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Impact of Climate Change on Soybean Cultivation in Malwa and Nimar Region of Madhya Pradesh: Farmers' Perspective

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ABSTRACT

Soybean, a relatively new crop for the farmers of Central India, has established itself as a major kharif crop and is commercially grown by the farmers since last five decades starting from 1970s. The crop, predominantly grown by small and marginal famers, has seen remarkable increase in area and production so far. The largest producer of soybean in India, soy state Madhya Pradesh alone is contributing nearly 56 per cent area and production in the country. But national productivity of soybean is hovering around 1,000 kg per ha since last decade. The reasons are being the climatic adversities as the crop is grown under rainfed conditions. The studies conducted in the past have also indicated changes in weather parameters including regular events of long dry spell and incidence of pest and disease complexes. In this background, a study was conducted to know the farmers perception about the climate change in the area and its relative impact on soybean yield levels. The data for the study was collected from 280 farmers belonging to six villages of three districts, namely Indore, Dewas and Dhar representing Malwa and Nimar Plateau using random sampling technique. The sample size of respondents included 60 farmers belonging to four villages from Indore as well as Dewas and 40 from two villages of Dhar district. The information was collected from these farmers using structured interview schedule containing decade-wise data on their perception of changes in soybean yield in the corresponding climatic situation. The results of the study revealed that the farmers are concerned about the changes in prevailing climate particularly delayed arrival and uneven distribution of monsoon, long dry spell as well as increased temperature during the crop growth period. They also perceived that the yield of soybean was affected due to delayed sowing, poor germination and establishment of the crop resulting in less podding, increased cost of cultivation on account of increased incidences of pest and diseases. More than 40 per cent farmers also perceived that the yield losses due to climatic adversities were even up to 50 per cent during the last two decades in spite of following management practices. The results also indicated that there has been a declining trend in yield for in the farmers who used to achieve more than 2,000 kg per ha. In order to mitigate the impact of adverse climate, the strategies involved are change in cropping pattern, preference for short duration and pest and diseases resistant varieties, planting of soybean on altered land configuration (BBF and/or Ridge andFurrow systems) and taking benefits of crop insurance scheme.

Key words: Climate change, farmers' perception, Madhya Pradesh, soybean

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Climatic variability and climate change poses formidable challenge on agricultural sector globally, particularly in developing countries, as the agricultural sector is most vulnerable to climate change which is supporting large proportion of population. The negative impact of climate change on agricultural sector and crop productivity has been reported by earlier studies globally (Vermeulen *et al*., 2012; Field *et al*., 2012; Stocker *et al*., 2013, Lobell *et al*., 2011; Bates *et al*., 2010; Thornton and Gerber, 2010) as well as in India (Kumar and Parikh, 2001; Mall *et al*., 2006; Zacharias *et al.,* 2014; Yadav *et al*., 2016, Bal and Minhas, 2017; Singh *et al.,* 2019). Cline (2007) projected that the agricultural productivity for the entire world is going to decline between 3 and 16 per cent by 2080 and the sharp concentration of losses in the developing countries. Vermeulen (2014) reported that climate change poses a serious threat to food access to rural as well as urban populations by way of reducing agricultural incomes, increasing risks and disrupting markets. Lobell and Gourdji (2012) estimated that without adaptation and mitigation strategies, climate change is likely to reduce world food levels by about 1.5 per cent per decade. The impact of climate change on soybean productivity in India was reported by Lal *et al.* (1999); Mall *et al.* (2004 and 2006) and Mohanty *et al.* (2017).

Soybean, a vehicle of socio-economic transformation for millions of small and marginal farmers of central India (Dupare *et al*., 2009; Sharma *et al*., 2016), is being commercially cultivated by the farmers since last 5 decades. During this period the crop has scripted resounding history of increase in area and production in the country from merely 30,000 hectares in 1970-71 to more than 11.6 million ha during 2018-19. However, the average productivity of soybean in India although, improved from 426 kg per ha during early 1970 to 1,219 kg per ha in 2016-17 (Anonymous, 2017), is stagnated at around 1,000 kg per ha since last few years and is a matter of concern. The increase in soybean yield has come mostly through improvement in harvest index, increased biomass, high number of pods per plant, and increased seed-filling duration (Agarwal *et al*., 2013). Most of Indian soybean varieties have yield potential of 2,500–3,500 kg per ha, while some can yield up to 4,000 kg per ha. Since, the crop is grown mainly under rainfed conditions, extreme variability in the duration, time and quantity of rains exposes the soybean crop to soil moisture deficit as well as excess moisture (Sharma *et al.,* 2019). The delayed monsoon, longer dry spells or early withdrawal of monsoon have been identified as major constraints for poor performance of the soybean crop (Dupare *et al*., 2017; Tiwari, 2014; Sharma *et al.* 2018). In last 10 years, there is a shift in the peak rainfall from July to August, and the total rainfall during the peak month was reduced (Ramteke *et al*., 2015). The rainfall during the emergence and vegetative growth of the soybean crop has been reduced. Earlier studies explicitly indicated that increase in temperature is most likely to significantly reduce the soybean grain yield due to

accelerated growth and effect on rate and duration of grain filling (Lal *et al*., 1999; Mall *et al*., 2004; Mohanty *et al*., 2017). The prolonged dry spells during monsoon season led acute water stress (Lal *et al*., 1999; Mohanty *et al*., 2017) or heavy rainfall could be the critical factors for the soybean productivity.

The climatic variation have been noticed particularly by the incidences of delayed onset of monsoon, prolonged dry spells during the crop growth stages coupled with high intensity rains for short period, early cessation of monsoon and sometime damage to the crop produce during maturity period of soybean (Dupare *et al*., 2017). The negative effects of climate change can be ameliorated to certain extent through adaptation measures ranging from changes in production practices to transformative shifts in farming practices. Adaptation as defined by IPCC is "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" (IPCC, 2014). In this background, it is necessary to understand the perception of farmers and their adaptation to the changing climate scenario. They need to make aware about the adaptive strategies considering different socio-economic, situational, technological and environmental factors.

MATERIAL AND METHODS

The study was conducted in three districts of Madhya Pradesh, namely Indore, Dewas and Dhar located in *Malwa* and *Nimar* Plateau, where the golden crop of soybean is commercially grown since last 5 decades. These districts are very popular for soybean cultivation as the crop covers more than 95 per cent of the cropped area under *kharif* season. The data was collected from randomly selected 280 farmers (*60 farmers belonging to four villages from Indore as well as Dewas and 40 from two villages of Dhar district),* for which sample were drawn from 6 villages using structured and pre-tested interview schedule. The response of farmers on season-wise crops grown, pattern of arrival of monsoon and its distribution, receipt of total rainfall, prevailing temperature, humidity and sunlight/photoperiod along with changes in agricultural practices like sowing method, sowing time, crop duration, insect/disease load, weed infestation and the strategies followed by the farmers for their management, yield losses and soybean yield during the period 1960-2010 were recorded decade-wise along with some open ended questions related to the farmers' experience and their opinion about the prevailing climatic situation as well as its impact on crops. After the data collection, the entire interview schedules were coded and the responses of farmers were computed. For some parameters, the qualitative data have been converted into quantifiable data. The quantitative data were tabulated and analyzed after applying statistical tools like percentage, mean, and standard deviation.

RESULTS AND DISCUSSION

Farmers' perception of prominent changes in various attributes of climate

When asked to enlist most prominent changes occurred in climatic parameters during the period of last 60 years (Table 1), majority of the farmers (97 %) reported a shift of monsoonic pattern (both its arrival time and its distribution during the crop season). According to them, the distribution of monsoon in their area during the last 10 years has mostly been erratic/scanty. Further they are experiencing the long dry spells more often during the *kharif* season affecting the crop growth and thereby yield (92.85 %). The condition become more vulnerable when there is increase in atmospheric temperature during the drought period resulting sometime in soil cracks (Vertisols), which are devastating. Further, 45.71 per cent of the farmers also reported to have observed the soil moisture deficit condition more frequently now days because of long dry spells resulting in short growth of the plants which bears very few/undersized pods. About 25 per cent of the farmers were also of the opinion that in addition to enhanced temperature, there is also a change in relative humidity (decreased) which in turn aggravates the problem of crop management in moisture stress condition. The results clearly suggested that the farmers in the study area are aware of the change in rainfall pattern and temperature during monsoon season.

Table 1. Most prominent changes in climatic parameters during last sixty years

Change	No. of farmers	Per cent
Change in rainfall pattern (Less, uneven and erratic)	272	97.14
Less soil moisture during crop season and cracking in soil	128	45.71
Increase in frequency of long dry spell	174	62.14
Increase in temperature	260	92.85
Change in humidity	70	25.00

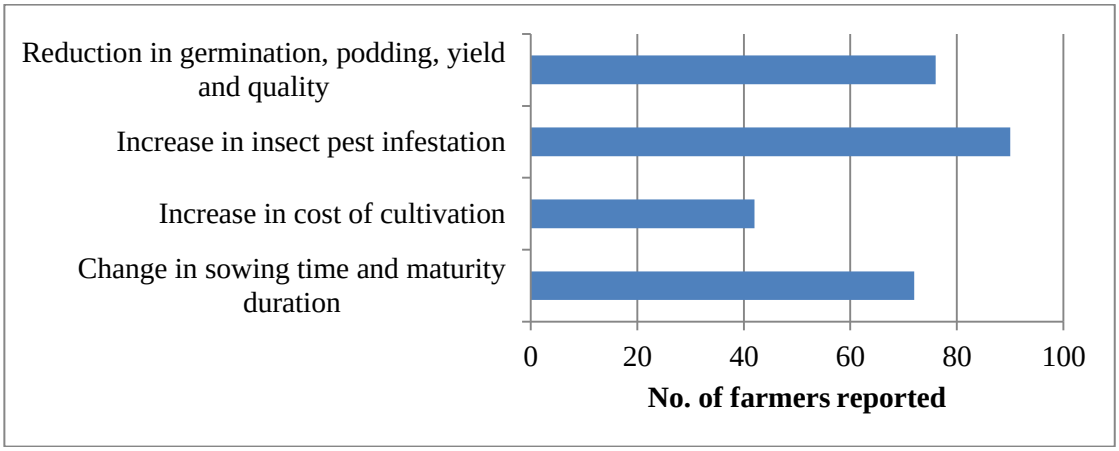
The results of farmers perception on climate change corroborates with the actual climate change study by Mishra and Shah (2015) in Madhya Pradesh, which indicated that a significant decline in monsoon season rainfall during the period 1951-2013, significant increase in air temperature in the post-monsoon season and increase in frequency of severe, extreme, and exceptional droughts. Study further indicated that there were severe and wide-spread droughts in the recent years along with significant increase in number of hot days and more frequent number of heat waves in the Madhya Pradesh.

Farmers' perceived impact of climate change on agricultural crops

An effort was made to understand the experience of farmers on the major impact of climatic variation with the overall condition of crop cultivation and its productivity. As has been mentioned,

soybean is a major *kharif* crop grown by the farmers in the area; the farmers could relate their experience of perceived impact of climate change on soybean (Fig. 1). Out of 280 sample farmers, majority of them (32.14 %) expressed that the infestation of insect-pests and diseases has increased tremendously, particularly during the last decade. Secondly, the productivity of soybean is also decreased consequent to poor germination and plant stand, less podding, and at times quality of the produce also gets affected with the high rainfall coinciding harvest season. Another 25.71 per cent farmers attributed the impact of climate change to delayed time of sowing as well as use of short duration soybean varieties in order to manage the crop from long dry spells or terminal drought. Rest of the farmers (15 %) have expressed the impact of climate change on increase in cost of cultivation of *kharif* crops due to expenditure on management of insect-pests and diseases, which were found in increasing order. Earlier studies have also indicated that there is significant increase in the share of plant protection chemicals in operational cost of soybean cultivation in all major soybean growing states (Sharma *et al.*, 2015; Sharma, 2016).

Fig. 1. Farmers' perceived impact of climate change on crops and productivity

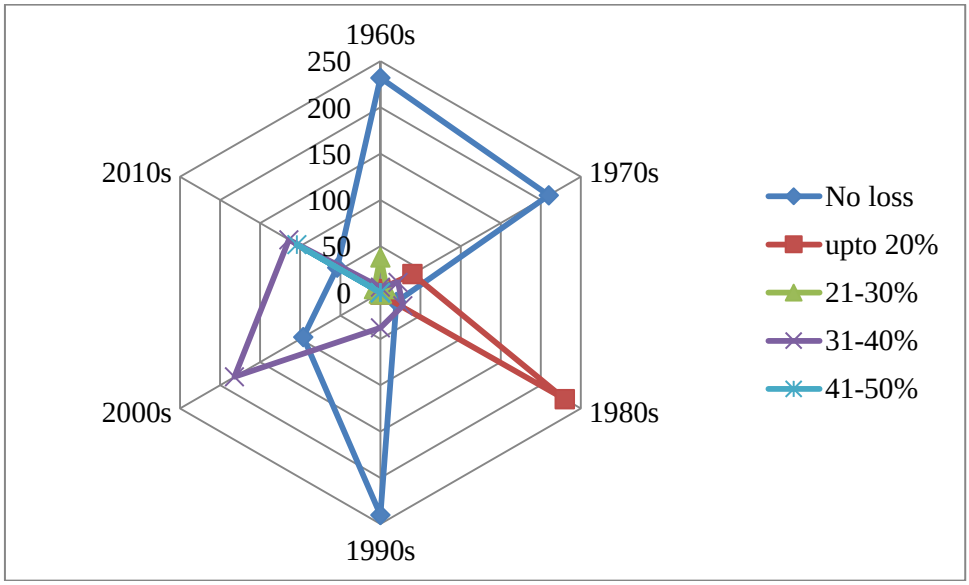


Farmers' perception of extent of yield loss due to climatic adversities

The farmers were asked whether they felt any effect of changing climate for reduction in yield of *kharif* crops. Majority perceived that the adverse climate contributed to about 20 per cent yield loss in their *kharif* crop. But it is astonishing to know that during the decades 2000-2009 of the farmers (Fig. 2) reported that there was no significant yield loss due to adverse climatic conditions during the period of1960s and 1970s. However, During 1980s, majority of farmers (82 %) and 2010-2019, about 65 per cent and 40 per cent of the farmers felt that the climatic adversities have resulted in about 31-40 per cent yield loss of soybean crop in their

area. Further, more than 37 per cent farmers also believed that during the last decade, the yield losses due to climatic adversities could be as high as 40-50 per cent in spite of adoption of recommended production technologies. The results clearly indicated that yield loss in the *kharif* crops due to aberrant weather conditions has increased over the years as perceived by the farmers in the study area.

Fig.2. Perception of yield loss due to adverse weather



Farmers' perception of changes in soybean yield during last 40 years

As the soybean crop became more popular among the farmers from 1980 onwards, majority of the farmers could reply to yield data of soybean only for the subsequent period and the same data (Table 2) was considered for the present study. As very few farmers initially started growing this crop, those who were cultivating soybean crop before eighties said that the yield of soybean in its about 600-1,000 kg per ha showed a gradual decline. Similarly, the percentage of farmers who harvested around 1,100-2,000 kg per ha during 1980s and 1990s showed declination with the primitive period (sixties and seventies) was very less (sometime less than 500 kg/ha). It was observed that in subsequent forty years there has been substantial increase in yield of soybean (Table 2). As responded by the sample farmers on the yield levels achieved, majority of the farmers harvested around 2,100-3,000 kg per ha soybean (61 %, 74 % and 64 % during 1980s, 1990s, and 2000s, respectively). However, the number of farmers getting average soybean yield of corresponding increase in higher yield category of 2,100-3,000 kg per ha and >3,000 kg per ha. The increase in yield of soybean was possible because of the release and adoption of short duration

high yielding varieties, varieties resistant to biotic and abiotic stresses, climate smart agronomic practices and farm machines for soil moisture conservation.

The average productivity of soybean during the last decade (2010s) showed a decline for majority of the farmers (only 25 % farmers with the productivity of 2,100-3,000 kg/ha and 75 per cent farmers with only 1,000-2,000 kg/ha). Furthermore, same trend was also seen in case of those farmers who achieved productivity levels of >3,000 kg per ha (12% during 1980s to only 1 % during 2010). The reduction in productivity of soybean during the recent decade could be attributed to effect of adverse climatic conditions which the farmers have encountered during last 20 years particularly related to increase in atmospheric temperature, reduction in atmospheric humidity, increased sunny days with less and erratic monsoon distribution coupled with decrease in total rainfall. Kawadia and Tiwari (2017) while studying the perception of the farmers about the climate change in Madhya Pradesh also found that 70 per cent of them identified significant decrease in crop yield due to climate change.

Table 2. Soybean yield (kg/ha) over the period

Range	1980	1990	2000	2010
< 500	-	-	-	-
600-1000	10 (3.57)	18 (6.43)	8 (2.86)	2 (0.71)
1100-2000	64 (22.86)	48 (17.24)	92 (32.86)	210 (75.00)
2100-3000	170 (60.71)	206 (73.57)	178 (63.57)	64 (22.86)
>3000	36 (12.86)	8 (2.86)	2 (0.71)	4 (1.43)

Adaptation strategies followed by the farmers for perceived climate change

When asked about the adaptation and mitigation strategies followed by them to overcome climatic adversities, the farmers have outlined changes mostly in the cropping pattern, varietal diversification, and crop management practices for biotic factors. About two third of the respondents (75.71 %) reported that they have started adoption of short duration soybean varieties as the best strategy to overcome the terminal drought which frequently occurs in the region since last few years. Similarly, more than 60 per cent farmers were found preferring cultivation of varieties resistant to pest and diseases. According to them, the trend of insect-pest-disease infestation now-a-days has got increased as compared to initial period of soybean cultivation. Interestingly, about 48 per cent farmers opined that their cost of crop cultivation has increased with the increase in cost of application of plant protection chemicals for saving the crop from biotic problems particularly weed, insect-pest and diseases. About one forth of the

respondents (24.28 %) have agreed that they have changed in the sowing time of soybean as an adaptation strategy whereas few farmers (17.85 %) have emphasized upon availing the benefits of crop insurance scheme, use of newly developed farm equipments like BBF/FIRB seed drills in order to escape the risk associated with severe drought during the crop season whereas few farmers (9.28 %) have agreed for creation of irrigation facilities facilitating the need based irrigation in adverse climatic situation (Table 3). Ramteke *et al*. (2015) and Billore *et al*. (2018) also reported the adaptation option such as delay in sowing, adoption of short duration and disease-insect resistant varieties, for farmers in order to minimize the impact of climate change. Sharma *et al*. (2019) reported that the adoption of BBF for sowing of soybean has increased soybean yield and net income of farmers.

Table 3. Adaptation strategies followed by the farmers to cope up with the climate change

Adaptation strategies	No. of farmers	Per cent
Change in cropping systems	82	29.28
Change of seed/Resistant Varieties	170	60.71
Shift toward short duration crop	70	25.00
Increased use of chemicals for management of insect, diseases and weeds	134	47.85
Change in sowing time	68	24.28
Short duration varieties	212	75.71
Increased use of FYM	30	10.71
Intercropping with soybean	4	1.42
Irrigation facilities created	26	9.28
Mechanization followed	30	10.71
Crop insurance	50	17.85

Soybean is a rainfed crop dependent primarily on seasonal monsoon. The farmers of the study area during the last few years have experienced adverse climatic conditions particularly the delayed, erratic and uneven distribution of rainfall, increased chances of long dry spell and increase in atmospheric temperature during the soybean crop season which affected the yield losses. They have followed several adaptation mechanisms in order to maintain soybean yield levels. Use of farm machineries such as BBF/FIRB seed drills along with other changes in management practices particularly forinsect-pest and diseases to some extent has helped them to address the problem. However, more efforts should be taken to develop climate resilient varieties as well as technologies considering the prevailing climate factors. Concerted efforts are also needed for popularization of location specific technologies and practices for their adoption among the farming community.

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