Asian Journal of Advances in Agricultural Research

12(3): 28-41, 2020; Article no.AJAAR.55223
ISSN: 2456-8864

Farmers' Perception and Micro-level Climate Adaptation Strategies in Bundelkhand Region, India

Surendra Singh[1*], Sanatan Nayak[2] and Ruby K. Kanojia[3]

[1]ICAR - National Institute of Agricultural Economics and Policy Research, New Delhi, India.
[2]Babasaheb Bhimrao Ambedkar University, Lucknow, India.
[3]Kamla Raja Girls Government Post Graduate College, Gwalior, Madhya Pradesh, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAAR/2020/v12i330086
Editor(s):
(1) Dr. Daniele De Wrachien, The State University of Milan, Italy.
Reviewers:
(1) Brian Gareau, Boston College, USA.
(2) Seyit Hayran, Cukurova University, Turkey.
(3) Niranjan Devkota, Pokhara University, Nepal.
Complete Peer review History: http://www.sdiarticle4.com/review-history/55223

Original Research Article

Received 28 December 2019
Accepted 02 March 2020
Published 11 March 2020

ABSTRACT

This study develops an understanding on human dimension approach of adaptation with special context to Indian agriculture. The study conducts a micro-level assessment of farmer's perception and adaptation responses based on survey data analysis of 200 farm household from two districts, i.e., Jalaun and Jhansi of Bundelkhand region. The study finds perceive and adapt cognitive condition to the main adaptation condition. The study recognizes the importance of social relations for developing an understanding of climate change. Government sources are found to be less impactful in delivering climate information along with other hypothesized sources. The study results provide a useful guide for identifying region-specific adaptation strategies options like, adoption of disease resistant seed varieties and use of new plant protection chemicals to deal with climate change. The role of government needs to be escalated in providing appropriate and adequate climate information to the farmers. Policy action is needed in creating awareness, increasing faith on reliability and accuracy of climate information services by the government.

Keywords: Climate change; farmers' perceptions; adaptation strategies; dry region; field data.

**Corresponding author: Email: surendra.singh735@gmail.com;*

1. INTRODUCTION

Global climate change impacts on agriculture impinge complex economic, social and political crisis. The nexus of climate change, food and agriculture appears to be more intense and complicated with devastating impacts for developing countries [1,2,3,4,5,6]. Amongst all developing countries, the IPCC [7,8] has recognized India as one of the most vulnerable countries towards climate change risks. The plight of Indian agriculture under climate change scenario is critical as staple crops such as rice, wheat, maize and millet are found to have highest climate sensitivities [6,9,10,11,12], which is raising serious concerns related to food security, poverty, social security and agriculture resilience.

So far years of careful research on impact assessment of climate change has majorly focused on estimating the equilibrium state of farm net revenue and crop yield under different climate change scenarios. The modeling technique used by these studies worked either with a 'dumb-farmer approach' or assumed adaptation as an impromptu [1] or spontaneous response to climate change. These studies are limited in their understanding of adaptation as a process in which human systems respond to uncertain and unpredictable climate conditions. Research on agricultural adaptation has matured overtime with the thoughtful recognition of human dimensions and human-environment systems. The human dimension of agricultural adaptation identifies farmer's agency as planners, performers, and innovators [13] working under a specific socioeconomic, cultural and ecological setting. The human dimension approach of adaptation focuses farmer's perception on climate changes, learnings from their past experiences in dealing with risks and uncertainties, developing their adaptive capacities and undertakes decisions on local adaptation strategies. Adaptation process at micro-level encompasses the interdependence of agents through their relationships with each other, with the institutions in which they reside and the resource base on which they depend [14]. In developing countries like India, agricultural adaptation is obstructed due to many socio-economic, geographical and metrological reasons. Institution arrangements and social relationship in form of climate extension services are needed to facilitate farm-level adaptation. An understanding of how farmers engage themselves in decision-making process and what are the major factors that induces and enhances adaptation responses is therefore important [15]. Fig. 1 gives a sample of farmer's adaptation decision-making process.

Successful and efficient adaptation is determined by three important factors i.e. (i) timely recognition of the need to adapt, (ii) incentive to adapt, and (iii) ability to adapt [16]. Understanding of the need to adapt requires farmer's to initially perceive and realize the actual changes in climate [17] and they need to alter the farming practices to maximize returns in each new climate [6]. The importance of farmer's perception on climate change in farm-level adaptation has been widely recognized by several studies [18,19,20,21]. Adaptation literature suggests several climate variables including increase/decrease of temperature and precipitation levels, regional monsoon variations, regional incidence of climate extremes (e.g. flood, drought, cyclones, and frosts) [18,19,20, 21]. Here it is equally important to understand and identify the key climate variables which are considered by farmers for framing their perceptions on climate change. Inter-annual variation in temperature, climate extremes are usually observed over short-term and are more erratic and uncertain. Famers are usually more concerned for seasonal climate forecasts as such changes leave very less response time and scope of efficient decisions under such cases might be limited. Wider gaps between farmers' anticipated climate variations and actual climate forecasts may also lead to indecisiveness [22, 23]. Farmer's place more weight to recent climatic events as information based on past personal experience and external sources differ significantly due to climate uncertainty [23]. Moreover, changes in agricultural system may not necessarily involve linear updating of farmer's decision making and therefore, the way in which farmers revise their anticipations on climate variation is important [19,21].

Farmer's choice of adaptation strategies normally reflects their risk-averse behaviors as probability of adopting only those adaptation strategies for which benefits exceed the costs is the highest [5]. Farmers' perception on climate events does not guarantee taking adaptation measures [21, 17]. As even though farmers may perceive changes in climate their ability to adapt might be

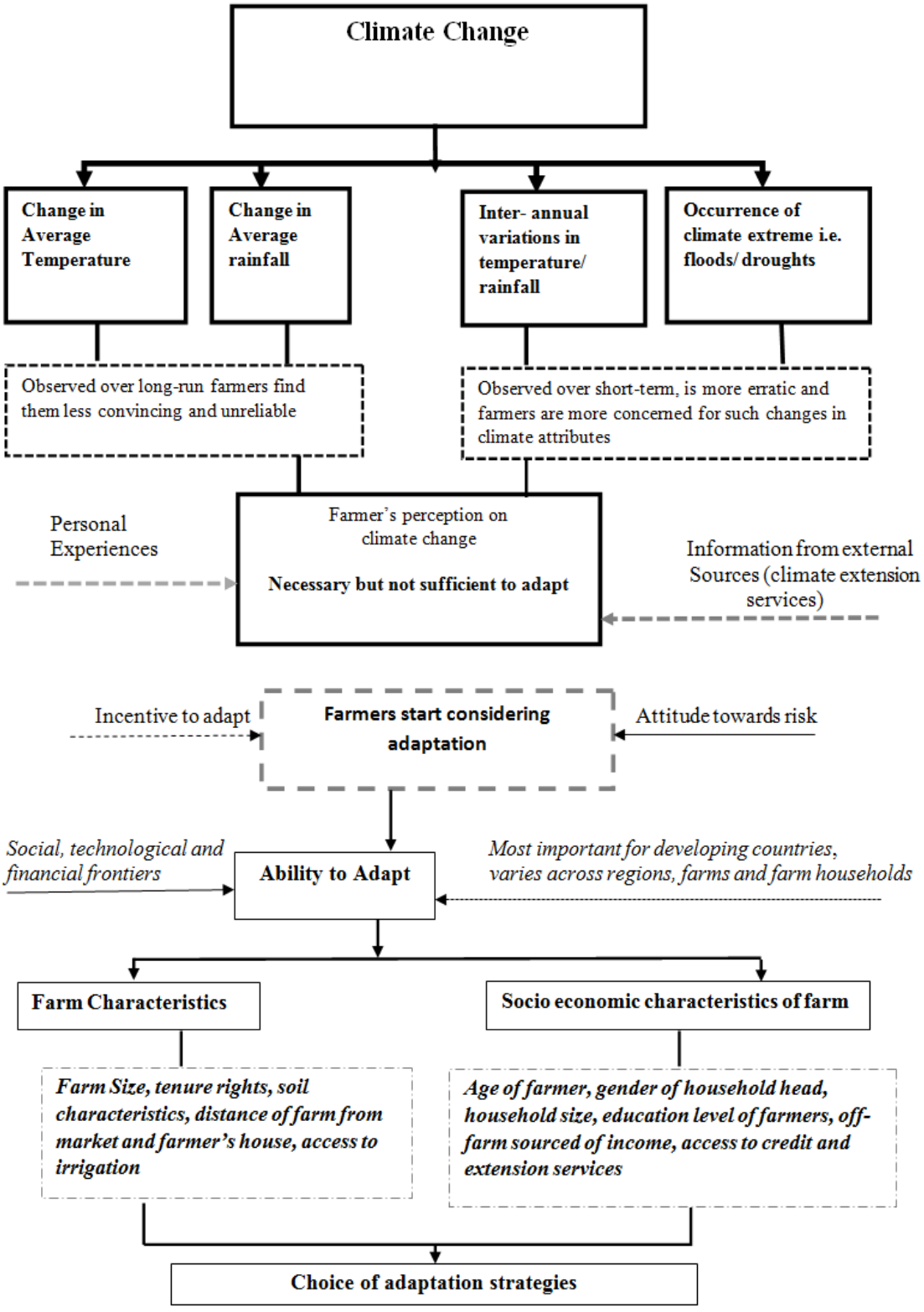

Fig. 1. Diagrammatic representation of farmer's adaptation decision-making process

restricted due to several factors. Ability to adapt depends on cognitive skills of farmers which varies across households depending upon age, educational qualification geographic locations, gender, economic contextual and ethnicity. Several studies have tried to assess factors responsible in framing farmer's perception and capacity to adapt [21,25,18,23]. Gbetibouo [21] finds that educated farmers might possibly observe no definite trends in rainfall and temperature levels over long-run, increase access to irrigation water enhance their resilience to climate fluctuations. Institutional arrangements and social relationships in form of climate extension services can play a key role in facilitating adaptation. Access to extension services can aid them in judging their ex-ante climate predictions in comparison to the actual climate occurrences. Also, perceptions of farmers can be influenced by external forces such as their peer's awareness and by societal ethics as well as their specialized alliances [19, 26,27]. Apart from these, factors like agro-ecological settings, social capital, wealth, climate information and age of household head also establish farmer's perception and ability to adapt. Local climate forecasts including, seasonal climate variations provided by the regional meteorological departments can be beneficial in framing up their observations on early warning of the gap between the widely recognized need for systems and agricultural risk management [28]. Availability of better climate and agricultural information augment farmer's decision-making capacity which enables convergence to best response [20].

1.1 Barriers to Effective Climate Change Adaptation

Adaptation barriers have emerged as the key concerns while the need for climate change adaptation has become evident. As adaptation research evolves, valuable insights are provided about various factors that hinder the implementation of adaptation to climate change. These factors help to describe adaptation and the general lack of action [29]. However, there is a little consensus about which barriers are the most significant to agricultural producers [25,28].

Barriers to adaptation are defined as 'conditions or factors that render adaptation difficult as a response to climate change' [30] but they are often mutable [31] or can be an 'overcome with concerted effort, creative management, change of thinking, prioritization and related shifts in resources, land uses, institutions, etc.' [32,33]. This means that barriers are dependent on attributes of adaptation, actors and their context [34]. It also suggests an endless list of barriers, which can make it difficult to strategically address impediments throughout the climate change adaptation process [35]. In response to this challenge, some studies have made efforts to introduce the dominant category of barriers to adaptation based on various factors, such as the nature of barrier and the way it manifests or the time of barriers' incidence in the adaptation process [33,36,37,38,39]. However, it is of concern that narrow categorization of barriers does not give a comprehensive picture of barriers to climate change adaptation, in developing countries' settings.

Based on the literature, five barrier types, i.e. institutional, social and cognitive, economic, uncertainty and technological, emerge as the most prominent barriers. Many studies [36,37, 38,39] pointed to institutional barriers as a central cause of ineffective climate change adaptation. This is because governance and policy define the processes and rules that govern access to markets and resources and regulate adaptation policies and laws. Formal institutional 'traps', such as institutional fragmentation [40], can lead to poor coordination and incapability [31,41], inequitable distribution of responsibility for adaptation [42], insufficient responsiveness of institutions to change [31,43], reactionary initiatives [40] and improper leadership [44,33]. These factors are all reinforced by institutional elites failing to involve non-governmental stakeholders [36,45].

Social and cognitive processes of society are also the other barriers to smooth adaptation in the agriculture sector [31,46,47,33]. Some studies suggest that emotions, ethics, knowledge, risk perception, and culture are the key aspects of social and cognitive barriers [31, 45,48,33,49,50]. Farmers perceive, interpret and think about climatic risks and adaptive strategies depending on their deeply held worldviews, values, and beliefs [33]. Also, culture, as a symbol declares meaning and brings collective outlooks and behaviours [35], has played a key role in shaping adaptive choices made in agricultural communities.

With the above background, the present study attempted; (i) to assess farmers' perception of climate change, (ii) to identify barriers to effective climate risk management strategies and to

identify the micro-level climate adaptation strategies in the survey villages.

2. MATERIALS AND METHODS

2.1 Study Area

The present study is undertaken in Bundelkhand region of Uttar Pradesh in India. Uttar Pradesh is one of the key states and plays a vital role in India's food and nutritional security by contributing 17.83% of country's total food grain output in 2016-17 [51]. Geographically, Uttar Pradesh is divided into four economic regions, viz., Western, Central, Eastern and Bundelkhand. This study was undertaken in two districts of Bundelkhand region, viz. Jalaun and Jhansi due to preponderance of droughts in the region (Fig. 2).

Compared to any other region of Uttar Pradesh, Bundelkhand is historically more vulnerable to climate change. The region had experienced drought in every 16th year during 18th and 19th centuries, which increased thrice during 1968 to 1992 and now has become the recurrent annual phenomenon [51]. The average annual rainfall of the region continued to be below average during 2004-2017 (Fig. 3). The severity of low rainfall was such that 40% of net sown area remained fallow which resulted to 30% less in food grains output [51]. Farmers are majorly grown Wheat, Soybean, Tur, Rape seed, Paddy, Gram, Maize, Groundnut, Jowar and Bajra.

Apart from droughts, variations in temperature also cause vulnerability to households. Data revealed that mean maximum and minimum temperature increased by 0.28°C during 1969-2017 over the base of 1960-1990 (Fig. 4). Rise in temperature leads to high evapotranspiration causing loss to soil moisture, reduction in groundwater recharge and surface water.

2.2 Sampling Framework

A Multi-Stage sampling technique was used to select study sites and households. In the first step, two districts, namely Jhansi and Jalaun, were chosen from seven districts in the Bundelkhand region. Next each of the

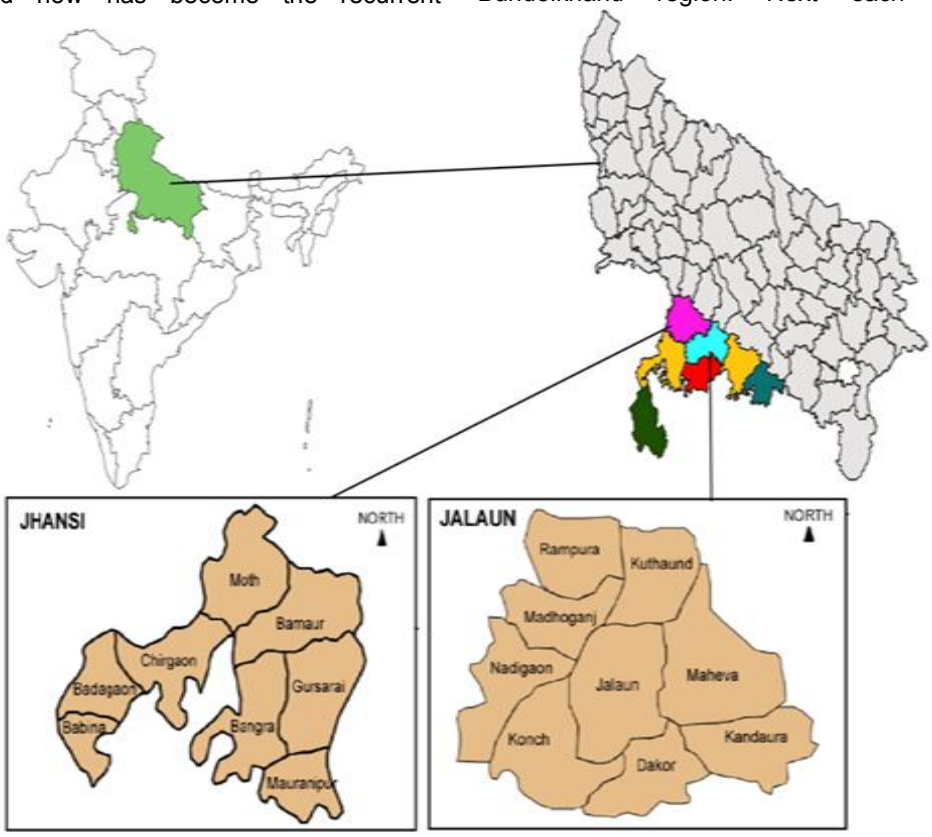

Fig. 2. Map of the study area
Source: Author' preparation

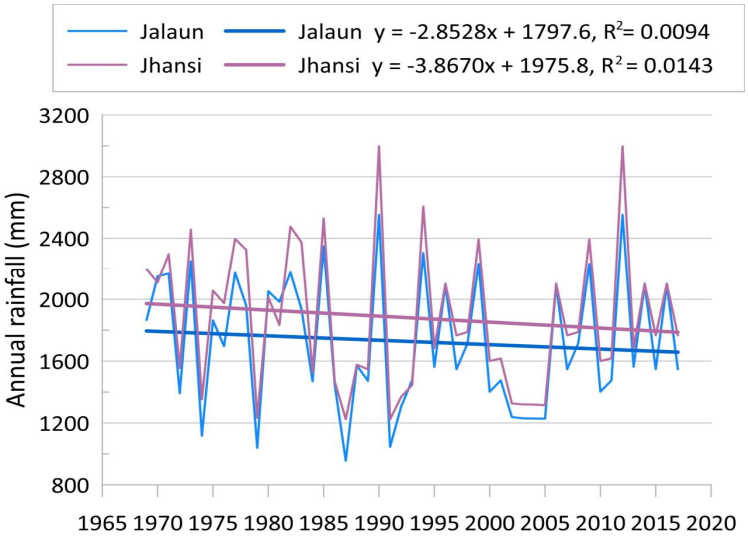

Fig. 3. Variability in annual rainfall
Source: Author' estimation (IMD, 2017)

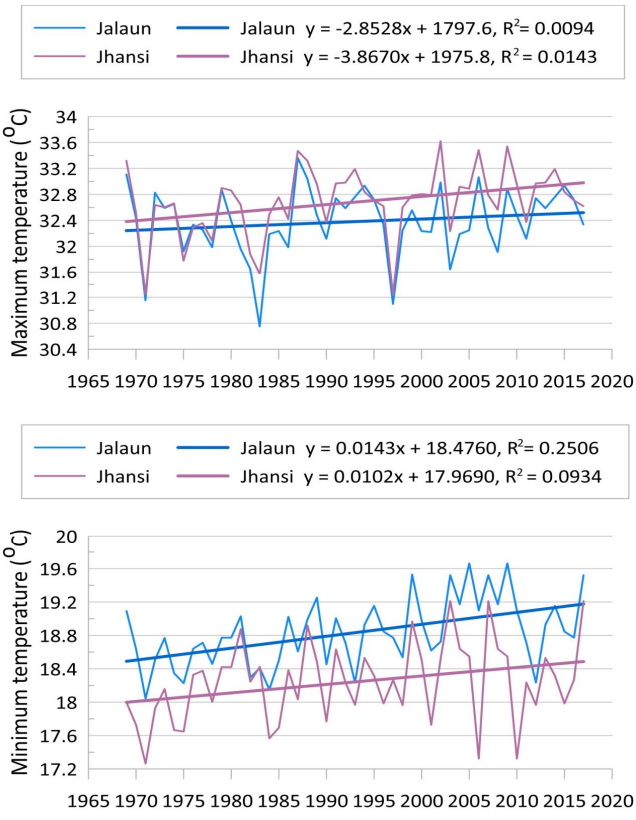

Fig. 4. Variability in maximum and minimum temperature
Source: Author' estimation (IMD, 2017)

five sub-divisions (i.e., *Tehsils*) in each district were selected. In the third step, one Development Block was selected purposively from each Tehsil. In the fourth step, one village from each selected block was chosen randomly. Finally, 20 households from each village were

Table 1. Socio-economic characteristics of sample households

Characteristics	Jalaun	Jhansi
Female headed households (%)	44.74	44.18
Literacy rate of households (%)	49.76	50.24
Unemployment rate in households (%)	50.06	49.94
Mean income of households (US$)	332.07	372.24
Average land size of households (in acre)	0.26	0.35
Average age of household (years)	31.36	30.04
Marital status (% of married to total family members)	52.39	53.32
Households having electricity connection (%)	65.00	80.00
Households having sanitation facility (%)	57.00	51.00
Households using improved drinking water facility (%)	61.00	60.00
Households below poverty line (%)	29.00	26.00

Source: Field survey data, 2017. Note: 1 US$= 69.49 Indian Rupees (INR)

selected randomly. The result was the selection of 2 Districts, 10 *Tehsils*, 10 *Developmental Blocks*, 10 *Villages,* and 200 *farm households*. Household farm holdings comprised marginal (<1.0 hectare, ha), small (1-2 ha), semi-medium (2-4 ha), medium (4-10 ha) and large (>10 ha) farms. The farmers selected comprised 20% of households from each of these farm size categories in the selected villages. A well-structured and pre-tested schedule was used to collect information about the selected farmers' perception of climate change and variability during the past five years and the choice of adaptation strategy. The survey was undertaken during May-June 2017 soon after harvesting of the winter crop to elicit information on climate-related variables and agricultural extension services. The survey data related to the agricultural year 2016-17 (July-June).

3. RESULTS AND DISCUSSION

3.1 Socio-economic Characteristics of the Households

The socio-economic characteristics of sample households of study area reflect the economic challenges prevailing in the region compared to that of Uttar Pradesh and all-India level (Table 1). The average landholding and mean income of sample households are lower in study districts as compared to Uttar Pradesh and national average (1.18 ha). Other personal attributes of sample households viz. low literacy rate and higher female headed households again reflect the backwardness in the region. Having access to basic amenities consisting of electricity connection, sanitation and drinking water facility, sample households were far behind the level of Uttar Pradesh and even national average (Table 1). Moreover, majority of the sample households are young having the mean age of 31.36 years and 30.04 years in Jalaun and Jhansi districts, respectively. Besides, between 26-29% of population belongs to the below poverty line. In totality, the study results show that the majority of the population is deprived of basic amenities and any climate change event has large influence on them.

3.2 Farmers' Perceptions of Climate Change

Analyzing farmers' perception of climate change is a prerequisite for assessing adaption. The literature on climate change perception has well identified the importance of timing and types of climate change instances, which usually farmers observe and utilize in framing their perceptions. Therefore, this study purposefully distinguishes normal changes in climate observed over long-term changes and climate extremes. Climate extremes are uncertain, and farmers are required to act instantaneously under such extremes to avoid losses. Decision making by farmers under such circumstances is quite difficult as the time lag between gatherings and processing information into a decision to adapt is quite small.

The study findings revealed that majority of sample farmers have perceived that there is a higher degree of variability in the climatic parameters. Above 90% of farmers perceived that summer days become hotter, frequency of droughts increasing and water level declined (Fig. 5). Further, more than 60% of farmers opined that rainfall has declined. Apart from quantitative analysis, qualitative analysis was also undertaken to captures farmers' experiences of changing climate. For instance, farmers reported that droughts have dual impacts on the livelihoods. Firstly, most of the farm

families in survey villages had lost either their crops or cattle or both that was first line of deference to deal with climate change. As the villagers themselves struggle to live during crisis time, survival of cattle is the last thing in their mind. For instance, farmers belonging to Amra village of Jhansi district had 1500 livestock population, as against 8000 livestock population 4 years ago (i.e. 2012-13). Lastly, there is no provision of compensation in the event of cattle's death. In a sense, livestock has not been considered as resource in the State policy of Uttar Pradesh. Farmers' perceive that government has not made any visible and significant provisions for livestock survival during extreme climatic variability, making them to dissuade from rearing livestock as an enterprise.

Due to erratic climatic behaviour, shortage of rainfall could not make much positive impact on agriculture, livestock and other livelihood systems in the region. The field experience in Jalaun and Jhansi districts also showed unequal rainfall in the region. In fact, it is visible that due to deforestation and frequent droughts in last five years, the overall capacity of the region in harvesting and storing rainwater for the future has substantially reduced.

These results are in the line with Indian Meteorological Department (IMD) temperature record for Bundelkhand region suggests significant increase in annual temperature levels by about 0.01°C/ year from 1951 to 2010. In case of rainfall, the actual annual rainfall trends for the period 1951-2010 shows an increase in 1.41 mm/year in rainfall. The summer and winter rainfall show an increase of about 0.59 mm/ year and about -0.06 mm/year respectively. It is more often the case that farmers give more weight to recent experiences of climate than the past and therefore the pattern in which farmers update their information is an important factor in determining farmer's perception on climate change.

Our results also matched with the previous studies that have pointed out that farmer's perception of climate change depends on their recent experiences [i.e., 52,18,24,23]. Hansen et al. [23] find that "farmers' memory of past climatic variability may be distorted in systematic ways, reflecting wishful thinking by distortions consistent with decision goals as well as being shaped by personality characteristics and pre-existing beliefs".

3.3 Barriers to Effective Climate Change Adaptation

Often it is the case that although farmers perceive climate change, they are reluctant to adapt due to several constraints which the face in undertaking adaptation decisions. It is pertinent to assess farmers' discernment on constraints to the adaptation to understand the relative importance and identifying the factors affecting their adaptation decisions. These factors may include accessibility and usefulness of climate information, socioeconomic conditions of farm households and the supportive institutional mechanisms [24]. For instance, lack of knowledge of adaptation options, information of long run and short-run change in climate can be the consequence of information gap and service and technological delays in the affected regions.

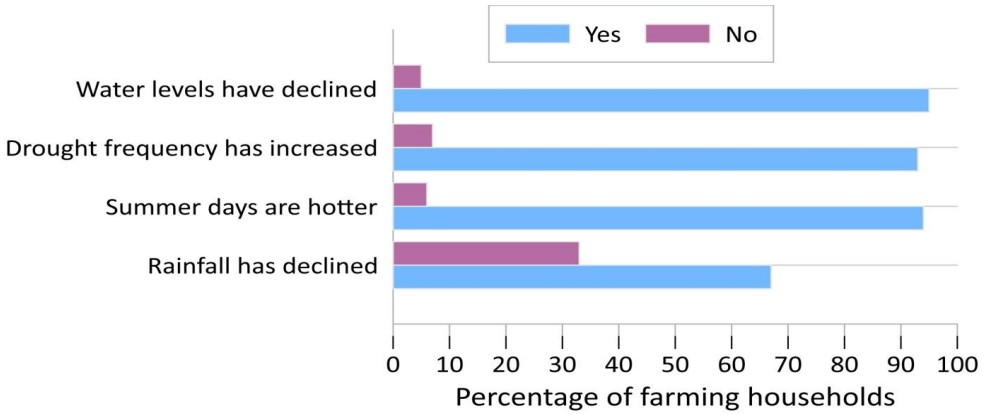

Fig. 5. Farmers' perception of climate change
Source: Field survey data, 2017

For instance, lack of knowledge of adaptation options, information of long run and short run change/variations in climate can be the consequence of information gap and service and technological delays in the affected regions. Farmers, specifically smallholder are vulnerable to high-cost debts and, therefore despite sensing the need to adapt they might be unsuccessful in adapting. Usually, barriers faced by farmers are associated with their income level, which might be the problem of intergenerational landlessness and poverty. Adaptation to climate change is costly and may require intensive labour use. Therefore, farm households facing acute shortage of family labour and income sources to hire labour, may not adapt. Lack of credit, lack of cost-effective quality seeds, information gap/awareness, credit shortage, labour shortage, inadequate land availability, and poor irrigation sources limit the ability of farmers to obtain necessary resources and technologies required to undertake adaptation activities.

Farmers were asked about what according to them are the main barriers to adaptation. They were given sixteen options to choose from; (i) awareness on crop insurance programmes, (ii) higher cost of agricultural inputs, (iii) water scarcity, (iv) higher wage rate, (v) unawareness on government welfare schemes, (vi) lack of access to common pool resources, (vii) lack of information on climate change, (viii) distance from district headquarter, (ix) poor potential for irrigation in the area, (x) No/lack of all seasonal approach road, (xi)expensive adjustments (xii) lack of storage capacity, (xiii) low price for products in the market, (xiv) lack of transportation facility, (xv) insecure and poorly defined property rights and (xvi) lack of access to institutional credit.

The present study findings reveal that farmers faced several constraints to effective climate change adaptation. Farm households facing acute shortage of family labour and income sources to hire labour, may not adapt. Lack of credit, lack of cost-effective inputs, information gap/awareness, inadequate land availability, and poor irrigation sources limit the ability of farmers to obtain the necessary resources and technologies required to undertake adaptation activities. About 90.83% of farmers perceive that lack of access to institutional credit is the main constraint that limits the ability of farmers to adopt climate change adaptation (Fig. 6). Farmer's responses on Insecure and poorly defined property rights, lack of transportation facility, low price for the product in the market ranges from 70 to 80%.

3.4 Adaptation Strategies in Rainfed Agriculture

Farming seasons vary based on the climate conditions and accordingly the choice of crops to be planted and agricultural management practices also differ by seasons. Consequently, the choice of adaptation strategies is also likely to differ. Also, farmer's decision to adapt or not to adapt is based on four probable cognitive conditions; (i) perceive/predict changes in climate and decide to adjust to maximize their returns out of the changing conditions, (ii) perceive/predict changes in climate yet do not adapt because of the constraints they face in adapting, (iii) do not perceive/predict any changes in climate conditions and therefore decide not to adapt, and (iv) do not perceive/predict any climat change yet undertake adaptation due to their personal choices for some new on-farm changes or copying their fellow farmers cropping pattern which they may find interesting and profitable.

The sample households of the region adopted differential adaptation strategies to cope with changing climate. More than 60% of households planted eucalyptus, citrus and mango trees surrounding of the farm lands and diversified their cropping pattern towards less water consuming crops (Fig. 7). Since Bundelkhand is a dry region and, therefore, irrigation has a potential impact on farm revenue. The study has observed that more than 40% of sample farmers had increased their irrigation coverage by digging ponds, storing surface rainwater and grow less water requiring drought resistant varieties of Jowar (Pusa Chari- 615), Bajra (APFB-2), kharif pulses (PUSA Arhar- 16), and oilseeds (RCC- 4). Few farm households believe that by increasing inputs, the productivity could be increased. By assuming this, nearly 35% of households increased the use of bio-pesticides and fertilizers. Besides, 20% of farm households were engaged in non-farm activities. The negligible numbers of sample households were engaged in non-farm employment opportunities during the off season and higher dependence on agriculture restricted farmers to change the cropping pattern and switch to non-farm employment activities.

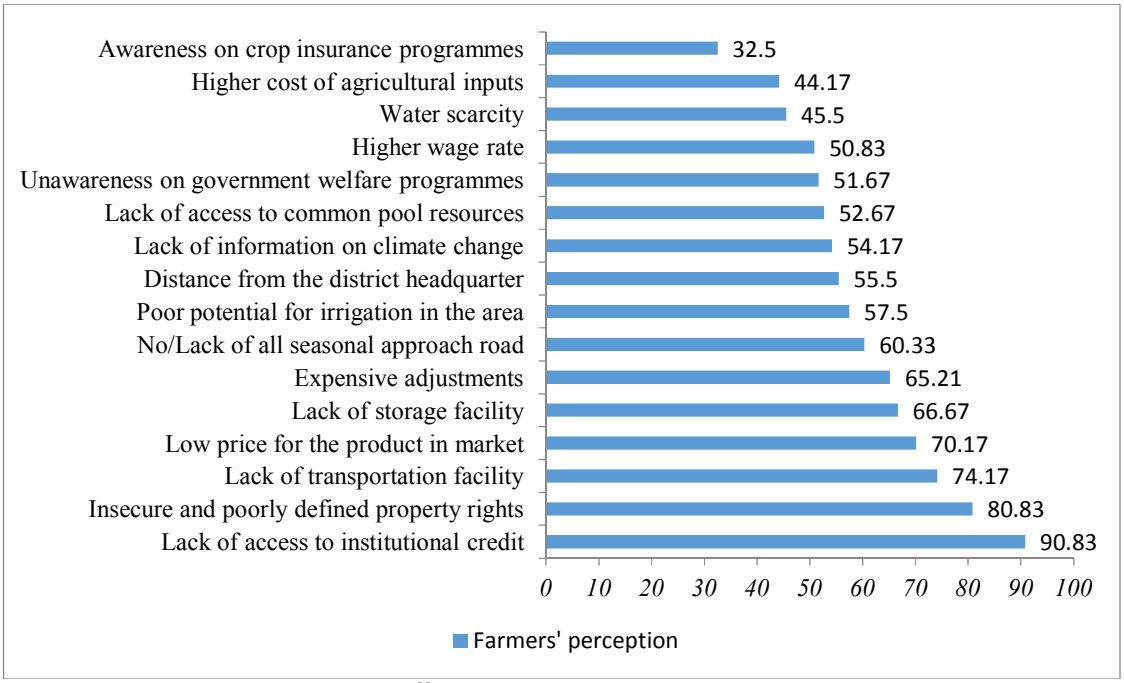

Fig. 6. Barriers to effective climate adaptation in the study area

Source: Field survey data, 2017. Note: figures are in percentage

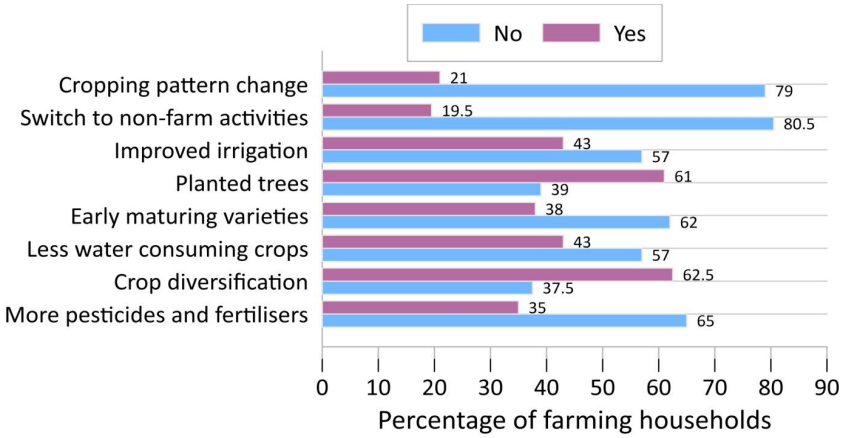

Fig. 7. Adaptation strategies adopted by surveyed households

Source: Field survey data, 2017

4. CONCLUSION AND POLICY IMPLICATION

Crop yield and farm net revenue are the main outcomes of decision-making and behavioural attributes of farmers and therefore, understanding of farmers' adaptation decision-making process is imperative to facilitate efficient farm adaptations. This study develops an understanding on micro-level adaptation decisions of farmers' as a process involving perceptions on climate change, their learning from past experiences in dealing with climate uncertainties, risks and hazard, their interdependence on fellow farmers (agents) through social relationships and the institutional mechanisms in for of extension services in which they undertake adaptation actions. This study through survey data analysis finds that this process in itself along with the socio-economic endowments of the farm households is the key enablers of farmers' adaptive capacity.

The study finds that most of the farmers perceive changes in temperature and rainfall. Farmers primarily rely on their own climate predictions

and information sharing with household head and fellow farmers. It is evident that adaptation decisions of farmers are mainly followed by their perception. The vital set of adaptation strategies, which farmers in the surveyed districts often cater to the seasonal adaptation includes, irrigation, changing crop variety and cultivation area. However, despite the fact that majority of the farmers opt for adaptation; efficient adaptation faces serious hindrances ascending from mental delusion regarding economic costs of farm-level changes, information asymmetry regarding climatic change, knowledge gap on adaptation options with higher returns, limited credit security, water shortages and limited access to markets.

The study results provide a useful guide towards identifying region-specific adaptation strategies and enable policy interventions in strengthening other non-farm specific adaptation strategies like crop insurance schemes and availability of non-climate sensitive crops. Policy interventions should prioritize eliminating asymmetry in information and communications. The first step in this direction must involve replacing generic climate advisories with district-level specifications. Enhancing institutional capacities to accurately forecast weather in small geographic regions and warranting accountability of meteorological departments is imperative. The government can work towards building a common platform for the scientific exchange of district or plot level information among farmers, seed and machinery retailers, fertilizer suppliers, banks and insurance companies. This can help in collaborative decision-making towards climate resilient and sustainable agriculture solutions involving all related stakeholders with adequate interventions from policy i.e., the government, private agencies, and NGOs. There is also a need to customize extension services for smallholders to improve the adaptation rate and ensure long-term impact. Further, to potentially utilize the benefit of farmers' social network it is necessary to enhance agricultural livelihood through community institutions.

CONSENT

As per international standard informed and written participant consent has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Rosenzweig Cynthia, Martin L. Parry. Potential impact of climate change on world food supply. Nature. 1994;367 (6459):133-138.
2. Reilly John, Neil Hohmann, Sally Kane. Climate change and agricultural trade: Who benefits, who loses?. Global Environmental Change. 1994;4(1):24-36.
3. Pearce David W, William R, Cline Amrita N. Achanta, Samuel Fankhauser, Rajendra K. Pachauri, Richard SJ Tol, Pier Vellinga. The social costs of climate change: greenhouse damage and the benefits of control. Climate change 1995: Economic and social dimensions of climate change. 1996;179-224.
4. Tol Richard SJ. Estimates of the damage costs of climate change. Part 1: benchmark estimates. Environmental and resource Economics. 2002;21(1):47-73.
5. Mendelsohn Robert, Ariel Dinar. Climate change, agriculture, and developing countries: does adaptation matter?. The World Bank Research Observer. 1999;14 (2):277-293.
6. Sanghi Apurva, Robert Mendelsohn. The impacts of global warming on farmers in Brazil and India. Global Environmental Change. 2008;18(4):655-665.
7. IPCC. Climate change 2007: Impacts, adaptation and vulnerability. In: Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Cambridge University Press, Cambridge, United Kingdom. 2007;210-220.
8. IPCC. Climate Change 2014: Impacts, adaptation and vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2014;1132.
9. Kumar KS Kavi, Jyoti Parikh. Indian agriculture and climate sensitivity. Global Environmental Change. 2001;11(2):147-154.

10. Lobell David B, Adam Sibley J. Ivan Ortiz-Monasterio. Extreme heat effects on wheat senescence in India. Nature Climate Change. 2012;2(3):186-189.
11. Guiteras Raymond. The impact of climate change on Indian agriculture. Manuscript, Department of Economics, University of Maryland, College Park, Maryland; 2009.
12. Jha Brajesh, Amarnath Tripathi. Isn't Climate Change Affecting Wheat Productivity in India?. Indian Journal of Agricultural Economics. 2011;66(3):353.
13. Crane Todd A, Carla Roncoli Joel Paz, Norman Breuer, Kenneth Broad, Keith T. Ingram, and gerrit hoogenboom. Forecast skill and farmers' skills: Seasonal climate forecasts and agricultural risk management in the southeastern United States. Weather, Climate and Society. 2010;2 (1):44-59.
14. Adger W. Neil, Saleemul Huq, Katrina Brown, Declan Conway and Mike Hulme. Adaptation to climate change in the developing world. Progress in development studies. 2003;3(3):179-195.
15. Sen Li, Lind Juhasz-Horvath Paula A. Harrison Laszlo, Pinter Mark DA. Rounsevell. Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. Journal of Environmental Management. 2017;185: 21-30.
16. Fankhauser Samuel, Joel B. Smith, Richard SJ Tol. Weathering climate change: some simple rules to guide adaptation decisions. Ecological Economics. 1999;30(1):67-78.
17. Bryan Elizabeth, Temesgen T. Deressa, Glwadys A. Gbetibouo and Claudia Ringler. Adaptation to climate change in Ethiopia and South Africa: Options and constraints. Environmental Science & Policy. 2009;12:(4):413-426.
18. Maddison David. The perception of and adaptation to climate change in Africa. World Bank Publications; 2007.
19. Bryant Christopher R, Barry Smit, Michael Brklacich, Thomas R. Johnston, John Smithers, Quentin Chjotti, Bhawan Singh. Adaptation in canadian agriculture to climatic variability and change. Climatic Change. 2000;45(1):181-201.
20. Nhemachena Charles, Rashid Hassan. Micro-level analysis of farmers adaption to climate change in Southern Africa. Intl Food Policy Res Inst; 2007.
21. Gbetibouo Glwadys Aymone. Understanding farmers' perceptions and adaptations to climate change and variability: The case of the Limpopo Basin, South Africa. Intl Food Policy Res Inst, 2009;849.
22. Roncoli Carla, Keith Ingram, Paul Kirshen. The costs and risks of coping with drought: Livelihood impacts and farmers responses in Burkina Faso. Climate Research. 2001; 19(2):119-132.
23. Below Till, Astrid Artner, Rosemarie Siebert, Stefan Sieber. Micro-level practices to adapt to climate change for African small-scale farmers. A review of selected literature. Environmental Production Technology Division. 2010: 953.
24. Hansen James W, Sabine M. Marx, Elke U. Weber. The role of climate perceptions, expectations and forecasts in farmer decision making: The Argentine Pampas and South Florida: Final Report of an IRI Seed Grant Project; 2004.
25. Deressa, Temesgen Tadesse, Rashid M. Hassan, Claudia Ringler, Tekie Alemu, Mahmud Yesuf. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change. 2009;19(2): 248-255.
26. Khanal Uttam, Clevo Wilson, Viet-Ngu Hoang, Boon Lee. Impact of community-based organizations on climate change adaptation in agriculture: Empirical evidence from Nepal. Environment, Development and Sustainability. 2017;1-15.
27. Khanal Uttam, Clevo Wilson, Boon L. Lee, Viet-Ngu Hoang. Climate change adaptation strategies and food productivity in Nepal: a counterfactual analysis. Climatic Change. 2018;148(4):575-590.
28. Vogel, Coleen, Karen O'Brien. Who can eat information? Examining the effectiveness of seasonal climate forecasts and regional climate-risk management strategies. Climate Research. 2006;33(1): 111-122.
29. Wolf J, Adger WN, Lorenzoni I. Social capital, individual responses to heat waves and climate change adaptation: An

empirical study of two UK cities. Global Environmental Change. 2010;20(1):44–52.

30. Nielsen OJ, Anette R. Cultural barriers to climate change adaptation: A case study from Northern Burkina Faso. Global Environmental Change. 2010;20:142 -152.
31. Adger W, Neil Suraje Dessai, Marisa Goulden, Mike Hulme, Irene Lorenzoni, Donald R. Nelson, Lars Otto Naess, Johanna Wolf, Anita Wreford. Are there social limits to adaptation to climate change?. Climatic Change. 2009a;93(3): 335-354.
32. Forouzani M, Karami E. Agricultural water poverty index and sustainability. Agronomy for Sustainable Development. 2010;31: 415–431.
33. Moser SC, Ekstrom JA. A framework to diagnose barriers to climate change adaptation. Procedings of National Academy of Science, U.S.A. 2010;107: 22026-22031.
34. Azhoni A, Ian Holman, Simon J. Adapting water management to climate change: Institutional involvement, inter-institutional networks and barriers in India. Global Environmental Change. 2017;44:144-157.
35. Waters E, Jon B, Aedan P. Contrasting perspectives on barriers to adaptation in Australian climate change policy. Climatic Change. 2014;124:691-702.
36. Glaas E, Jonsson A, Hjerpe M, Andersson-Sko Y. Managing climate change vulnerabilities: Formal institutions and knowledge use as determinants of adaptive capacity at the local level in Sweden. Local Environment. 2010;15(6): 525–539.
37. Lebel L, Salamanca A, Kallayanamitra C. The governance of adaptation financing: Legitimacy at multiple levels. International Journal of Global Warming. 2017;11(2): 226-245.
38. Mandryk M, Reidsma P, Kanellopoulos A, Groot JJ, Ittersum M. The role of farmers' objectives in current farm practices and adaptation preferences: A case study in Flevoland, the Netherlands. Regional Environmental Change. 2014;14(4):1463-1478.
39. Reid H, Alam M, Berger R, Cannon T, Huq S, Milligan A. Community-based adaptation to climate change: An overview. Participatory Learning and Action: Community-Based Adaptation to Climate Change. 2009;60(13):11-33.
40. Islam M, Nursey-Bray M. Adaptation to climate change in agriculture in Bangladesh: The role of formal institutions. Journal of Environmental Management. 2017;200: 347-358.
41. Mukheibir P. Potential consequences of projected climate change impacts on hydroelectricity generation. Climate Change. 2013;121:67-78.
42. Baker IA, Peterson G, Brown C, McAlpine. Local government response to the impacts of climate change: An evaluation of local climate change adaptation plans. Landscape Urban Planning. 2012;107: 127-136.
43. Bastakoti R, Manita R, Anoj K, Prasun D. Assessing value chain opportunities for smallholder vegetable growers in eastern gangetic plains. Working Paper, Australian Centre for International Agricultural Research, Australia; 2017.
44. Burch S. Transforming barriers into enablers of action on climate change: Insights from three municipal case studies in British Columbia, Canada. Global Environmental Change. 2010:20:287-297.
45. Wise RMI, Fazey M. Stafford Smith SE, Park HC, Eakin ERM, Archer Van Garderen B. Campbell. Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environmental Change. 2014;28:325-336.
46. Field CB, Mortsch LD, Brklacich M, Forbes DL, Kovacs P, Patz JA, Running SW, Scott MJ. North America. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry ML, Canziani OF, Palutikof JP, van der Linden PJ, Hanson CE (eds.)]. Cambridge University Press, Cambridge, U.K. and New York, U.S.A. 2007;617-652.
47. Jones L, Boyd E. Exploring social barriers to adaptation: Insights from Western Nepal. Global Environmental Change. 2011;21(4):1262-1274.
48. Kuruppu N. Adapting water resources to climate change in Kiribati: The importance of cultural values and meanings.

Environmental Science & Policy. 2009;12 (7):799-809.

49. Pavageau C, Gaucherel C, Garcia C, Ghazoul J. Nesting sites of giant honeybees modulated by landscape patterns. Journal of Applied Ecology. 2018; 55(3):1230-1240.
50. Spires M, Sheona E, Shackleton A. synthesis of barriers to and enablers of pro-poor climate change adaptation in four South African municipalities. Climate and Development. 2018;10(5):15-29.
51. GoI. Annual Report, Indian Meteorological Department of India. Ministry of Earth Science, Government of India, New Delhi, India; 2017.
52. Smit B, Blain R, Keddie P. Corn hybrid selection and climatic variability: Gambling with nature?. Canadian Geographer. 1997;41:429-38.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/55223