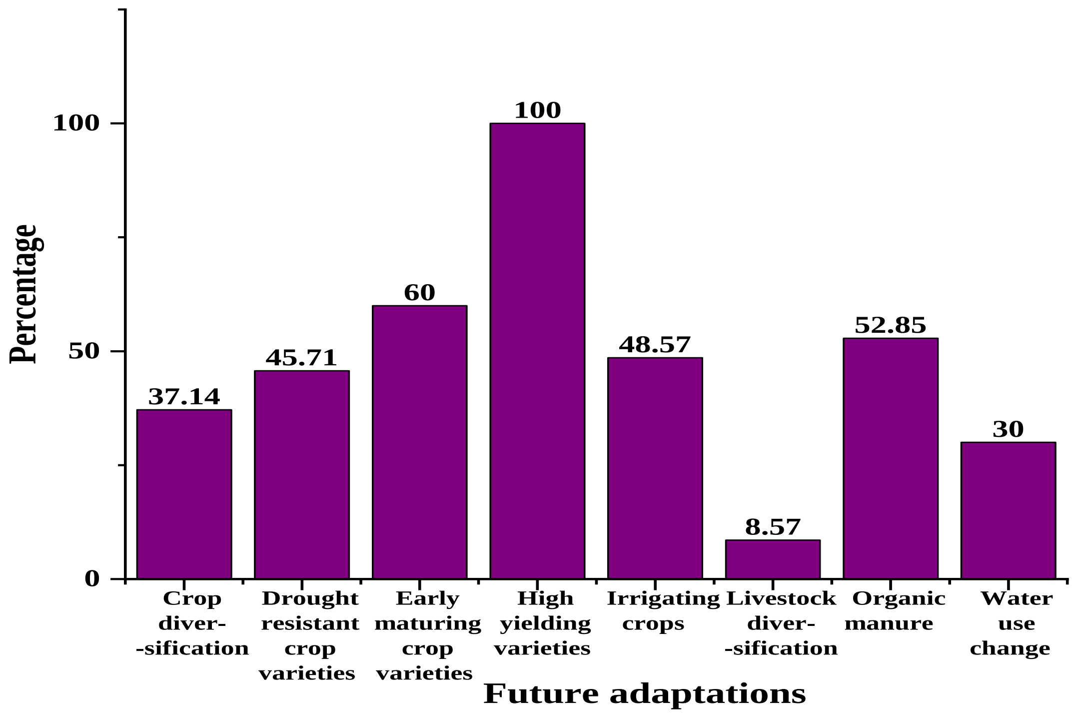

Fig. 23: Future adaptation strategies for climate change

Developing cultivars with adaptive traits to improve sustainability in the face of climate change is an important option for climate-smart agriculture (Gerardeaux *et al.*, 2018). Adaptive measures such as changes in planting time and more responsive cultivars may further boost cotton production in India (Hebbar *et al*., 2013). High-density short-season cotton could increase yields and reduce input costs in irrigated and rainfed cotton (Gutierrez *et al*., 2015). Future adaptation strategies reported by the farmers from the study area include high-yielding varieties, early maturing crop varieties, organic manure use, irrigating crops, drought-resistant crop varieties, crop diversification etc. Development of adaptive traits should be the focus of research institutes working on cotton as marginalised farmers lack technological input, they may not able to develop these traits. Change in planting time needs field trials and this planting time will vary spatially due to change in climatic conditions.

Rainfed cotton production is more sensitive to varying climate conditions (Jans *et al*., 2020). Climate change reduces the level of soil fertility, favours pest resistance, and leads to an increase in consumption of cotton production inputs per unit of area (Soviadan *et al*., 2019). These findings are in agreement with the findings obtained in this study. Rainfed cotton is depending on rain as only source of irrigation and in case of non-availability of the same farmers from the study area have very few other irrigation options to manage the same.

Water-saving irrigation technology is an effective way for agriculture to adapt to the arid climate. Shortening farmers' waiting times to adopt such technology is important for saving water resources and stabilizing agricultural production (Mi *et al*., 2021). Farmers from the study area have adopted water management strategies and include an adaptation of rain-fed crop, mulch, increased use of canal/tanks, and restoration of traditional rainwater harvesting technologies. Water demand management during non-availability season includes the use of nearby river/canal, borewell, and farm pond. The construction of the new rainwater harvesting structures have received a poor response this may be perhaps because of capital investment required to carry out this option. As these marginalised farmers have agricultural land ≤ 2.5 ha, many farmers do not have a pond to cope up with non-availability of water during non-rainy season. To overcome this situation a community tank in the marginalised farmer dominated area can help to solve this issue.

A low level of adaptation of cotton farmers to climate change is reported by Sovidan *et al*., 2019. These findings corroborate with the findings from the study area. The sample population comprises of marginalized farmers with poor purchasing capacity, entrapped in the vicious cycle of climate change, crop failure, and debatness and thus they found it difficult to adapt to climate smart agricultural methodologies. These farmers purchasing capacity needs to be enhanced so as to explore new climate-smart adaptation methodologies.

Raising farmers' awareness of the reality of climate change and adopting adaptation techniques and strategies would greatly improve cotton farmers' adaptive capacity and positively affect cotton production (Sovidan *et al*., 2019). Marginalised farmers owing to the lack of access to modern technological means (smartphone and internet) are not aware of near future environmental disasters. A village-level weather display board will make them aware of these incidences and thus will facilitate them to take appropriate measures. In addition, climate-smart adaptation options training should be provided so as to enhance their capacity to overcome climate change induced adverse impacts on cotton cultivation and pave the way for sustainable agriculture.

As conclusion, global climate change perceptions, impacts, and adaptation strategies of cotton cultivating marginalised farmers are addressed in this study. The perception of global climate change is well understood and clear and it is in agreement with the prevailing scientific knowledge of the subject domain. Pronounced climate change impacts are witnessed by these farmers in sowing, crop growth, harvesting, and yield. Also, impacts have been observed in cows and buffaloes. Additional secondary and tertiary impacts may be resulted due to global climate change on these farmers which will pose a threat to their livelihood security. Owing to the less education and poor social-economic status of these farmers, adaptation strategies adopted are limited.

To reduce the adverse impacts of global climate change on cotton cultivating marginalised farmers, climate-smart agriculture adaptation strategies need to be adopted. These strategies can be adopted at sowing, crop growth, harvesting, and yield stages besides, for livestock rearing. Furthermore, technological support, easy access to microcredit, and appropriate minimum support price will further strengthen the capacity of these farmers. As this farmer’s climate change induced agricultural impacts issue is quite different from well-developed farmers, a special policy at the national level will bring these farmers to the mainstream of the society. To possess a comprehensive understanding of the issue a Pan-Indian study will pave the way for sustainable adaptation strategies for climate smart agriculture for cotton cultivation which will guide to livelihood security and sustainable development.

ACKNOWLEDGEMENTS

This study was carried with the funding support provided by the Indian Council of Social Science Research (ICSSR), New Delhi, India under Impactful Policy Research in Social Sciences (IMPRESS) scheme (IMPRESS/P759/280/SC/2018-19/ICSSR). The authors are grateful to ICSSR for this purpose.

REFERENCES

Aggarwal, P. K. (2008). Global climate change and Indian agriculture: Impacts, adaptation and mitigation. Indian Journal of Agricultural Sciences, 78: 911-919.

Bange, M., Baker, J. T., Bauer, P. J., Broughton, K. J., Constable, G. A., Luo, Q., Oosterhuis, D. M., Osanai, Y., Payton, P., Tissue, D. T., Reddy, K. R., and Singh, B. K. (2016). Climate change and cotton production in modern farming systems. ICAC review articles on cotton production research. CABI International.

Gérardeaux, E., Loison, R., Palaï, O., and Sultan, B. (2018). Adaptation strategies to climate change using cotton (*Gossypium hirsutum* L.) ideotypes in rainfed tropical cropping systems in sub-Saharan Africa. A modelling approach. Field Crops Research, 226: 38–47.

Gutierrez, A. P., Ponti, L., Herren, H. R. *et al.* (2015). Deconstructing Indian cotton: weather, yields, and suicides. Environmental Sciences Europe, 27: 12. https://doi.org/10.1186/s12302-015-0043-8.

Hebbar, K. B., Venugopalan, M. V., Prakash, A. H., and Aggarwal, P. K. (2013). Simulating the impacts of climate change on cotton production in India. Climatic Change, 118: 701–713.

Hearn, A. B. and Constable, G. A. (1984). Irrigation for crops in a sub-humid environment VII. Evaluation of irrigation strategies for cotton. Irrigation Science, 5: 75–94.

Jans, Y., von Bloh, W., Schaphoff, S., and Müller, C. (2020). Global cotton production under climate change – Implications for yield and water consumption, Hydrology and Earth System Sciences. (https://doi.org/10.5194/hess-2019-595, in review, 2020).

Jasserina, F. A. (2007). Effects on resilience on Indian cotton production due to climate change. Centre for Transdisciplinary Environmental Research. Stockholm University. 1-62.

Mi, Q., Li, X., Li, X., Yu, G., and Gao, J. (2021). Cotton farmers' adaptation to arid climates: Waiting times to adopt water-saving technology. Agricultural Water Management, 244: 106596.

Mishra, S., Shroff, S., Shah, D., Deshpande, V., Kulkarni, A., Deshpande, V., and Bhatkule, P. (2006). Suicide of farmers in Maharashtra background papers.

Mohapatra, B. S. (2002). Why cotton Matters: The importance of multilateral trade negotiations, Secretary to Government of India Ministry of Textile. New Delhi.

Soth, J. (1999). The impacts of cotton on freshwater resources and ecosystems. A preliminary synthesis. World Wide Fund for Nature (WWF).

Soviadan, M., Koffi-Tessio, E., Enete, A., and Nweze, N. (2019). Impact of climate change on cotton production: Case of savannah region, Northern Togo. Agricultural Sciences, 10: 927-947.

Ton, P. (2011). Cotton and climate change: impacts and options to mitigate and adapt. International Trade Centre. 1-17.

Turner, N. C., Hearn, A. B., Begg, J. E., and Constable, G. A. (1986). Cotton (*Gossypium hirsutum* L.): Physiological and morphological responses to water deficits and their relationship to yield. Field Crops Research, 14: 153–170.

Received: 15th June 2021; Accepted: 08th August 2021; First distribution: 10th February 2022.