Ethiopian Journal of Environmental Studies & Management 14(5): 629 – 644, 2021.
ISSN:1998-0507 doi: https://ejesm.org/doi/v14i5.6
Submitted: June 13, 2021 Accepted: August 12, 2021

WHEAT, MUSTARD AND BARLEY CULTIVATING MARGINALIZED FARMERS' CLIMATE CHANGE PERCEPTIONS, IMPACTS AND ADAPTATION STRATEGIES IN ALWAR AND JHUNJHUNUN DISTRICTS, RAJASTHAN, INDIA

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Abstract

This study aims to assess wheat, mustard, and barley cultivating marginalized farmers' (landholding ≤1 hectare) climate change perceptions, impacts, and adaptation strategies in Alwar and Jhunjhunun districts of Rajasthan, India. Purposive sampling of 50 marginal farmers was carried out in winter 2020. A specially designed, developed and pre-tested questionnaire was used as a tool to elicit the information from the respondent. From the identified sample respondents, all farmers are engaged in rainfed crop cultivation followed by livestock rearing (76%). Farmers have well-understood perceptions of climate change and reported rain pattern change (100%) and high temperature (98%) as crucial issues. Crop residue burning is identified as a major agricultural activity responsible for climate change. Soil moisture reduction (100%) and crop destruction by climate change (98%) are reported by respondents. Insect/pest incidences increased (100%), irrigation water scarcity (100%), production reduction (88%), crop growth reduction (76%), and reduction in soil fertility (58%) are some of the impacts on agriculture. Farmers have reported decreased (84%) in crop yield in the last five years and increased (0-20%) in the cost of insecticide/pesticide during crop cultivation. Heatstroke (83.88%) and summer diseases (100%) in livestock are described by respondents. Willingness to climate change adaptation options is reported by 68% of farmers. Future adaptations options for coping with climate change impacts are reported in the order of high yielding and drought resistance crop varieties (100%) > crop and livestock diversification (82%) > early maturing crop varieties (76%) > water storage method (58%) > organic manure (52%). The farmers' perceptions are in agreement with scientific evidence and impacts on these crops vary according to their growth stage. To enhance the resilience of this group of farmers they should be made aware of climate-smart agriculture measures. In addition, micro-credit, crop and farmers' insurance, advanced weather forecast and national level policy will pave the way for sustainable agriculture which will further result in livelihood security.

Key Words: *Barley, Climate change, Climate-smart agriculture, Marginalized farmers, Mustard, Wheat*

Introduction

Agriculture is strongly influenced by climate and weather. Climate change and agriculture both are interconnected. Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity (IPCC, 2007). Climate change affects agriculture in two ways- direct and indirect. Changes in climatic factors (for example, temperature, and rainfall) affect agricultural productivity through physiological changes in crops (Chakraborty *et al*., 2000). In addition, climate change also affects other factors of agriculture production, such as water availability, soil fertility, insect and pests, etc. (Porter, 2014). The climate sensitivity in the agricultural sector is uncertain, as there are many regional variations in rainfall, temperature, crops and cropping patterns, farming systems, soils and other management practices.

Rice, wheat, maize, sorghum, soybean and barley are the six major crops in the world grown in 40% cropped area and contribute to 55% of non-meat calories and over 70% of animal feed (FAO, 2008). Therefore, any effect on these crops will adversely affect food security. Each crop requires different types of climate and environmental conditions to grow. So, if climate change events occur, the main areas of production also change. As per Simane *et al*. (2016), average temperatures are projected to increase by 1.4 to 2.9°C. According to Aryal *et al*. (2019) climate change can severely affect agricultural productivity, food security and the risk of agricultural communities.

In developing countries, climate change will cause major yield declines for the most important crops and increase in price for the most important agricultural produces i.e., rice, wheat, maize, and soybeans (Nelson *et al*., 2009), and biomass declining with increasing temperature (Rawson *et al*., 1995). Marginalized farmers in developing countries are expected to be the most affected by these climatic changes (Maskrey *et al*., 2007).

Globally wheat (*Triticum aestivum* L.) occupies about 217 million hectares (ha) and holding the position of highest acreage among all crops with an annual production of around 731 million tonnes (Ramadas *et al*., 2019). Wheat is one of the key cereal crops cultivated worldwide and one of the principal staples of nearly 2.5 billion of the world population. Wheat production (Average 1994-2019) in China is the highest (112728196 tons) followed by India (79122379 tons) (FAO Statistics, 2021). In the case of India, Uttar Pradesh contributes highest wheat production (32.75 million tons). Of the top five states contributing to wheat production in India, Rajasthan is one of them (10% of the total production) (Agricultural Statistics at a Glance 2019, 2020). In India, the wheat crop is cultivated in the Rabi season sown during November and harvested between March and April.

As the temperatures are very likely to rise in the coming years, a fall in yield is likely for many wheat-production regions in the world (Martre *et al*., 2015) like Russia and India Zhao *et al*. (2017) has been projected for the same. Lobell *et al*. (2012) suggest that warming presents a bigger challenge to wheat growers.

In wake of the climatic variability, wheat production is facing serious pest problems globally. Currently, wheat is affected by numerous fungal, bacterial and viral pathogens, which cause diseases of varying severity (Bockus *et al*., 2010). Wheat pathogens vary regarding optimal and conducive environmental conditions; some are active at freezing temperatures, while others cause diseases at temperatures above 35°C (Sabburg *et al*., 2015).

Weeds cause potential yield losses in wheat, reportedly about 23% (Oerke, 2006).

The flowering date in wheat is strongly regulated by temperature and is highly sensitive to climate change. During the meiotic phase, wheat and rice suffered from the 35–75% reduction in grain set due to water deficit (Sheoran and Saini, 1996). Wheat yield was decreased from 1% to 30% during the mild drought stress at post-anthesis while this reduction improved up to 92% in case of prolonged mild drought stress at flowering and grain formation (Oliveira *et al*., 2013).

Mustard (*Brassica nigra*) is cultivated in more than 50 countries worldwide in subtropical and temperate climates. Canada (189123 tonnes) tops the mustard producing countries in the world followed by Nepal (141276 tonnes) (Average 1994-2019) (FAO Statistics, 2021). In India, Rajasthan with a production of about 4 million tonnes tops the position (Agricultural Statistics at a Glance 2019, 2020). In Rajasthan, the mustard is mostly cultivated in Alwar, Jhunjhunun, Bharatpur, Jaipur, Dholpur, Sawaimadhopur, Sriganganagar, and Sikar districts. All these districts together contribute more than 50% of mustard production in the state (Kumrawat and Yadav, 2018). The rapeseed mustard is the second most important oilseed in India with average productivity of 771.0 kg/ha (Chattopadhyay *et al*., 2005). It needs a relatively cool temperature, a fair supply of moisture in the growing season and a relatively dry harvest period.

Mustard is much sensitive to weather as proved from the variable response to different dates of sowing (Kumar *et al*., 2007). One month delay in sowing from mid of October resulted in the loss of 40.6% in seed yield (Lallu *et al*., 2010). Mustard suffers from exposure to low temperature during the vegetative and early pod filling stage and relatively higher temperature during grain filling and maturity.

Mustard is more prone to climatic changes and hence could have a significant effect on its production (Arvind, 2005). High temperature during mustard crop development (mid-September to early November), cold spell, fog and irregular rains during crop growth also affect the crop adversely and cause considerable yield losses by physiological condition along with appearance and proliferation of downy mildew, white rust, aphid pest, and stem rot diseases (Butterworth *et al*., 2010).

Barley (*Hordeum vulgare*) is the fourth most important cereal crop in the world, grown in more than 100 countries and used for animal feed, human food and the production of alcohol. It is cultivated globally, in both highly productive, high-input agricultural systems and in low-input agriculture across a wide range of environments (Newton *et al*., 2010). Barley production in Russia is the maximum (17156157 tonnes) followed by Germany (11467836 tonnes) (FAO Statistics, 2021). India's barley production fluctuated substantially in recent years, it tended to decrease from 1971-2020 ending at 1,687 thousand metric tonnes in 2020 from 590 thousand hectares with per ha productivity of 2821 kg/ha. In India, major barley cultivating states are Rajasthan and Uttar Pradesh with a contribution of 40% and 31%, respectively. Rajasthan ranks second in terms of acreage under barley and holds first place in terms of production due to a higher yield. Rajasthan accounts for 40% of the total production of barley followed by Uttar Pradesh (31%), Madhya Pradesh (9%), and Haryana (6%) (Khatkar *et al.,* 2016). Xie *et al.* (2018) reported global barley yields will decline between 3–17% due to extreme climatic events, and the negative projected yield changes will impact food security (Wheeler and Von Braun, 2013).

Wheat, mustard, and barley are important crops in the world. Negative impacts of climate change will reduce crop quantity and quality. In the light of future climate change projections in India, these crops will face adverse impacts. Moreover, marginalized farmers due to their limited resilience will be at receiving end. Print and online literature review revealed that no study was carried out on wheat, mustard and barley cultivating marginalized farmers in India. Thus, this is the identified gap in this subject domain. This study was carried out to assess the climate change perceptions, impacts and adaptation strategies of marginalized farmers from the wheat, mustard and barley cultivating region of Rajasthan, India. This study outcome will add a new understanding of perceptions, impacts and adaptation means used by this (marginalized) group of farmers. Furthermore, the initiatives have to be taken at the national/regional level to enhance the resilience of these farmers thus paving the way for sustainable agriculture leading to livelihood security.

Study Area

Alwar district (27°34′ to 28°4′ North latitudes and 76°7′ to 77°13′ East longitudes) (Figure 1) is situated in the eastern part of Rajasthan at an altitude of 270 meters above mean sea level. The district has a geographical area of 8380 km^2. According to the Census of India 2011, the population of the district was 36.74 lakhs (3.67 million). Of the total population, Scheduled Caste (SC) population was 17.77% whereas, Scheduled Tribe (ST) 7.87%. Of the total workers, the cultivator contributes 52.61% whereas, agriculture labour 12.69% (Census of India, 2011).

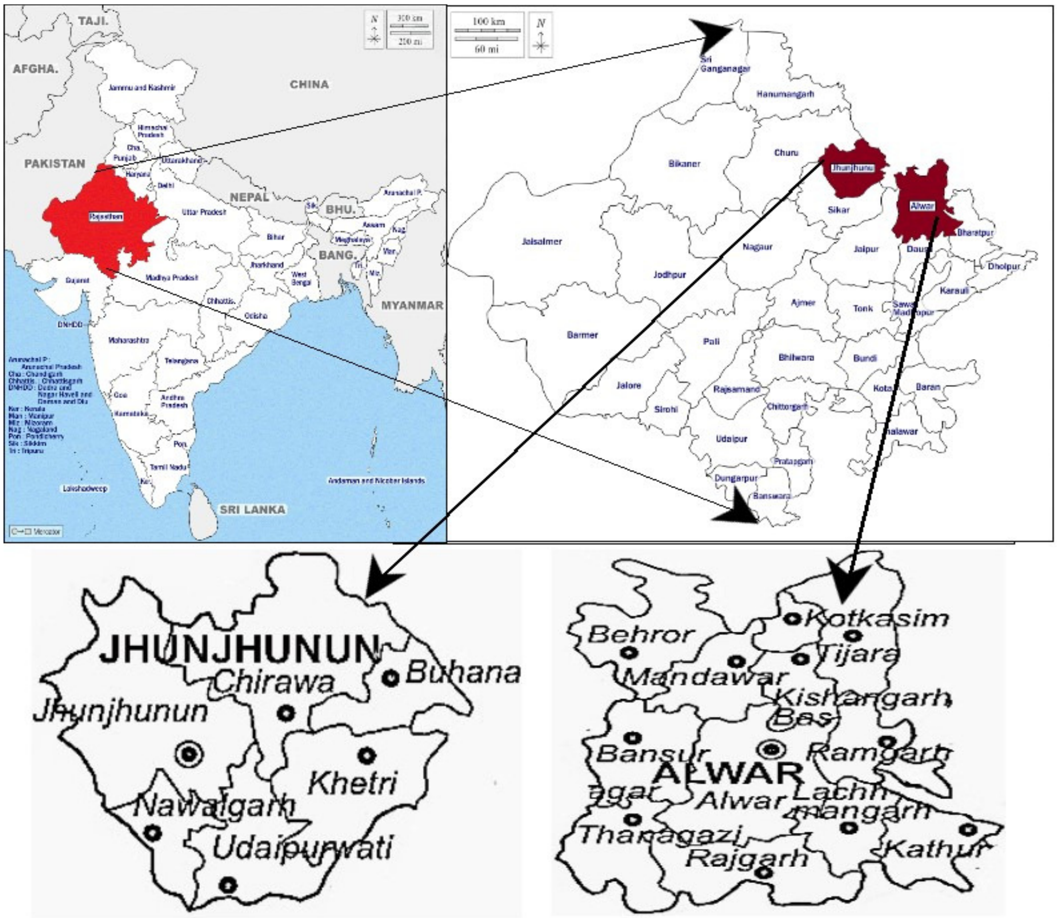

Fig. 1: Study area

The major soil type of the district includes lithosols and regosols of hills, older alluvial soils, and red sandy soils. The average annual rainfall is <650 mm. The rainfall distribution in the district is uneven and scattered which sometimes result in flood or drought problems affecting the agriculture production as well as cropping pattern in Kharif and Rabi seasons. The minimum temperature in winter goes up to 8^{o}C and the maximum temperature goes up to 42^{o}C in summer (CGWB, 2013).

The economy of the district is largely dependent on agriculture and the need for water has increased over the years. Mustard is the major crop while wheat and bajra are the major grains produced. Onions are the main vegetable grown in the district. According to the Indian Council of Agricultural Research, only 60% of the land is used for multi-crop cultivation. The net cultivated area is 5,09,107 ha from which about 83% (4,26,204 ha) is irrigated and the remaining 17% (82903 ha) is unirrigated. The double-cropped area is 2,72,508 ha of which 12% (32230 ha) is irrigated and the remaining 2,40,278 ha (88%) is unirrigated. The total cropped area of the district is 7,81,615 ha. In the Kharif season bajra, maize, jowar, Kharif pulses, sesamum, cotton, etc. are sown in about 3,29,088 ha (42%) and in Rabi season wheat, barley, gram, mustard, taramira, rabi pulses etc. are shown in about 4,52,527 ha (58%) (KVK, 2016). Principal crops cultivated include wheat 193992 ha, barley 13011 ha, bajara 273147 ha etc. The irrigation is carried out by tubewells 324632 ha and other wells 12615 ha (CGWB, 2013).

Jhunjhunun district (75º02′ to 76º06′ East latitudes and 27º38′ to 28º31′ North longitudes) (Figure 1) has a geographical area of 5928 sq km. According to the Census of India 2011, the total population of the district was 21.37 lakhs (2.13 million). The SC population was 16.88% while ST contributes 1.95%. Of the total workers, cultivators contribute 58.31% and agricultural labourers were 7.70% (Census of India, 2011).

The major soil types of the district include desertic (45%), sand dunes (36%), red desertic (8%), lithosols and regosols of hills (6%) and older alluvium (5%). The district has a dry climate with a hot summer and storms are common in summer. The rainy season is of short duration from July to mid-September. The normal rainfall mostly received from the southwest monsoon with average annual rainfall (1971-2006) of 485.6 mm. During summer the maximum temperature goes up to 47ºC and in winter the minimum temperature falls up to 1ºC. The average temperature of the area is 22ºC. The annual average relative humidity is 56% however, it varies from maximum up to 78% in the rainy season to as low as 15 to 20% in summer. Winds, in general, are of moderate speed except in summer when dust storms are common (CGWB, 2008).

Bajra (*Pennisetum glaucum*), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare*), and mustered (*Brassica nigra*) are important crops of the district. The other crops are cotton, gram, and chilly but the production of these crops is not done on a commercial scale. In the year 2014, the major crops wheat, barley and mustard grew in 86716 ha, 11501 ha and 80411 ha of area respectively. Irrigation is carried out by dug well/tube well/bore well in 2267.38km^2 and by tanks/ponds in 0.36km^2 (CGWB, 2008).

Methodology

To evaluate the marginalised farmers' (landholding size ≤ 1 ha) climate change perceptions, perceived impacts, and adaptation behaviour, two districts i.e., Alwar and Jhunjhunun from Rajasthan state were purposively selected. From these two districts, 50 marginal farmers were selected randomly. The villages included in the study include Bansuri, Girudi, Chatarpura, and Gyanpura from Alwar district and Jhajjar, Nawalgarh, and Parasrampura from Jhunjhunun district. A questionnaire especially designed, developed and pre-tested was used to elicit the information from the respondent. Likert scale was used for the responses of the questions to get quantitative and comparable responses. Marginal farmers having farming as the main occupation and with a minimum of 15 years of farming, experiences were the inclusive criteria.

The study was carried out in winter 2020. The quantitative approach was used for data collection. Primary data was collected by eliciting the information from these respondents emphasizing climate change perceptions, impacts during sowing, crop growth, post-harvest, livestock, and adaptation strategies used and planned to execute in the future. Secondary data viz. study area, climate, rainfall, demographic profile, etc. were gathered from government databases such as Census of India, Central Ground Water Board, Ministry of Agriculture & Farmers Welfare and India Meteorological Department. The collected data was analysed with the help of OriginPro and SPSS.

Results and Discussion

Profile of the Sample Population

Of the 50 marginalised farmers identified for this study, 98% (n = 49) were male and 2% (n = 1) female. The major occupation of these farmers (100%) is the cultivation of wheat, mustard, and barley, followed by livestock rearing (76%) and farm labours in other farmers' farms (60%). All farmers are engaged in rainfed crop cultivation however, 48% had irrigation facility for the non-rainy season. In the field activities, they receive assistance from their family members, especially from their wives (42%) and other farm labourers (38%). Maximum (80%) farmers carry out crop cultivation activity twice a year whereas 20% take a single crop. Of the total farmers, 30% were illiterate and 26% had high school education and stays in a nuclear family (66%). Maximum (90%) farmers own the agricultural land whereas, 10% had it on a lease basis. Only 28% had soil health cards for soil quality. The cell phone use profile of the farmers indicates, 64% don't use a cell phone and of the remaining (36%), 24% had a feature phone and only 12% had a smartphone. Of the study population, 66% belong below poverty line and all farmers had food grain cards and purchase food gains from government outlets.

Monthly electricity consumption for domestic purposes is maximum (56%) in the range of Rs. 251-500/- (US$ 3.25-6.49), >Rs. 500-1000/- (US$ 6.89-13.78) 24% and <Rs. 250/- (US$ 3.24) reported by 20% of respondents.

Perceptions of Climate Change

Marginalized 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 high temperature (98%) and an increase in drought incidences (76%). Intense temperature (86%), prolonged summer (84%), and winds getting warmer (72%) are reported in summer (Figure 3). In the rainy season (Figure 4), late-onset of rain and rainfall decreased (100%) followed by uneven rainfall and early withdrawal of monsoon (98%) is reported. A short period of winter (82%), increase in cold severity (76%) and heavy smog/fog formation (38%) are important changes reported by farmers in winter (Figure 5). Forest vegetation cover decreased (86%) in the last ten years is another observation reported by them (Figure 6). Of the different causes responsible for climate change, crop residue burning (100%) followed by irrigation water wastage (76%) are perceived as a major agricultural activity responsible for it (Figure 7). Destruction of crops by climate extremes is reported by 98% of farmers whereas, 96% reported partial crop destruction (Figure 8).

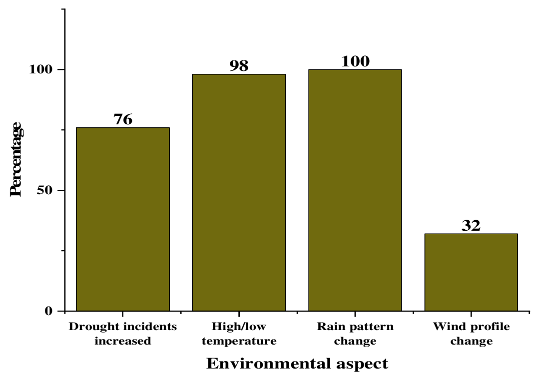

Fig. 2: Climate change perceptions in various environmental aspects

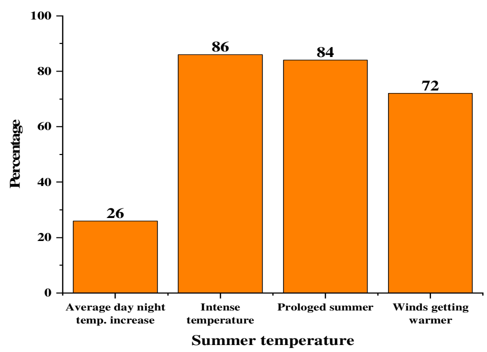

Fig. 3: Climate change perceptions for the summer season

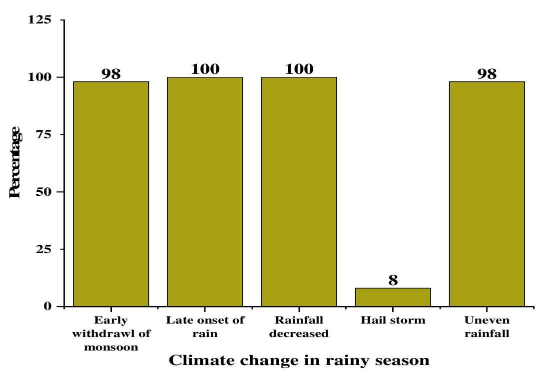

Fig. 4: Climate change perceptions for the rainy season

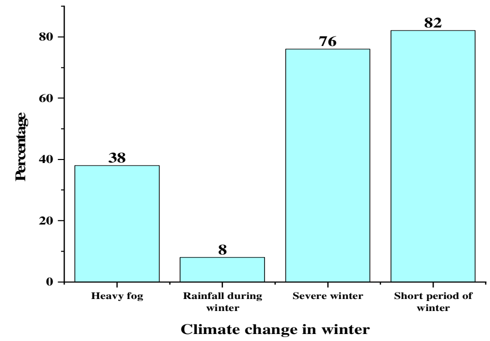

Fig. 5: Climate change perception for the winter season

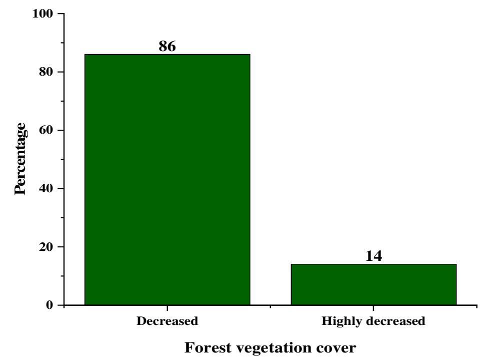

Fig. 6: Climate change perception for forest vegetation cover

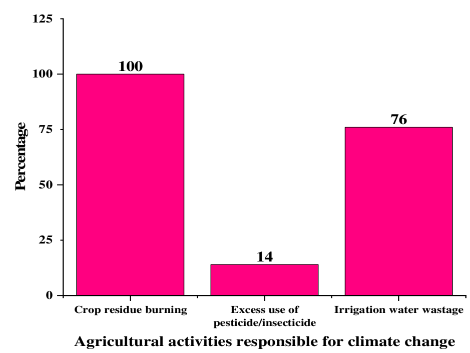

Fig. 7: Agricultural activities responsible for climate change

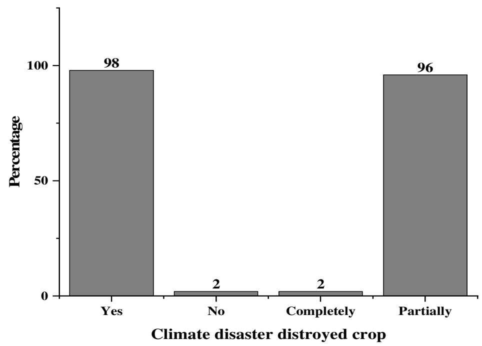

Fig. 8: Climate change destroyed the crop

Perceived Impacts of Climate Change on Crop Cultivation

Impacts of climate change on agricultural activities revealed, soil moisture reduction (100%) followed by soil fertility reduction (84%) (Figure 9). Impacts on irrigation include, the quantity of surface water decreased (80%) and quality deteriorated (32%). On the contrary, groundwater quantity depleted 80% and quality is marginally (24%) affected (Figure 10). Figure 11 depicts the effects of less irrigation water on crops. From the figure, it can be seen that insect/pest attacks increased (100%) followed by productivity reduction (76%) and poor quality of yield (64%). Impacts of climate change on agriculture (Figure 12) reported insect/pest incidences increased (100%), irrigation water scarcity (100%), production reduction (88%), crop growth reduction (76%), and soil fertility reduction (58%). Figure 13 presents impacts of climate change on crop production with 100% reporting insect/pest attack increased, production reduced (74%) and food quality deteriorated (66%). Crop yield per acre in the last five years is presented in Figure 14. Farmers have reported a decrease (84%) in crop yield and this is in the range of 0-20% (80%), whereas 21-40% is reported by 8%.

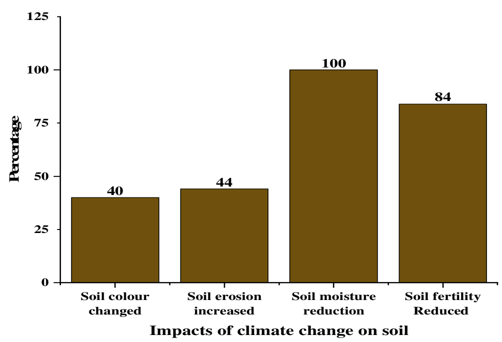

Fig. 9: Impacts of climate change on soil

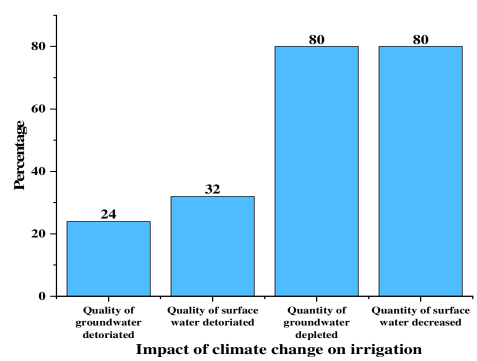

Fig. 10: Impacts of climate change on irrigation

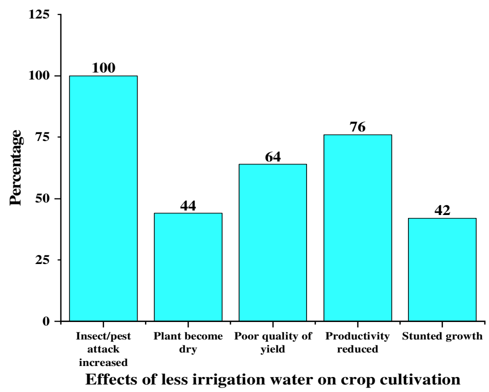

Fig. 11: Effects of less irrigation water on crops cultivation

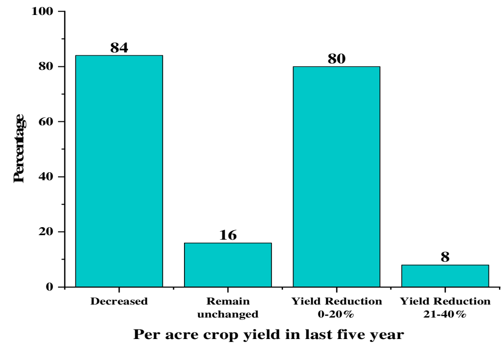

Fig. 14: Per acre crop yield in last five years

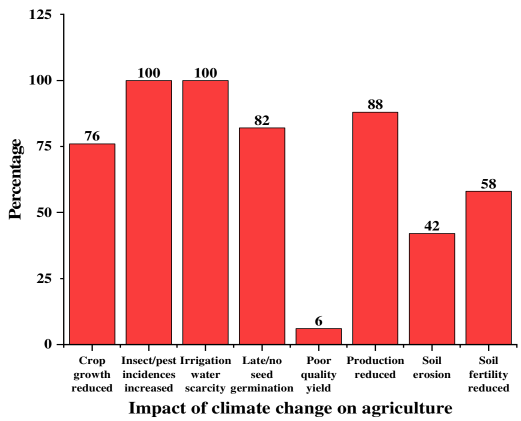

Fig. 12: Impacts of climate change on crop

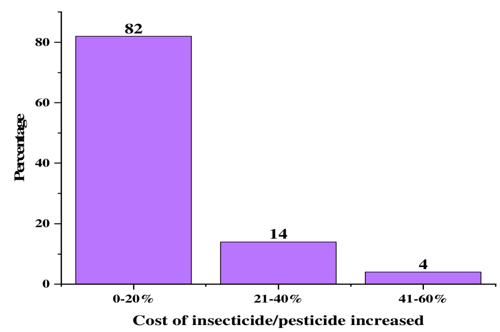

Fig. 15: Cost of insecticide/pesticide in cotton cultivation

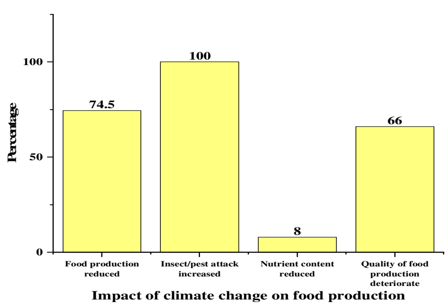

Fig. 13: Impacts of climate change on food production

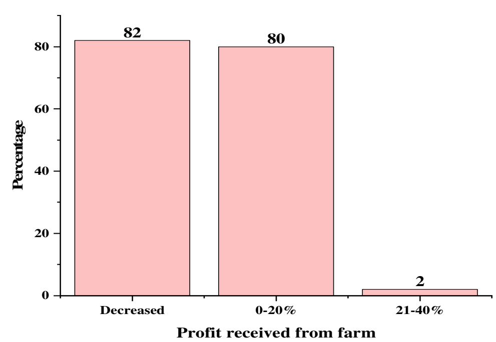

Fig. 16: Profit received from crop cultivation

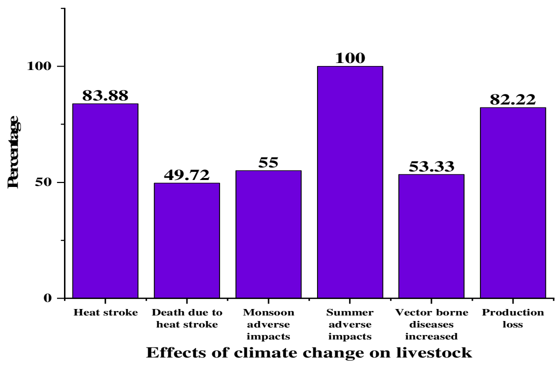

Fig. 17: Impacts of climate change on livestock with crop producer

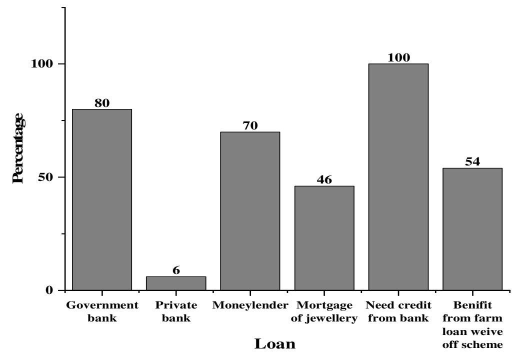

Fig. 18: Loan facility availed by farmer

Cost of insecticide/pesticide use during cultivation has increased in the range of 0-20% (82%) and 21-40% (14%) (Figure 15). In the case of profit received from the farm (Figure 16), 82% of farmers reported a decrease in profit and it was in the range of 0-20% (80%). Impacts of climate change on livestock are reported as heatstroke (83.88%) and death due to it (49.72%). The summer season has adverse impacts on livestock (100%) followed by monsoon (55%). Livestock production loss in summer is reported by farmers (82.22%) (Figure 17). To manage the challenges posed by climate change farmers are taking loans from various sources (Figure 18). Maximum (80%) farmers took a loan from government banks followed by moneylenders (70%) and loans against mortgages of gold jewellery (46%) are also common.

Adaptation Behaviour and Capacity

Willingness to adapt to climate change is reported by 68% of farmers (Figure 19). This willingness is in the order of during irrigation (78%) > seed change (44%) > harvest (28%) > post-harvest and during sowing (24%). To cope up with climate variability, farmers have a desire for a better weather forecast (86%) closely followed by a change in cropping pattern/crop management (84%) and 70% of farmers are interested in adopting new farming techniques (Figure 20). Measures to be taken for effective water management during climate change (Figure 21) include mulching (78%) and the use of modern rainwater harvesting techniques (52%). Restoration of traditional rainwater harvesting systems has received a moderate response (34%). To manage the irrigation water demand during non-availability season (Figure 22) is most relied on bore wells (56%) followed by farm pond (18%) and nearby river/canal (12%). 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 and drought-resistant crop varieties (100%) > crop diversification and livestock diversification (82%) > early maturing crop varieties (76%) > water storage method (58%) > organic manure (52%).

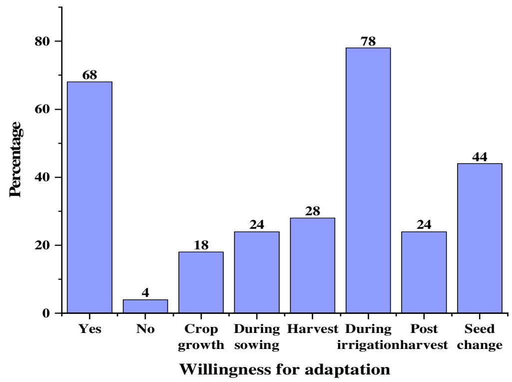

Fig. 19: Farmer's willingness for climate change adaptation

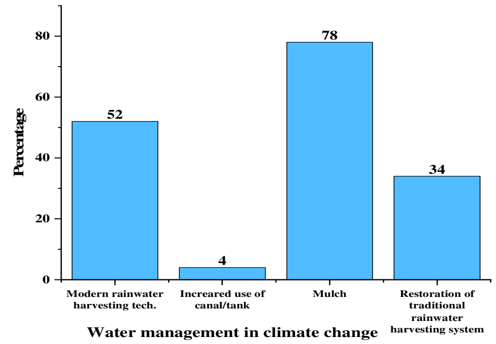

Fig. 21: Water management strategies for climate change

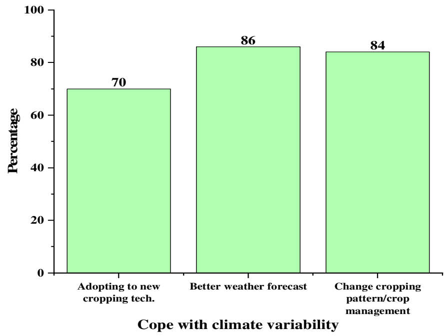

Fig. 20: Crop cultivator's coping with climate change

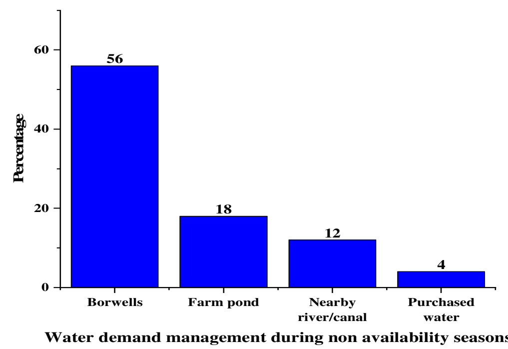

Fig. 22: Irrigation water demand management during non-availability season

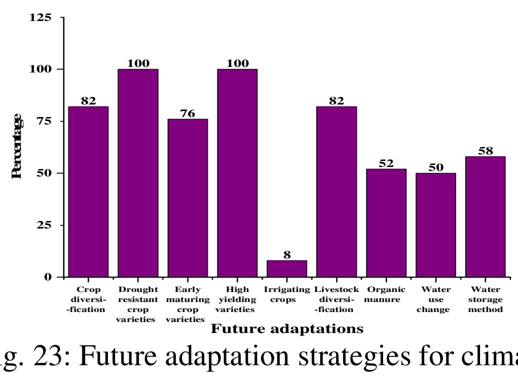

Fig. 23: Future adaptation strategies for climate change

The results obtained in this study indicate that climate change has pronounced effects on wheat, mustard and barley. These results corroborate with Somboonsuke *et al.* (2016), Makuvora *et al.* (2018), and Jamshidi *et al.* (2019). High temperature during summer as reported by farmers may reduce the number of flowers (Morison and Stewart, 2002) further the yield. Crop residue burning (100%) is one of the critical concerns related to climate change in the area. The observed impact in terms of the increase in pests and diseases due to uncertainty in rainfall and climate along with loss of yields because of untimely out of season rains is consistent with scientific assessments (Moorhead, 2009). Enhanced insect/pest attack (100%) due to climatic change was also identified from the study area. An increase in both crop and animal diseases as reported by Panda and Singh (2016) corroborates with the results obtained in this study.

Farmers are willing to adapt to changing climate conditions like soil conservation, shifts in the growing season, higher input use, cultivation of varieties with greater drought tolerance, retention of crop residues, or other agronomic strategies (Mirzabaev, 2013). Similar observations were also recorded from the study area. Landholding size is strongly associated with all adaptation– in line with the generally reported positive association between farm size and technology adoption (Bryan *et al*., 2013; Abid *et al*., 2015). Marginalized farmers owing to their small landholding size have shown limited adaptation strategies. In addition to landholding size, there can be several factors that may govern this. The high rate of illiteracy may be a major constraint for adopting well-defined long-term adaptation strategies. The respondents' perceptions of climate change differed based on their level of climate-related knowledge and experience (Below *et al*., 2012). These observations have been observed from the study area.

Conclusion

The present study investigated the impacts of climate change on the three strategic crops i.e., wheat, mustard and barley growing marginal farmers. Marginalized farmers' perceptions of climate change are inconsistent with scientific assessment. Furthermore, they are affected by climate change which is site and crop-specific. These impacts are at various stages of crop growth in addition, livestock was also affected. Marginal farm size (<1 ha), lack of technology, poor capitalization, and various non-climate stressors will tend to increase the vulnerability of these farmers to climate change soon.

To overcome the negative impacts of climate change on this group of farmers, they should be made aware of crop and site-specific climate-smart agriculture measures by carrying out awareness/training camps at the village level. Training on livestock rearing in climate change scenarios should be made available to them. Moreover, interest-free financial assistance in the form of micro-credit should be made available to them. As this group of farmers lacks technological support (smartphone) weather forecasts should be made available to them at the village level by displaying the information at prominent places. In addition, technological support by providing village-level farm machinery hiring centre should be provided. Furthermore, weather-based crop insurance and farmers' family insurance should be encouraged. As these farmers' plight is different from other groups of farmers, a specialized policy at the national level by incorporating the above-mentioned remedial measures will enhance their resilience to carry out sustainable agriculture and thus to have a sustainable livelihood. A pan India study on these crops and this group of farmers will further strengthen the conclusions which will help to draw a blueprint to enhance their resilience.

Acknowledgement

This study was carried out with funding support from the Indian Council of Social Science Research (ICSSR), New Delhi, India under the Impactful Policy Research in Social Sciences (IMPRESS) scheme

(IMPRESS/P759/280/SC/2018-19/ICSSR). The authors are grateful to ICSSR for this purpose.

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