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Knowledge and passive adaptation to climate change: An example from Indian farmers

Amarnath Tripathi [a], Ashok K. Mishra [b,*]

[a] Institute of Economic Growth, University of Delhi Enclave, Delhi, India

[b] Morrison School of Agribusiness, Arizona State University, W.P. Carey School of Business, 235M Santan Hall, 7231 E Sonoran Arroyo Mall, Mesa, AZ 85212, United States

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ABSTRACT

This study is an attempt to use group information collected on climate change from farmers in eastern Uttar Pradesh, India to address a key question related to climate change policy: *How to encourage farmers to adapt to climate change?* First, we investigate farmers' perception of and adaptation to climate change using content analysis and group information. The findings are then compared with climatic and agriculture information collected through secondary sources. Results suggest that though farmers are aware of long-term changes in climatic factors (temperature and rainfall, for example), they are unable to identify these changes as climate change. Farmers are also aware of risks generated by climate variability and extreme climatic events. However, farmers are not taking concrete steps in dealing with perceived climatic changes, although we find out that farmers are changing their agricultural and farming practices. These included changing sowing and harvesting timing, cultivation of crops of short duration varieties, inter-cropping, changing cropping pattern, investment in irrigation, and agroforestry. Note that these changes may be considered as passive response or adaptation strategies to climate change. Perhaps farmers are implicitly taking initiatives to adapt climate change. Finally, the paper suggests some policy interventions to scale up adaptation to climate change in Indian agriculture.

1. Introduction

Climate change is no more a distant problem. We have been experiencing changes in climatic variables, such as rising temperature, variable rainfall, frequent droughts, hurricane and typhoons (Lobell et al., 2012; Auffhammer et al., 2011), and have almost failed to reach a global consensus on the mitigation of greenhouse gas (GHG) emissions (Sharma, 2015). Additionally, policymakers in rich nations (for instance United States) have shrugged off the whole notion of climate change. However, countries such as members of European Union have recognized the effects of climate change and have adopted measures to reduce its impact.[1] As a result, response to climate change has not been addressed properly. Additionally, Füssel (2007) notes that slow mitigation response will not reduce adverse effects of GHGs that is already in the atmosphere,

* Corresponding author.
E-mail addresses: Amarnath@iegindia.org (A. Tripathi), Ashok.K.Mishra@asu.edu (A.K. Mishra).

[1] The EU climate and energy package was adopted in 2009 to implement the 20-20-20 targets endorsed by EU leaders in 2007 – by 2020 there should be a 20% reduction of GHG emissions compared with 1990, a 20% share of renewables in EU energy consumption, and energy improvement by 20%. (*Source:* http://www.eea.europa.eu/themes/climate/policy-context.)

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but would significantly reduce the rate of growth in global warming. Therefore, along with fast response mitigation responses, we require adaptation to climate change. Adaptation is not a new phenomenon—it has been in practice since the beginning of life. The theory of evolution is its best example.

Adaptation to climate change refers to adjustments or changes in the system to minimize the negative impact and optimize the positive impacts of climate change (CC). Further, adaptation could be at different levels of government, for example, regional, national, sub-national and local levels. Adaptation at local level is the most critical issue as local actors are the ones that realize the severity of climate change (UNFCCC, 2009). Adaptation is a two-step process. First, one has to perceive climate change and associated risks; then steps taken to minimize the adverse effects of climate change. Perception should be more or less correct, otherwise steps taken based on wrong perception could have an adverse effect. Correct perception depends on the knowledge and access to information. However, knowledge depends on the educational attainment and experience of the person. Perception is a cognitive process that involves receiving sensory information and interpreting it. Despite perceiving the phenomenon correctly, sometimes people do not respond to effects of CC due to constraints, including lack of capacity, lack of resources, and lack of information. Apart from these constraints, people do not respond to perceived CC because of their orientation or beliefs. For example, farmers are aware of adverse effect of overuse of groundwater, inspite of this they continue with overuse of water—their focus is on sustaining their income rather than environmental sustainability. Hence, it is important to understand the level of people's perception, its correctness, and how perception of CC motivates adaptation.

Adaptation strategies vary from sector to sector and each sector faces specific challenges in adaptation to CC. In this study, the primary focus is on the agricultural sector because it is the most vulnerable sector to CC (Porter, 2014). Adapting agriculture to CC is a major challenge, especially in a developing country like India, where a vast majority of farmers are marginal and smallholder farmers, less educated, and have significantly lower adaptive capacity. As a result, one cannot expect autonomous adaptation. Even if it were possible, it would not be sufficient to offset losses from CC (McCarthy, 2001). Perhaps the only way out is a planned or policy-driven and incentivized adaptation strategies.

Using three villages in eastern Uttar Pradesh (UP), India and applying focused group research method (FGR), this study attempts to identify farmers' perceptions of both CC and climate risks and assess the accuracy of such perceptions by comparing the observed perceptions with changes in the observed in climate and agricultural data collected from different sources. Findings from FGR are then compared with available studies conducted in both India and abroad. The selected villages (Sariyawa, Gauhaniya, and Kinauli) are located in Faizabad district, a district in the eastern part of UP, India. This district was chosen because they are more likely to be affected by CC and are characterized by low per capita income, high population density, and the dominance of small and marginal resource-poor farmers (Tripathi, 2016).

The remainder of this paper is organized as follows. Section 2 discusses the inter-relationship between climate change and agriculture, and also highlights initiatives taken by the Government of India (GoI) to address issues in agriculture as it relates to climate change. This section also reviews relevant studies that focus on the impact of climate change on Indian agriculture. Section 3 describes the study area and methods used in data collection and analyses. Section 4 presents the results of our study and Section 5 concludes the paper and discusses policy implications.

2. Climate change, agriculture, and policy initiatives

Climate change and agriculture are interrelated. The interrelationship between the two is depicted in Fig. 1. The figure shows that on the one hand, agriculture and changes in land cover, food system, emit greenhouse gases (GHGs) that contributes to climate change and on other hand, climate change affects agriculture. Several studies (for example, EPA (2014) and Vermeulen et al. (2012) suggest that the food system contributes about 19–29 percent of the total GHG emissions. Direct emissions from crop cultivation and livestock account for about 10–12 percent of the total GHG emissions (Solomon et al., 2007). Not only the magnitude of agricultural emissions but also its trend is alarming. Recent data released by the Food and Agriculture Organization (FAO), shows that emissions from agriculture, forestry, and fisheries have nearly doubled over the past 50 years. The report also suggests that it could increase to an additional 30 percent by 2050 if greater efforts are not made to reduce them.

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 production agriculture, such as water availability, soil fertility, and pests (Porter, 2014). The overall effect of climate change on agriculture could be positive or negative; the magnitude of impact can also vary from very low to very high, depending on regional or geographical location and status of socioeconomic development (Mendelsohn et al., 2006; Tol, 1995; Tol et al., 2004; Tripathi, 2016). These studies suggest that whether a little change in climate is bad or good depends on one's location. For instance, Tol (1995 and 2004) found that a 1 °C increase in temperature and a 0.2-meter rise in sea-level had a positive impact in member-countries of the Organization for Economic Co-operation and Development (OECD), Middle East countries, and China, but a negative impact in other regions.

In another study Mendelsohn et al. (2006) provided empirical support for the distributional impact of climate change by examining the impacts of climate change between poor and rich countries. Findings from this study revealed that the poorest half of the world's nations suffer the bulk of the damages from climate change, whereas the wealthiest nations experience

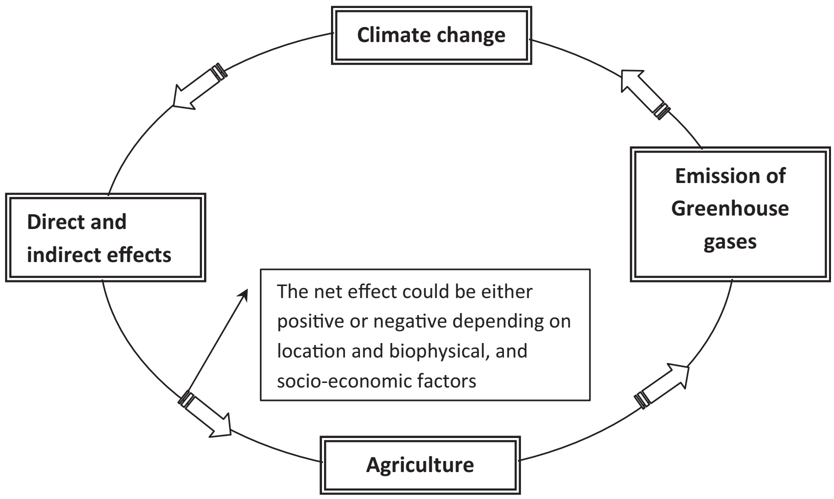

Fig. 1. Interrelationship between climate change and agriculture.

almost no net impact. There are many reasons why this is so, however, Mendelsohn et al. (2006) underscore location as the main reason—poor nations bear the brunt of climate change damages primarily because they are located in the low latitudes, which are already very hot. It can be argued that Mendelsohn et al. (2006) ignored economic reasons: they accepted that the proportion of GDP in agriculture, technology, wealth, and adaptation also contributed to the distributional outcome. However, the authors concluded that these factors played a much smaller role. Finally, in a recent study Hertel and Lobell (2014) confirmed the findings of Mendelsohn et al. (2006) and noted that the effects of climate change on farming would be most severe in low-income, agriculture-dependent, tropical countries because these countries are least equipped to cope with climate change.

Let us take the case of India, where temperature has been increasing[2] and is economically less developed—fits in Mendelsohn et al.'s classification, and India is of particular interest to the present study. Further, climate change is likely to have adverse impact on Indian agriculture (Auffhammer et al., 2011; Haris et al., 2013; Mishra et al., 2013; Dasgupta et al., 2013; Gupta et al., 2014; Jha and Tripathi, 2011; Lobell et al., 2012; Pattanayak and Kumar, 2014; Bapuji Rao et al., 2014). However, to better understand the impact of climate change on the agricultural sector, it is important to discuss findings from few important studies, mentioned above.

Using nine years of satellite measurements of wheat growth in northern India, Lobell et al. (2012) examined the rate of wheat senescence following exposure to a temperature greater than 34 °C. The study found a statistically significant acceleration of senescence from extreme heat; this was above and beyond the effects of increased average temperatures. This result implies that warming presents a greater challenge to wheat growers. In another study in India Auffhammer et al. (2011) noted a stronger adverse impact of climate change on rice crop than previously reported. The authors found that during 1996–2002 rice yield, in India, decreased by about 5–10 percent and this reduction in yield could be attributed to climate change. Study results indicate that monsoon rainfall is not the only weather variable affecting *Kharif* rice in India; an even greater impact on yield at the end of the growing season is of nighttime temperature. This observation is supported by a recent study (Bapuji Rao et al., 2014) that found a decline in paddy yield by about 411–859 kg/ha was due to a rise in temperature (1 °C). Note that the study used district-level data for the 1971–2009 period. Finally, studies (Jha and Tripathi, 2011, 2014) document that various stages of crop respond differently to climate change. Its impact is found to be more visible during the flowering and grain-filling stages of the crop.

Note that climate change affects food production negatively, decreases food availability and limits access to food (because food prices increase) for a significant share of the population. As a result, climate change further threatens a country's food and nutrition security program. Today, there are 842 million undernourished people in the world, and 98 percent of them live in underdeveloped countries (FAO, 2014; Mottaleb et al., 2016); due to global climatic changes, this number is likely to increase in the future. A possible solution is shifting agriculture practices towards 'climate-smart agriculture' (CSA), which minimizes adverse effects of climate change and also controls GHG emissions from agriculture.

Recently, CSA has become a popular term and several multi-government organizations (such as FAO, World Bank, Consultative Group on International Agricultural Research, CGIAR) have been working in this area. For example, Cooper et al. (2013) identified 16 success stories of large-scale action in agriculture and forestry sectors that have adaptation and/or mitigation outcomes. Under its climate change, agriculture, and food security research program, the CGIAR has been developing

[2] Annual surface air temperatures over India have shown a warming trend of 0.85 °C over the period 1901–2014. (Annual Climate Summary – 2014, 2014, National Climate Centre, India Meteorological Department, p24. Available at http://imdpune.gov.in/Clim_Pred_LRF_New/Reports.html. Date of access: 01/10/2016.)

climate-smart villages in some parts of the world (East Africa, West Africa, Latin America, Southeast Asia, and South Asia). Additionally, some villages in India are also being piloted by the CGIAR, in collaboration with the National Initiative on Climate Change Resilient Agriculture (NICRA), an initiative by the GoI through its Indian Council of Agriculture Research (ICAR) to enhance the resilience of Indian agriculture to climate change and variability. Strategic research and technology demonstration are major pathways to achieving program's objectives.

In 2013, the GoI started the National Mission of Sustainable Agriculture (NMSA), one of the eight missions outlined in the National Action Plan on Climate Change. It aims at promoting sustainable agriculture through a series of adaptation measures that focus on 10 key dimensions of Indian agriculture. These include improved crop seeds, livestock, and fish culture; water use efficiency; pest management; improved farm practices; nutrient management; agriculture insurance; credit support; markets; access to information; and livelihood diversification strategies. Some of these dimensions are already built into other missions or schemes of the Department of Agriculture and Cooperation (for example, National Food Security Mission, Rashtriya Krishi Vikas Yojana). Therefore, all ongoing missions or schemes are geared toward achieving NMSA objectives. The focus of NMSA is on soil and water conversation, water use efficiency, soil health management, and rain-fed area development. In its budget (2014–15), the GoI proposed an adaptation fund of Rs. 100 crores[3] (GoI, 2014). Additionally, in India two other programs—agro-meteorology advisory service and farmers' awareness program—have been launched; these seem to be scaled-up sustainable agriculture program.

It should be noted that the agro-meteorology advisory service (AMAS) is an old program, in practice by the Indian Meteorological Department (IMD), since 1945. Initially, AMAS was provided at the national level only and was extended to the states in 1976. Despite this improvement, the program was not able to meet the demand of farming community in various states. During the Eleventh Five Year Plan AMAS was integrated into agro-met services through a multi-channel dissemination system at three different levels—national, state, and district. Further, along with the ICAR, state agriculture universities, local NGOs, and other stakeholders, the IMD started organizing one-day farmer awareness program in different agro-climates zones of the country. Its goal is to educate farmers on weather and climate information and their role in farm management. During 2009–10 and 2010–11, 60 Agromet field units located at agriculture universities and ICAR institutes are responsible for the program, and approximately 7000 farmers have attended the training program (IMD). Such programs are also being organized under the NICRA project; during 16–30 March 2013, its Raipur centre conducted awareness program in eight districts of Chhattisgarh state. The program was offered through Krishi Vigyan Kendra, Indira Gandhi Agriculture University, Raipur.

3. Study area and methods

3.1. Study area

This is a field-based study conducted in three villages (Sariyawa, Gauhaniya, and Kinauli) of Faizabad, a district located in eastern UP, India. In terms of agricultural production, UP is the leading state in the country, and its comparative advantage stems from a strong agricultural base with the most fertile landmasses and a well-connected river network. UP plays a significant role in India's food and nutrition security program. However, climate sensitivity to agriculture in UP is very high (O'Brien et al., 2004), and recent changes in its climate may be an obstacle to development (Tripathi, 2016). Moreover, UP, India's fifth largest and populous state, is diverse in geography and culture. The state is divided into four regions: western, central, eastern, and Bundelkhand. Its eastern region is of particular interest to the present study because, compared to other parts, it is likely to have larger impacts of climate change. Eastern region is characterized by low per capita income, low educational attainment, high population density, and dominance of small and marginal resource-poor farmers.[4] Finally, literature on climate change vulnerability reveals that above characteristics adequately reflects regions high sensitivity and low adaptive capacity to climate change by farmers (Deressa et al., 2009; Deressa and ttderessa, 2011; Bryan et al., 2013; Esham et al., 2012; Kibue et al., 2016).

Faizabad, situated on the banks of Ghaghara river (also known as Saryu), is well known because of Ayodhya, a town of religious significance to Hindus. It is said that Lord Rama was born in Ayodhya. Faizabad occupies about 1 percent of UP's total area and about 1.24 percent of its population. Faizabad is divided into 11 development blocks. These blocks include Amaniganj, Bikapur, Hartinganj, Masodha, Mavai, Mayabazar, Milkipur, Purabajar, Rudauli, Sohawal, and Taarun. Of these 11 blocks, Masodha and Milkipur blocks were chosen for the study. Compared to Milkipur, Masodha is closer to the city (Faizabad) and is more developed in infrastructure and other services.

The district's total geographical area is about 26.1 thousand hectare and out of which 17 thousand hectare (66 per cent) is cultivable area. The gross district domestic product (GDDP) at constant price is reported about 9979.52 crore rupees for year 2013–14. About 26 per cent of GDDP is contributed by agriculture and its allied sector, which is much greater than country's level, which is about 14 per cent. Its total population is 2,470,996, as reported by the latest Census of India (2011). About 85 percent of the total population of the district lives in rural areas. Recent Census (2011) reveals that, compared to 2001 Cen-

[3] 1 crore=$1million.

[4] Eastern UP's per capita income (Rs 9859) is significantly lower than that of western UP (Rs 17,273), central (Rs 13,940), and Bundelkhand (Rs 12,737), but around 40 per cent of the state's population lives there. Over 80 per cent of farmers in this region are small and marginal farmers.

sus, population growth is on the decline, while sex ratio, average literacy rate, and the gender gap in literacy have improved. Despite these improvements, its rank on the Human Development Index has been declining continually since 1991 (Government of Uttar Pradesh, 2007). The majority of the population in Faizabad is employed in agriculture and is characterized by rice-wheat cropping system (Hobbs et al., 1992). In some parts of Faizabad district (particularly Masodha and Bikapur), because a sugar mill in Masodha, sugarcane has also been cultivated for a long time. Recently, however, some sugarcane growers are now engaged in peppermint farming, primarily because: (1) sugarcane is an annual crop whereas peppermint takes 3–4 months to grow; (2) compared to sugarcane peppermint is more remunerative; (3) payments from peppermint farming is on time, compared to payments from sugar mills which were routinely delayed. Finally, Sohawal block of Faizabad district is known for mango cultivation, but and parts of the district also cultivates guava. A shift in horticultural products is also taking roots in the district; areas that have 100 percent irrigation facility have started cultivating bananas.

The three villages selected are Sariyawa and Gauhaniya (in Masodha block of Faizabad district) and Kinauli (in Milkipur block of the same district). Of the 41 facilities considered as basic facilities[5] required for quality of life, 14 are available in Sariyawa, 10 in Gauhaniya, and 5 in Kinauli (Table 1). These villages lack health, transportation, and communication facilities, and Kinauli has only one primary school. The other two villages have primary, junior high, and high schools. Interestingly, Sariyawa village has a separate high school for girls and boys, and an optional education centre, but no health facility. Gauhaniya has one primary health centre. There is no banking facility in any of the three villages, but Sariyawa village has one post office that offers savings account.

Considering above description and facts one may conclude that Sariyawa village is more developed than the other two villages. Field visits to this village found the facts to be true. Most households are upper-caste *Kshatriya,* almost all households engage in both farm and non-farm activities, and have at least one or two members employed in the government or private jobs or self-employed businesses. Gauhaniya is similar, except that most of its population is *Kurmi*, an upper backward caste, and engage mainly in farming activity. These villages are interconnected, and residents know each other well. But unlike farmers in Sariyawa and Gauhaniya, most people in Kinauli lack farming resources and work as sharecroppers or tenant farmers. Few farmers in Kinauli own tube wells or tractors. Several farmers, particularly tenants, still use animals to plow their fields.

3.2. Methods

This study is based on both primary and secondary information. Primary information was collected through the focus group method (FGM), which can be integrated into an overall study design or used individually, depending on the nature of research. In exploratory studies, it is used individually. In the FGM, group discussions among selected individuals are organized to explore in depth people's thinking, understanding, and perception of phenomena being studied, and involve both group interviews and group interaction (Morgan, 1988). The FGM has several advantages over individual interviews: it saves time and money and provides an opportunity to collect diverse information on a particular topic (Morgan, 1988).

In this paper, five groups were formed and farmers' aged 40–60 with at least 20 years of farming experience (two groups each in Sariyawa and Gauhaniya village; one group in Kinauli) included in the FGM. Each group comprised of nine farmers, selected with the help of the head of each village (*gram pradhan*). The selection criterion enables us to understand long-term changes in agricultural practices and climate change in selected villages. The focus group (FG) discussions were held within each village and facilitated by a researcher. Participants' attributes are presented in Table 2, revealing that each group has a mix participants belonging to each caste (general, backward caste and scheduled caste) and farm size category (marginal, small, medium, and tenants). However, first, second and fifth group is dominated by general caste while the third and fourth group is dominated by backward caste. Age of participants in each group varies between 40 and 60 years and average participant has a farming experience of over 25 years.

Further, observations obtained from FG discussions were validated using climate data collected from the IMD and agriculture data collected by the Department of Economics and Statistics, Faizabad—secondary data. Climate data, particularly on temperature and rainfall, is collected from the IMD, while agriculture data, particularly on food grain, rice, and wheat production, is collected from the Department of Economics and Statistics, Government of UP. Secondary data were then analyzed using descriptive statistics and trend analysis. In this paper, the trend was analyzed by fitting different trend equations, like linear and non-linear.

4. Findings

4.1. Farmers' perception of climate change and its impact

Perception is a necessary prerequisite for adaptation. Adapting agriculture to climate change depends on whether farmers perceive it. More importantly, how farmers perceive the risks associated with climate change, as this perception of risk is

[5] Basic facilities required for quality of life in this paper includes social and infrastructure facilities that help to improve well-being or living standards. These include education, health, banking, communication and road connectivity (Thirlwall, 2003).

Table 1
Fundamental facilities available in sample villages, Uttar Pradesh, India.

Facilities	Kinauli	Gauhaniya	Sariyawa
Block	0	0	0
Village development office	1	1	1
Fair price shop	1	1	1
Drinking water facility	1	1	1
Agricultural service centre	0	0	0
Market (*Haat)*	0	0	1
Whole sale market	0	0	0
Cold storage	0	0	0
Seed sales centre	0	0	0
Fertilizer sales centre	0	0	0
Pesticides sales centre	0	0	0
Veterinary hospital	0	0	0
Veterinary dispensary (D-Category)	1	0	0
Animal care centre	0	0	0
Artificial insemination centre	0	0	0
Cooperative milk collection centre	0	0	0
Primary agriculture credit cooperative societies	0	0	0
Merchandise cooperative societies	0	0	0
Government sales centre	0	0	0
Primary school (co-added)	1	1	1
Junior high school (boys)	0	1	1
Junior high school (girls)	0	1	1
Secondary school (boys)	0	1	1
Secondary school (girls)	0	0	1
Optional education centre	0	0	1
Primary health centre/dispensary (Allopathic)	0	1	0
Primary health centre/dispensary (Ayurveda)	0	0	0
Primary health centre/dispensary (unani)	0	0	0
Primary health centre/dispensary (Homeopathic)	0	0	0
Family welfare centre	0	0	0
Mother and child care centre	0	0	0
Paved road	0	1	0
Post office	0	0	1
Letter box	0	0	1
Telegraph	0	0	0
Public telephone booth	0	1	1
Railway station holt	0	0	0
Bus stop	0	0	0
Cooperative agriculture and rural development bank	0	0	0
Commercial rural cooperative bank	0	0	0
Post office saving bank	0	0	1
Score	5/41	10/41	14/41

Source: Field Survey.

Table 2
Demographic, socio-economic and cultural background of focus group, selected villages, Uttar Pradesh, India.

Attributes	Group 1	Group 2	Group 3	Group 4
Name of Villages	Sariyawa	Sariyawa	Gohaniya	Gohaniya
Religion of participants	Hindu	Hindu	Hindu	Hindu
Caste	Mix caste dominated by general category	Mix caste dominated by general category	Mix caste group dominated by backward category	Mix caste group dominated by backward category
Farm size	Small and large farmers	Small and large farmers	Small and large farmers	Small and large farmers
Farming experience	>25 years	>25 years	>25 years	>25 years
Age	40–50	40–50	40–50	40–50
Education	Educated at either primary or secondary level	Educated at either primary or secondary level	Except for one, educated at either primary or secondary level	Except for one, educated at either primary or secondary level
Primary occupation	Farming	Farming	Farming	Farming
Secondary occupation	Service sector	Service sector	Self-employed business owner	Self-employed business owner

Source: Field Survey.

essential for motivating farmers in their decision to adapt (Grothmann and Patt, 2005; Frank et al., 2011). In FGDs, it was observed that farmers noticed changes in warming, rainfall or rainfall variability, and weather or seasonal variability over the preceding 20 years, but (barring 2 of the 45 farmers surveyed) did not know that these changes constitute climate change. This finding shows that surveyed farmers lacked education and awareness. It should be noted that agricultural extension services in the study region were weak. The role of extension services is very critical in the perception of and adaptation to climate change. Several studies (for example, Bryan et al., 2013) found that farmer households that did not receive visits from extension agents were more likely to either not perceive climate change or perceive it wrongly. However, most of these studies (See Table 4) were conducted in other countries.

In the FGDs conducted in Gohaniya village, two farmers who recognized that changes they noticed in warming, rainfall or rainfall variability, and weather or seasonal variability constituted climate change were educated and read newspapers daily, even though they were in different age groups. These attributes make them different from other farmers in the FGDs as well. This observation emphasizes the role and importance of media in raising public awareness of climate change and has been noted by Sampei and Aoyagi-Usui (2009). Findings here suggest that along with farming experience, education and exposure to media news help shape farmers' perception to climate change, along with farming experience (Maddison, 2007; Gbetibouo et al., 2010; Bryan et al., 2013). Therefore, increasing access to print or digital media would help in spreading awareness of climate change and associated production risks among farmers. These observations remind us that climate information services could play a critical role in forming correct perceptions. A recent study by Habtemariam et al. (2016) in Ethiopia found a significant positive impact of climate change information on farmers' perception of climate change.

Most of the farmers who participated in the FGDs reported a gradual increase in warming, less, but more erratic, rainfall, and increasing the incidence of strong winds. Farmers agreed strongly that rainfall and wind patterns had changed, but disagreed on the increasing trend of warming; subsequent detailed discussions revealed that this disagreement occurred because of confusion over the sunshine and hot winds (known as loo[6]) and only a few farmers perceived a declining trend in warming. Farmers who believed that warming has declined argued that they observed fewer incidences of the loo in the preceding few years. However, this perception is not in agreement with our scientific evidence, available in the public domain. When asked if they had noticed any change in the weather or the seasons, most farmers claimed that summers had lengthened, and winters had shortened, and many reported that winters had become colder and received significant amounts of rain. Most farmers participating in the FGD perceived negative impacts of climate change on agriculture and were aware of the fact that climate change reduces grain quality and decreases the amount of food crop production, which could lead to lower income. Small and marginal farmers and tenants depended on wages (off-farm work) for survival. Indeed, climate change increases temporary migration from rural areas to urban areas.

Incidentally, above perceptions of farmers on climate change are in line with the observed trends in climatic variables. Analysis of climatic data from secondary sources show an increasing trend in surface temperature and decreasing the annual amount of rainfall in Faizabad district. Fig. 2 shows anomalies of average annual surface temperature (*i.e.* average of maximum and minimum temperature) for the period from 1901 to 2002.[7] Temperature anomalies are calculated by taking the difference between long period average temperature[8] and actual annual temperature. Fig. 2 shows that there has been increasing trend in annual surface temperature, by about 0.004 °C per year. Although a rising trend in temperature is observed in both maximum and minimum temperature during the 1901–2002 period, increasing trend in minimum temperature has been more visible during this period (Fig. 3). One could conclude that minimum temperature has been rising faster than the maximum temperature. Even, a similar trend has been observed in recent data. For the 1970–2002 period, we observe an increase in both maximum and minimum temperature by about 0.022 °C and 0.034 °C, respectively (Fig. 4).

More importantly, Fig. 4 shows that, compared to previous years (before 1970), warming trend has been accelerating in recent years (after 1970). It may reflect effects of global warming. Note that 1970 was chosen arbitrarily as a breaking year. Additionally, our finding of a rise in minimum temperature compared to maximum temperature has already been reported in different parts of India as well (Jain and Kumar, 2012; Jha and Tripathi, 2011, 2014). Like temperature, perceived changes in rainfall by farmers are also similar to the trend in observed rainfall. Rainfall in Faizabad district shows a decreasing trend; it seems from the Fig. 5 that since 1901 amount of rainfall in Faizabad has been decreasing by about 1.41 mm per year; the rate increases significantly for recent decades. For the last two decades, except for few years, rainfall in Faizabad district has been much lower than the long-term average rainfall, 30 years (1971–1990).

4.2. Adaptation to climate change

There have been several changes were observed in agricultural practices in the villages considered in our study. These changes include, more use of ground water for irrigation, use of PVC pipes to carry water on farms, change in timing of crop

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[6] The loo is a strong, hot and dry summer afternoon wind from the west which blows over the western Indo-Gangetic Plain region of North India and Pakistan. It is especially strong in the months of May and June.

[7] Analysis of data on temperature is restricted to year 2002 in both maximum and minimum temperature cases because of limited access to data beyond year 2002.

[8] The long period average temperature is here basically average of temperature of 30 years from 1971 to 1990. 1971–1990 period is referred as long-term period by the World Meteorology Organization.

Table 3
Summary of farmers' personal interviews.

Issues	Description of responses
Crop diversification	Farmers, particularly from Sariyawa and Gohaniya villages, are gradually shifting towards the cultivation of peppermint from sugarcane. However, when they queried about its reason most of them answered that on one hand, peppermint is more profitable crop than sugarcane; on the other hand, there is no problem in its marketing. They noted that there were many problems in sugarcane marketing. For instance, farmers do not get output price of their product immediately and sometimes farmers are not allowed to sell their cane to sugar mills. Famers are forced to sell their produce to influential people in the village at very low prices
Agroforestry	Some farmers in these villages were found to be planting trees, particularly mango and eucalyptus trees, to generate more income rather than to reduce the negative impact of climate change. Even after knowing the hydrological consequence of eucalyptus trees, that it lowers water level very rapidly. Farmers clearly mentioned that they do not bother it because of their prime concern of profit that they get from selling eucalyptus wood
Increasing use of ground water for irrigation	Most of the farmers in our group discussion have installed their own tube-wells for irrigation purposes. This practice has significantly reduced their dependency on rainfall and helped them to minimize the adverse effect of drought. But, the way they irrigate their farms is not appropriate. Farmers basically overuse the water—flooding the field, which further depleted water table. They are not aware of efficient irrigation system like sprinkler irrigation and drip irrigation

Note: All above personal interviews were conducted in one village called Gauhaniya out of three studied villages during the month of April 2013. The reason for selecting farmers from this village only for personal interviews is that farmers from this village were found more skilled and innovative farmers from other two villages.

Table 4
List of adaptation strategies in agricultural sector as identified by IPCC, 2014.

	List of strategies
1	Modifying planting, harvesting, and fertilizing practices for crops
2	Changing amount or area of land under cultivation
3	Using different varieties (e.g. early maturing, drought-resistant)
4	Diversifying crops and/ or animal species
5	Commercialization of agriculture
6	Water control mechanisms (including irrigation and water allocation right)
7	Shading wand wind breaks
8	Conservation agriculture (e.g. soil protection, agroforestry)
9	Modifying grazing patterns for herds
10	Providing supplemental feeding for herds/ storage for animal feed
11	Ensuring optimal herd size
12	Developing new crop and livestock varieties (e.g. biotechnology and breeding)

Source: IPCC (2014).

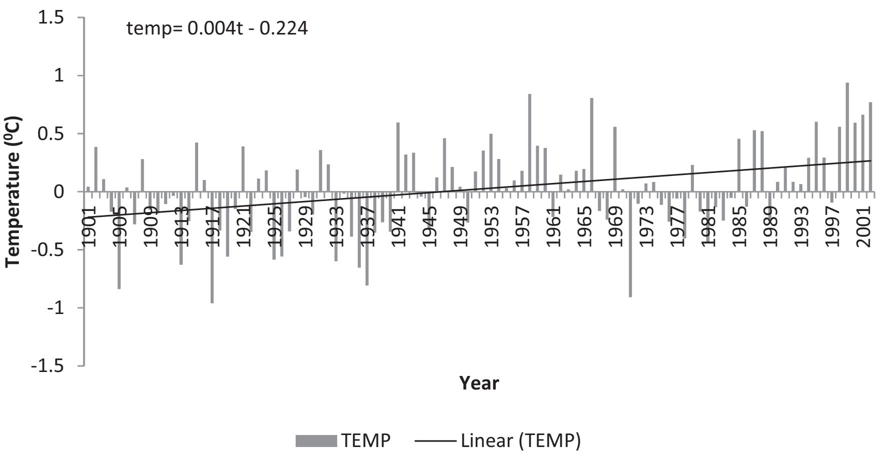

Fig. 2. Temperature anomalies in Faizabad district (1901 onwards) *Note: Equation given in the figure is linear trend equation estimated using EXCEL command 'add a trendline,' where TEMP = Temperature, t = time trend, and coefficient of 't' shows an annual rate of change. Source: Author's own calculation based on temperature data collected from Indian Meteorology Department, Government of India, New Delhi.*

sowing and harvesting, higher use of high-yield crop varieties, more use of short-duration cultivars, started growing short-duration crops, mix-cropping (inter-cropping), agroforestry, and crop diversification. Besides, farmers have diversified their livelihood strategies from farm to non-farm activities. Some members of farmer households were found working in nearby

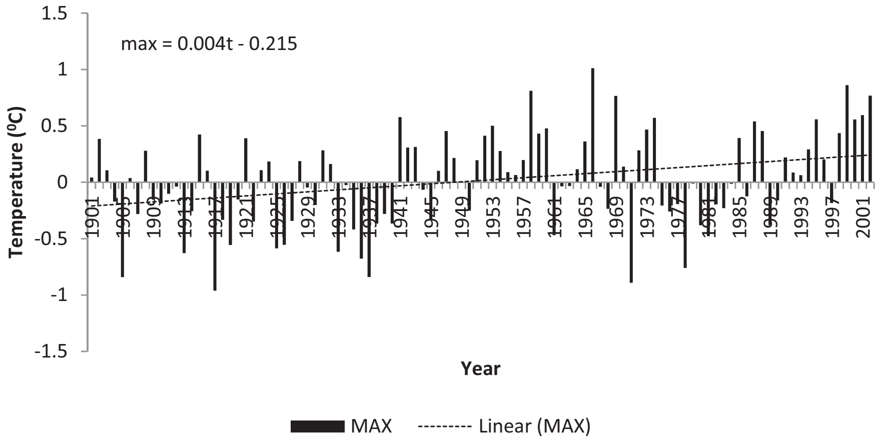

Fig. 3.1. Maximum temperature anomalies in Faizabad district (1901–2002) Note: Equations given in the figure are linear trend equations estimated using EXCEL command 'add a trendline,' where max = Maximum temperature, min = minimum temperature, t = time trend and coefficient of 't' shows an annual rate of change. Source: Author's own calculation based on temperature data collected from Indian Meteorology Department, Government of India, New Delhi.

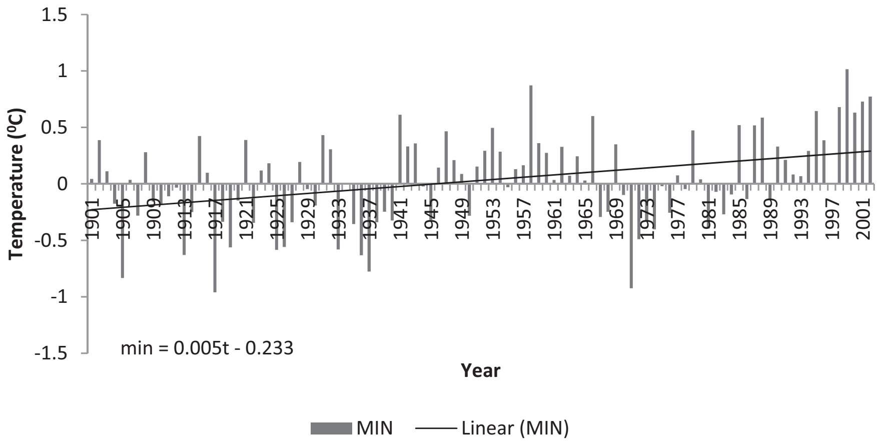

Fig. 3.2. Minimum temperature anomalies in Faizabad district (1901–2002) Note: Equations given in the figure are linear trend equations estimated using EXCEL command 'add a trendline,' where max = Maximum temperature, min = minimum temperature, t = time trend and coefficient of 't' shows an annual rate of change. Source: Author's own calculation based on temperature data collected from Indian Meteorology Department, Government of India, New Delhi.

urban centers as salesmen and security guards. Few of them have opened their own businesses (*i.e.* provision store, mobile and repair shops) in the village. All these changes in agriculture and farming practices and livelihood pattern are mainly triggered by social and economic factors, as appears from responses of farmers in FG discussions. Even though farmers were directly asked about their climate-induced responses; they could not ascertain climate change as a driver of above changes. Moreover, some farmers responded 'change in climate is a natural disaster, so no one can escape from it.'

In order to validate above observation noted by farmers in the FG, we found that three of the above changes in agricultural practices. These include increasing use of groundwater for irrigation, agroforestry, and crop diversification. We also further examined these issues in detail by taking personal interviews of farmers. The outcome of these personal interviews is reported in Table 3. The table shows that observed changes in agricultural practices are being adopted to secure better income rather a response to climate change. Though, it should be noted that climate change as the main driver of changes in agricultural practices, identified in this study, is not so simple. However, according to IPCC, 2014 changes in agricultural practices are considered as adaptation strategies in the agriculture sector to climate change (see Table 4 adapted from IPCC, 2014). It suggests that farmers unintentionally (passively) adapt to climate change by undertaking several changes in agricultural practices. Additionally, others have observed passive adaptation to climate change in the literature (see, for example, Mertz et al., 2009; Apata et al., 2009). Moreover, several studies focusing on purposeful adaptation to climate change have found a large chunk of farmers do not respond or take the initiative in reducing the negative impacts of climate change. This

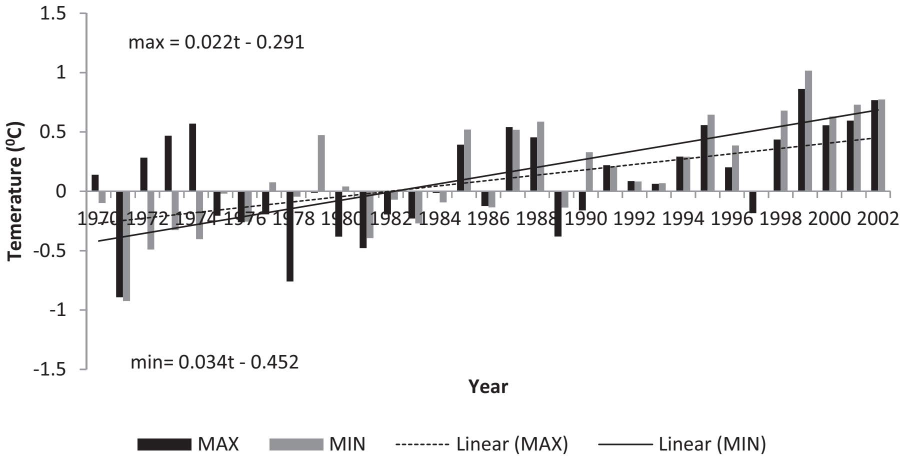

Fig. 4. Maximum and minimum temperature anomalies in Faizabad district (1970–2002) Note: Equations given in the figure are linear trend equations estimated using EXCEL command 'add a trendline,' where max = Maximum temperature, min = minimum temperature, t = time trend and coefficient of 't' shows an annual rate of change. Source: Author's own calculation based on temperature data collected from Indian Meteorology Department, Government of India, New Delhi.

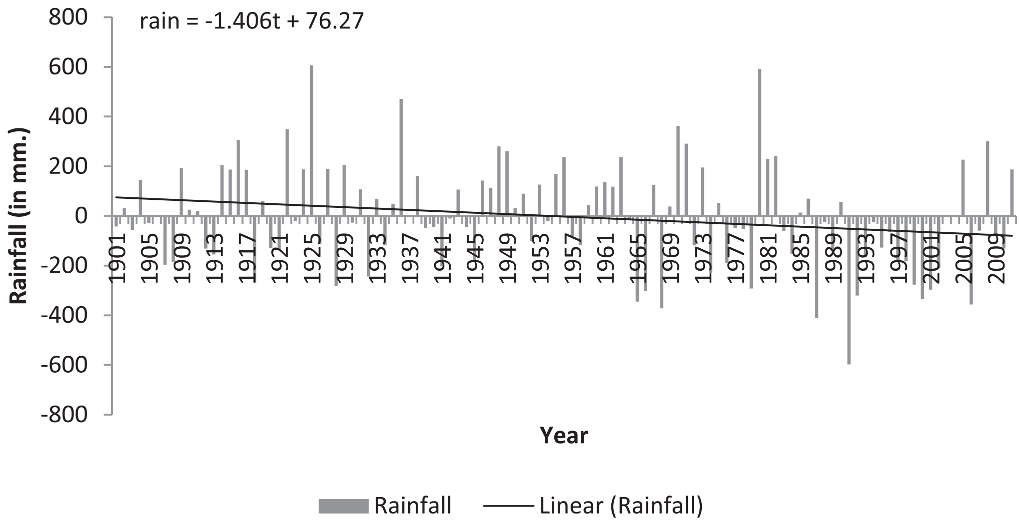

Fig. 5. Rainfall anomalies in Faizabad district (1901–2012) Note: Equation given in the figure is linear trend equation estimated using EXCEL command 'add a trendline,' where rain = rainfall, t = time trend and coefficient of 't' shows an annual rate of change. Source: Author's own calculation based on temperature data collected from Indian Meteorology Department, Government of India, New Delhi.

share varies from 16% to 69% depending on the location and types of farmers (see Table 5); together indicate either unintentional (passive) adaptation or low level of purposeful adaptation to climate change. Perhaps, due to lack of initiatives or responses to climate change, the agricultural sector will remain most vulnerable sector.

Agriculture extension services and capacity building programs seem to be important for encouraging adaptation to climate change in the agricultural sector. We wanted to strengthen above idea by providing an interesting example of 'soil testing'. When farmers in Kinuali village were asked about 'soil testing and its procedure,' none of them, even progressive farmers, were aware of it. On other hand, farmers in the other two villages (Sariyawa and Gauhaniya) were aware of it and performed soil testing on their farms. One may argue that extension services could be the difference—it does not require a whole team of extension agents. For example, one agricultural scientist lived in Sariyawa village helped farmers in soil testing. Several other studies have also reported the importance of agriculture extension services and capacity building in adaptation to climate change (see Table 6). Additionally, social infrastructures like education and physical infrastructure like access to credit, electricity have been reported as important factors in facilitating adaptation to climate change.

Table 5
Studies on farmers and climate change.

	Authors	Percentage of farmers who do not adapt to climate change	Country/Region
1	Deressa et al. (2009, 2011)	42	The Nile Basin of Ethiopia
2	Bryan et al. (2013)	16	Kenya
3	Bryan et al. (2009)	37	Ethiopia
		62	South Africa
4	Gbetibouo et al. (2010)	66	Limpopo Basin, South Africa
5	Fosu-Mensah et al. (2012)	60	Sekyedumase districts in Ghana
6.	Esham et al. (2012)	15	Sri Lanka
7.	Alam (2011)	45	Malaysia
8.	Kibue et al. (2016)	53	Yifeng, China
9.	Kibue et al. (2016)	69	Qinxi, China

Table 6
Factors affecting climate change adaptation in agriculture.

Study	Factors identified as adaptation strategies in agriculture in response to climate change
Kibue et al. (2016)	Access to extension services and climate information, education, off-farm income.
Bryan et al. (2013)	Access to food aid or other assistance, weather forecast, access to irrigation, access to social safety nets (emergency food relief, food subsidies, or other farm support), access to extension services, access to electricity, and farming experience
Esham et al. (2012)	Climate changes perception and social networking
Fosu-Mensah et al. (2012)	Access to extension services, credits, and soil fertility
Below et al. (2012)	Economic potential and infrastructure of area, production factors, Education, gender of household head, and farmers' social and financial capital
Frank et al. (2011)	Social identity
Alam (2011)	Training and government support
Deressa et al. (2009, 2011)	Household characteristics such as education, farm, and non-farm income, etc., extension on crop, and livestock production, access to information, access to credit and social capital
Apata et al. (2009)	Farming Experience and access to education
Hassan and Charles (2008)	Better access to market, extension, and credit services, technologies, farm assets, and information about adaptation to climate change

Source: Authors collection form literature review.

4.3. Other Striking behavior facilitating adaptation to climate change

Furthermore, two interesting actions of farmers that may facilitate adaptation to climate change have been observed in our village study. These include collective action and social networks and learning. Since Mahatma Gandhi Rural Employment Guarantee Act, farmers in the sample villages have been facing a labor shortage, which has led to increased cost of cultivation. In order to overcome this problem, farmers have started cooperating with each other, as is mentioned in FGDs. Farmers come together and perform agricultural practices collectively. They work and help each other, even crossing caste structure.[9] Similarly, strong social network effect was observed in study villages. For instance, farmers participating in FGDs reported that they followed neighboring farmers in adoption of new technologies, cultivars, and farming practices. First, farmers observed the behavior of neighboring farmers, including their experimentation with new technology and farming practices. Once a year's harvest was realized, farmers then would update their priors concerning the technology, which may increase the probability of adopting the new technology in the subsequent year. In another survey conducted by the Cereals System Initiative of South Asia, farmers have revealed that friends, neighbors, or other farmers are their major source of information. More than 50 percent of surveyed farmers reported getting information on new technologies and seeds from their friends, neighbor, or other farmers.

Finally, we acknowledge limitations that readers should keep in mind. First, internal validity cannot be established, due to lack of controls, and due to small sample size, findings may not be generalized to other settings. Note that focus groups are well suited for exploratory research and not generally used for explanatory or descriptive research. Nevertheless, our present study tries to overcome above limitations by comparing findings from available related literature and data. Finally, another limitation is selection bias (gender bias): only male farmers participated in the focus group discussions.

5. Conclusions and policy implications

Climate change is here and it is an important area of the policy domain. People can experience it, and its impacts are quite visible, especially in agriculture. Agriculture—which provides food, raw materials, and livelihoods—is under significant threat from climate change. On the other hand, agriculture itself contributes to climate change by emitting GHGs—several esti-

[9] It does not mean that social barriers or caste structure is being eliminated. There are still some frictions, for example, caste discrimination.

mates suggest that the agriculture and food system emits 15–20 percent of all GHGs. Both aspects should be considered in addressing climate change and, hence, adaptation to climate change could be a better option. But the main challenge, particularly in developing countries, is that farmers have the low adaptive capacity, as most of them are small and marginal farmers. It follows that autonomous adaptation cannot be expected; even if adaptation were autonomous, it would not be sufficient to offset losses from climate change. Hence, policy-driven incentivized adaptation is required. Adaptation is a two-step process—*first*, perceiving climate change and its associated risks; *second,* responding to perceived changes to minimize their adverse impacts. Perception is a cognitive process that involves receiving sensory information and interpreting it. The accuracy of perception is a necessary condition for a meaningful response, which eventually depends on knowledge and experience.

Against the above background, this paper made an attempt to understand farmers' perception of climate change and its associated risks. It also attempted to identify changes in technology and production practices that farmers make in order to mitigate losses from climate change. The findings of this paper suggest that farmers are aware of changes in climatic variables, especially increasing temperature and changing the seasonal pattern, and impacts of climate change, particularly declining crop productivity, increasing the cost of cultivation, and livelihood insecurity. While farming experience seems to be the major factor in farmers' perception of climate change, this study has observed that the print media contributes significantly to such perception. However, it may not be instrumental in spreading climate change information, as few farmers read newspapers or other print media offerings because most of the farmers in our study are less educated. But most farmers use mobile phones, so sending farmers climate information and advice through text and voice messages could be a better option. Social network effects, which is noted strongly in FGDs, can be utilized to reduce time and resources incurred in the above training programs.

Despite perceiving climate change, farmers are not responding to it. But they are changing their agricultural and farming practices to deal with socioeconomic changes, and some of these changes—such as changing sowing and harvesting timing, cultivation of crops of short-duration, inter-cropping, changing cropping pattern, investment in irrigation, agroforestry—help in adapting agriculture to climate change. So, we may conclude that farmers are passively taking initiatives to adapt to climate change. It suggests that farmers have the inclination to adapt to climate change. There are also sufficient support systems available in the village, for example, the social network and collective activities. In sample villages, the study has noted a strong network effect; farmers learn from other progressive farmers; by working collectively farmers are solving common problems, like labor shortage. These effects could be instrumental in boosting adaptation strategies in production agriculture in response to climate change. Perhaps government can provide incentives to foster networks and/or to form clubs that bring likeminded farmers together in forming communication and adaptation strategies as a response to climate change.

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