

## Farmers level of Awareness and Adaptation Practices about Climate Change and Climate Smart Technologies

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### ABSTRACT

*The impact of climate change on agriculture is varying over space and time. The consequences highly uncertain are heterogeneous in nature. Agricultural sector must focus on adopting climate smart technologies to successfully achieve food security and climate change challenges. Climate Smart Technologies in agriculture is clearly a crucial response for an effective and equitable adaptation and mitigation strategy. To shift the focus towards climate smart agricultural technologies in India, innovation will be the key. The present study focused on level of awareness and adaptation strategies of farmers about climate change and Climate smart technologies. Farmers' knowledge and perceptions about climate change, and adoption of climate smart technologies, will help development practitioners, researchers and policy makers to develop more promising technologies according to the needs and interests of farmers. The paper advocates various agricultural innovations including technological innovations, managerial innovations and traditional agriculture as a climate-smart approach for sustainable food production.*

### Introduction

The concept of climate change has caught the eye of every researcher and stakeholders. It emerged as an integral component of development and debate globally as it is affecting both developed or developing countries. The sectors like agriculture, forestry and fisheries, are crucial for food security and rural incomes as well as other essential products like energy, fiber, feed and a range of ecosystem services (Raghuvanshi *et al.*, 2017). The research on climate change has identified several avenues that will affect agriculture which includes rising temperatures around the world, migration of people from regions closer to the tropics to regions closer to the poles,

rising sea levels, increased snowmelt and change in the volume and timing of water use for irrigation, and increased probability of extreme events (FAO, 2018). The continuous increase in temperature level, reduce the winter season wheat crop's duration which strike terminal heat stress and drought conditions (Arshad *et al.*, 2016; Krupnik *et al.*, 2015a,b). The immeasurable consequences of climate change have increased the rate of human migration especially of farmers. Migration of farmers is not only a response to poverty and social deprivation but also an adaptive response to changing climate (Scheffran *et al.*, 2012). The phenomenon like occurrence of extreme weather events, sea level rise and environmental degradation leads to loss of climate-sensitive occupations. These changes are prime

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causes of short or long-term migration (Bhatta and Aggarwal, 2016; Kumar and Viswanathan, 2012; Deshingkar and Akter, 2009, Deshingkar and Start, 2003). Most developing countries face resource constraints in meeting the demands of high populations and thus have low adaptive capacity (Ahmed *et al.*, 2012). The impacts of climate change will reduce productivity and lead to greater instability in production in the agricultural sector.

There are multiple components attached to the concept of food security, and adapting food systems to climate change involves adoption of various approaches and resources. One of the important means to achieve stability between these situations is nothing but the development and adoption of climate smart agricultural practices which calls for meeting three objectives such as sustainable food production with increasing its productivity and income of farmers, building resilience and adapting to climate change, and reducing emissions of greenhouse gases (FAO, 2013). Precision conservation agricultural practice is profitable and can help bridge the yield gap; increase incomes as well facilitate the capacity of smallholder farming households to adapt and mitigate climate change (Shitu *et al.* 2018). Climate-smart agricultural practices supports sustainable agriculture and rural development objectives which, if reached, would be instrumental in achieving the Millennium Development Goals of reducing hunger and enriched environmental management. More productive and resilient agriculture is built on the sound management of natural resources, including land, water, soil and biodiversity (FAO, 2014). The various climate smart practices including conservation agriculture, agroforestry, livestock and water management, integrated pest management and ecosystem approaches to fisheries and aquaculture are critical component which contributes to improve the quality of the climate. The concept of CSA (Climate Smart Agriculture) is holistic in nature. It is a combination of issues related to agricultural development and global development objectives. It specially focused on environmental issues such as energy and water and social issues like gender, and economy. Adoption of modern agricultural practices helped to enhance the food productivity but on the other hand it also accelerate several environmental problems like climate change, biodiversity loss, soil degradation, food insecurity, and environmental degradation (Zhang *et al.*, 2017a). In the context of sustainability, food insecurity in changing climate, adoption of climate-smart agricultural practices is a primary call.

## Methodology

The study is based on secondary data which were collected from books, journals, government reports, websites, and NSSO reports. The study aims to provide the overall awareness of farmers about the term "Climate Change" and further it seek to analyze the adaptation practices and climate smart technologies. The study carried out to study the level of awareness of farmers about climate change and to analyze the adaptation practices adopted by the farmers and finally elicit the importance of climate smart agricultural innovations.

## Result and Discussion

### Awareness about Climate Change

Climate change is the biggest threat to Indian agriculture but the farmers are not fully aware of the concept of climate change, its indicators, causes, and impacts on agriculture. Only 38 per cent of the farmers had heard about climate change and a large number are not aware of the phenomena of climate change (Sarkar and Padaria, 2010). Farmers have experienced the changing climatic conditions but they are not aware about the term climate change. On the other hand 87.5 percent of farmers have heard about climate change (Adewale and Owolade, 2012). Communities in the mountain areas of Utrkhand are well aware that weather is changing as temperatures are more variable and periods of drought are longer. In some areas rainfall is erratic, some plant species are flowering earlier, there is a vertical shifting of trees and crops, some natural resources are disappearing, and new and unfamiliar pests and diseases are emerging (Sogani, 2011). Ado *et al.*, found that majority of respondents (84.40%) were aware of climate change risks, but had differing perceptions of climate change impacts on agriculture. Farmers were aware of climate change and variability despite that they were more familiar with the terms weather changes, rainfall and drought (Elia, 2017). To cope with the climatic changes up with climate change, level of awareness of farmers about climate change plays an important role. Farmers level of awareness about climate change, its causes and impacts are expected to adopt adaptation and mitigation practices. Overall knowledge level of agricultural scientists on impact of climate change in agriculture was low to moderate and hardly one third had high knowledge on the issue of impact of climate change on various facets of agriculture (Ghanghas *et al.*, 2015). The socio-economic and psycho-personal variables like education, occupation, family type, land holding, social participation, economic motivation, innovativeness, scientific orientation and risk orientation showed positive and significant relationship with knowledge level and in regression analysis education, scientific orientation were positive and had significant contribution to the knowledge level of respondents (Ravi Kumar *et al.*, 2015)

### Climate Change Adaptation Practices

There were certain types of adaptation practices that were practiced by farmers in order to cope up with the adverse impact of climate change. Farmers should be able to adapt in order to minimize the negative impact of climate change. There are distinctive adaptation options proposed by the farmers. Even though majority of them have started to adapt themselves by cultivating short-duration heat tolerant crops such as pulses maize millet's, vegetables and floriculture crops, especially Jasmine, as they understood from their farming experience that these crops can withstand heat and water stress as an adaptation response to the climate variability (Dhanya and Ramachandran, 2016). The mechanism of adaptation to climate changes is a two-step process, which states that farmers perceive climate change

**Table 1.** Climate-smart innovations

SL.No.	Climate Smart Innovations	Description
1.	Technological Innovations	<p><b>Resilient crops and livestock:</b> To tolerate climatic changes such as rising temperatures and increased variability researchers should focus on early-maturing cereal crop varieties, heat-tolerant varieties, drought-tolerant legumes or tuber crops and varieties with enhanced salinity and submergence tolerance, can help farmers to better cope with climate shocks (Acevedo <i>et al.</i>, 2020).</p> <p><b>Pest control:</b> An integrated approach (biological, mechanical, and chemical) in concert with genetic approaches, will be needed.</p> <p><b>Input use efficiency enhancing technologies:</b> Some crop varieties may increase output while the change in feeding regimes for livestock may decrease greenhouse gas emissions. A considerable proportion of the GHGs produced by agriculture are due to the production and application of nitrogen fertilizer alone (Stern, 2006) reduction in nitrogen use efficiency could substantially mitigate GHGs emissions in agriculture.</p> <p><b>On-farm storage:</b> Small or subsistence farmers lack storage facilities and because of it there is significant post-harvest loss occur on the farm . Innovative on-farm storage infrastructure can help address yield losses caused due to increased temperature (Parfitt <i>et al.</i>, 2010).</p> <p><b>Higher yield and longer shelf life:</b> Crops and livestock, that increase yield per area leads to reduce agricultural footprint. Enhancement of shelf life is another important way to cope with the climatic changes because increased temperatures increase the likelihood of spoilage of crops (IPCC, 2018).</p> <p><b>Sustainable Land Management (SLM):</b> Adoption of Sustainable Land Management practices such as organic fertilization, minimum soil disturbance, and incorporation of residues, terraces, water harvesting and on servation, and agroforestry helps to increase yield and sequester carbonwith out degrading soil and water resources (Branca <i>et al.</i> 2013).</p>
2.	Farm System Approaches	<p><b>Low-cost flood protection and water storage facilities:</b> Due to the concern of rising water level due to floods, innovations that reduce the cost of protection against rising water levels and floods is needed.</p> <p><b>Weather information distribution technologies:</b> Timely availability of weather information including its implications on crops and livestock enable farmers to modify their irrigation and pest control strategies which leads to significant increase in yield and saving of other inputs (Parker and Zilberman 1996).</p>
3.	Managerial Innovations	<p><b>Precision technologies:</b> Dobermann <i>et al.</i> (2004) stated that precision farming is one of the alternative to reduce the impact of climate change. It saves input and increase crop and also helps in monitoring spatial or other sources of variability.</p> <p><b>Integrated Pest Management (IPM):</b> The integrated approach to pest management is another managerial innovation which can contribute in reducing the impact of climatic changes. The continuous increase in pest pressure because of climate change requires technical innovations.</p> <p><b>Land use and on-farm management practices:</b> Improved managerial tools such as selection of crop types and crop varieties, allocation of land among crops, and selection and implementation of production practices are required to balance with the changing climatic conditions accompanied by changes in technologies and economic conditions.</p>

Source: (Zilberman *et al.*, 2018)

in the first step and respond to changes in the second step through adaptation (Deressa *et al.* 2011). There are some climate change adaptation practices including Laser land levelling is a climate-smart technology that improves water use efficiency and reduces risk in crop cultivation due to weather variability. Hence, this technology is useful for cultivating water-intensive crops in a sustainable way (Pal *et al.*, 2021). Alternate Wetting and Drying (AWD) is an climate-smart innovation for lowland rice production which seeks to reduce water consumption and methane emissions by shifting the draining and re-flooding of the paddy field 1-2 weeks after transplanting. This technique reduces methane emissions by 48% without hampering the crop yield. It also helpful in efficient nitrogen use and application of organic inputs to dry soil can further reduce emissions (CCAFS, 2014). Conservation agricultural practices including minimum

tillage, permanent soil cover, management of crop rotations, and soil fertility management are widely promoted as CSA (FAO, 2020). The adoption of higher yield varieties and conservation technologies that reduce the land, atmospheric, and fossil fuel footprint of agriculture is another important mitigation strategy (Lal 2011; McCarthy *et al.* 2012).

## Climate-smart Innovations in Agriculture

Food and Agriculture Organization introduced the climate-smart agriculture (CSA) approach with the aim of regulating agriculture for food security in the era of global warming (FAO 2010). Lipper *et al.* (2014) defined CSA as the strategy that transforms and reorients agro-ecosystems to produce food in cli-

mate change scenario. According to Olayide et al. (2016), CSA is an budding innovation to enhance food production, biodiversity, agro-ecosystem resilience, environmental quality, livelihoods and economic development while pitching the climate change impacts. Climate-smart innovations in agriculture contribute to achievement of development goals. It aims to simultaneously increase agricultural productivity, food security, and farmers' adaptive capacity to climate extremes, and also lowering greenhouse gas emissions (Campbell et al., 2014). Over the past years, on-station and on-farm validation trials across Bihar have been developed which produce alternatives like cropping systems and conservation agriculture (Jat et al., 2014; Laik et al., 2014; Sapkota et al., 2015). These innovations were the alternatives for intensive tillage in rice which helped to mitigate global warming potential, on the other hand rotational options for direct seeded maize and wheat, use of crop residues as a surface mulch to conserve soil moisture (Singh et al., 2012; Jat et al., 2014; Laik et al., 2014). If these innovations when cautiously implemented, can reduce production costs, energy demand, and greenhouse gas emissions, while also increasing and augmenting yield (Gathala et al., 2013; Jat et al., 2014, 2016; Gathala et al., 2016). Some of the climate smart innovations are depicted in table 1.

## Traditional Agriculture

Traditional agriculture is the collection of the experiences of the local people about local farming practices over thousands of years (Pulido and Bocco 2003). Traditional agricultural practices plays a crucial role in building of scientific knowledge of farmers (Sandor and Furbee 1996; Singh et al. 1997a). Integration of local people knowledge into climate change policies open up the way for cost-effective and sustainable mitigation strategies

**Table 2.** Climate-smart traditional agricultural practices and their role in climate change

SL.NO.	Climate Smart Traditional Agricultural Practices	Role in Climate change
1.	Agroforestry	It mitigates nitrous oxide (N <sub>2</sub> O) and methane (CH <sub>4</sub> ) emission and enhance the carbon Sequestration (Mutuo et al., 2005 and IPCC, 2000)
2.	Inter-cropping	Inter-cropping enhances carbon Sequestration (West and Post, 2002)
3.	Integrated crop with animal farming	Diversify livelihood and optimum utilization of natural resources in changing climate (Howden et al., 2007). Duck-rice culture reduces the external input of nitrogen fertilizers and consequently lowering of N <sub>2</sub> O emission (Long et al., 2013)

Source: (Singh, R. and Singh, G.S. 2017)

(Nyong et al. 2007). Indigenous knowledge governs by farmer should be used in climate change adaptation practices and policies (Bernstein et al. 2008). Several techniques were used by the small farmers to reduce climate driven crop failure such as use of drought-tolerant local varieties, poly-culture, agroforestry, water harvesting and conserving soil (Browder 1989; Altieri and Nicholls 2008; Chhetri et al. 2012).

## Conclusion

Climate change is emerged as one of the critical factor affecting agricultural productivity in India. It is of utmost concern for the policy makers as well as researchers to figure out the factors which negatively affect productivity and efficiency of agriculture sector. Understanding farmers' awareness and perception towards climate change and climate smart agricultural practices and its adaptation practices is important for the farmers. Adoption of these technologies will help in sustainable agriculture growth thereby ensuring food security. To achieve long-term benefits, planned adaptation should be incorporated and implemented by state government in their developmental planning. Policy makers should execute a new agriculture developmental framework focusing on these site-specific adaptation needs proposed by the farmers. This would for certain enhance their coping capacity to tackle the future potential impacts of climate change.

## References

- Acevedo, M., Pixley, K., Zinyengere, N. (2020). A scoping review of adoption of climate-resilient crops by small-scale producers in low- and middle-income countries. *Nat. Plants* **6**, 1231–1241 (2020). <https://doi.org/10.1038/s41477-020-00783-z>
- Adewale, O., Adetayo and Owolade, E. O. (2012). Climate change and mitigation awareness in small farmers of Oyo state in Nigeria. *Open Science Repository Agriculture*, doi: 10.7392/Agriculture. 70081902.
- Ado, A.M., Leshan, J., Savadogo, P. 2019. Farmers' awareness and perception of climate change impacts: case study of Aguié district in Niger. *Environ Dev Sustain* **21**, 2963–2977. <https://doi.org/10.1007/s10668-018-0173-4>
- Ahmed, A.U., Hassan, S.R., Etzold, B. and Neelormi, S. (2012). Where the Rain Falls, Case Study: Bangladesh, United Nations University and Institute for Environment and Human Security (UNU-EHS), Bonn.
- Altieri, M. A. and Nicholls, C.I. (2008). Scaling up agroecological approaches for food sovereignty in Latin America. *Development*. Vol. 51(4). pp: 472– 480.
- Arshad, Md., Amjath-Babu, T.S., Aravindakshan, S., Krupnik, T.J., Kächele, H and Müller, K. 2016. Climate variability and yield risk in South Asia's rice-wheat systems: emerging evidence from Pakistan. *Paddy Water Environ*. <http://dx.doi.org/10.1007/s10333-016-0544-0>.
- Ayal, D.Y. and Leal, F.W. (2017). Farmers' perceptions of climate variability and its adverse impacts on crop and livestock production in Ethiopia. *J Arid Environ*. Vol.140. pp:20–28.

- Bernstein, L., Bosch, P., Canziani, O., Chen, Z., Christ, R. and Riahi, K. (2008). IPCC 2007: climate change 2007. synthesis report. IPCC, Bangkok.
- Bhatta, G.D., Aggarwal, P.K., Poudel, S. and Belgrave, D.A. 2015a. Climate-induced migration in South Asia: migration decisions and the gender dimensions of adverse climatic events. *Journal of Rural and Community Development*. Vol. 10(4).
- Branca, Giacomo, Lipper, L., McCarthy, N. and Jolejole, M.C. (2013). Food security, climate change, and sustainable land management. A review. *Agronomy for sustainable development*. Vol.33(4). pp: 635–650.
- Browder, J. O. (1989). Fragile lands in Latin America: strategies for sustainable development. Westview Press, Boulder.
- Campbell, B.M., Thornton, P., Zougmore, R., van Asten, P. and Lipper, L. 2014. Sustainable intensification: what is its role in climate smart agriculture? *Curr. Opin. Environ. Sustain*. Vol. 8. pp: 39–43.
- Chhetri, N., Chaudhary, P., Tiwari, P.R. and Yadaw, R. B (2012). Institutional and technological innovation: Understanding agricultural adaptation to climate change in Nepal. *Appl Geogr*. Vol.33. pp:142–150.
- Deressa, T. T., Hassan, R. M. and Ringler, C. 2011. Perception of an adaptation to climate change by farmers in the Nile basin of Ethiopia. *J Agric Sci*. Vol.149(1). pp:23 –31. doi:10.1017/S0021859610000687.
- Deshingkar, P. and Akter, S. (2009). Migration and Human Development in India, Research Paper 2009/ 13, Human Development Reports, UNDP.
- Deshingkar, P. and Start, D. (2003). Seasonal Migration for Livelihoods in India: Coping, Accumulation and Exclusion, Overseas Development Institute, London.
- Dhanya, Pand Ramachandran, A. (2016). Farmers' perceptions of climate change and the proposed agriculture adaptation strategies in a semi arid region of south India. *Journal of Integrative Environmental Sciences*. Vol. 13(1). pp: 1-18. DOI: 10.1080/1943815X.2015.1062031.
- Dobermann, Achim, Blackmore, S., Simon, E., Cook, and Viacheslav, I. A. 2004. Precision farming: challenges and future directions. In *Proceedings of the 4th International Crop Science Congress*. vol. 26.
- Elia, E. 2017. Farmers' Awareness and Understanding of Climate Change and Variability in Central Semi-arid Tanzania. *University of Dares Salaam Library Journal*. Vol 12(2). pp: 124-138. ISSN: 0856-1818.
- FAO. 2013. The State of Food and Agriculture, Food systems for better nutrition. Rome.
- FAO. 2014. Sustainable food value chain development – Guiding principles. Rome.
- Food and Agricultural Organization (2010) Climate smart agriculture: policies, practices and financing for food security. Adaptation and Mitigation, Food and Agriculture Organization of the United Nations (FAO), Rome, Italy
- Gathala, M.K., Kumar, V., Sharma, P.C., Saharawat, Y.S., Jat, H.S., Singh, M., Kumar, A., Jat, M.L., Humphreys, E., Sharma, D.K., Sharma, S. and Ladha, J.K. 2013. Optimizing intensive cereal-based cropping systems addressing current and future drivers of agricultural change in the northwestern Indo-Gangetic Plains of India. *Agric. Ecosyst. Environ*. Vol. 177. pp: 85–97.
- Gathala, M.K., Timsina, J., Islam, Md.S., Krupnik, T.J., Bose, T.K., Islam, N., Rahman, Md.M., Hossain, Md.I., Harun-Ar-Rashid, Md, Ghosh, A.K., Khayer, A., Tiwari, T.P. and McDonald, A. 2016. Productivity, profitability, and energy: multi-criteria assessments of tillage and crop establishment options for maize in Bangladesh. *Field Crop Res*. Vol. 18. pp: 32–46.
- Ghanghas B.S., Shehrawat P.S., Nain M.S. (2015). Knowledge of extension professionals regarding impact of climate change in agriculture. *Indian Journal of Extension Education*, 51(3&4),125-129.
- IPCC special report on climate change, Food security, available at <https://www.ipcc.ch/srccl/chapter/chapter-5/>
- IPCC, Inter governmental Panel on Climate Change (2007a) Synthesis report. Contribution of working groups I, II and III to the fourth assessment report of the intergovernmental panel on climate change. IPCC, Geneva, Switzerland IPCC, Intergovernmental Panel on Climate.
- IPCC, Intergovernmental Panel on Climate Change (2000) Land use, land-use change, and forestry. Cambridge University Press, Cambridge West Post WM (2002) Soil organic carbon sequestration rates by tillage and crop rotation: a global data analysis. *Soil Sci Soc Am J* 66:1930–1946.
- Jat, M.L., Dagar, J.C., Sapkota, T.B., Yadvinder-Singh, Govaerts, B., Ridaura, S.L., Saharawat, Y.S., Sharma, R.K., Tatarwal, J.P., Jat, R.K., Hobbs, H. and Stirling, C. 2016. Climate change and agriculture: adaptation strategies and mitigation opportunities for food security in South Asia and Latin America. *Adv. Agron*. Vol. 137. pp: 127–236.
- Jat, R.K., Sapkota, T.B., Singh, R.G., Jat, M.L., Kumar, M. and Gupta, R.K. 2014. Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic Plains of South Asia: yield trends and economic profitability. *Field Crop Res*. Vol. 164. pp: 199–210.
- Juana, J., Kahaka, Z. and Okurut, F. (2013). Farmers' perceptions and adaptations to climate change in sub-Saharan Africa: a synthesis of empirical studies and implications for public policy in African agriculture. *J Agric Sci* Vol. 5(4).
- Khanna, Madhu, and Zilberman, D. (1997). Incentives, precision technology and environmental protection. *Ecological Economics*. 23(1) pp: 25–43.
- Krupnik, T.J., Ahmed, Z.U., Timsina, J., Shahjahan, Md, Kurishi, Rahman, S., Miah, A.A., Gathala, M.K. and McDonald, A.J. 2015a. Forgoing the fallow in Bangladesh's stress-prone coastal deltaic environments: effect of sowing date, nitrogen, and genotype on wheat yield in farmers' fields. *Field Crop Res*. Vol. 170. pp: 1–7.
- Krupnik, T.J., Ahmed, Z.U., Timsina, J., Yasmin, S., Hossain, F., Mamun, A. and McDonald, A.J. 2015b. Untangling crop management and environmental influences on wheat yield variability in Bangladesh: An application non-parametric approaches. *Agric. Syst*. Vol. 139. pp: 166–179.
- Kumar, K.K. and Viswanathan, B. (2012). Weather Variability and Agriculture: Implications for Long and Short-Term Migration in India, Centre for Development Economics Department of Economics, Delhi School of Economics.
- Laik, R., Sharma, S., Idris, M., Singh, A.K., Singh, S.S., Bhatt, B.P., Saharawat, Y., Humphreys, E., and Ladha, J.K. 2014. Integration of conservation agriculture with best management practices for improving system performance of the rice–wheat rotation in the Eastern Indo-Gangetic Plains of India. *Agric. Ecosyst. Environ*. Vol. 195. pp: 68–82.

- Lal, R. 2011. Sequestering carbon in soils of agro-ecosystems. *Food Policy*. Vol.36. pp:33-S39.
- Lipper, L., Thornton, P., Campbell, B.M/, Baedeker, T., Braimoh, A., Bwalya, M. and Hottle, R. (2014). Climate-smart agriculture for food security. *Nat Clim Change*. Vol.4(12). pp: 1068–1072.
- Long, T.B., Blok, V. and Coninx, I. (2016). Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. *J Clean Prod*. Vol.112. pp:9–21.
- McCarthy, N., Lipper, L.W., Mann, G., Branca, and Capaldo, J. 2012. Evaluating synergies and tradeoffs among food security, development and climate change.” *Climate Change Mitigation and Agriculture*.pp: 39–49.
- Mutuo, P. K., Cadisch, G., Albrecht, A., Palm, C.A. and Verchot, L. (2005). Potential of agroforestry for carbon sequestration and mitigation of greenhouse gas emissions from soils in the tropics. *Nutr Cycl Agroecosyst*. Vol. 71(1). pp: 43–54.
- Nyong, A., Adesina, F. and Elasha, B. O. (2007). The value of indigenous knowledge in climate change mitigation and adaptation strategies in the African Sahel. *Mitig Adapt Strat Glob Change*.Vol. 12(5). pp:787–797.
- Olayide, O.E., Tetteh, I.K. and Popoola, L. (2016). Differential impacts of rainfall and irrigation on agricultural production in Nigeria: Any lessons for climate-smart agriculture? *Agric Water Manag* Vol.178. pp: 30–36.
- Pal, B.D., Kapoor, S., Saroj, S., Jat, M.L., Kumar, Y and Anantha, K. H.2021.Adoption of climate-smart agriculture technology in drought-prone area of India – implications on farmers’ livelihoods. *Journal of Agribusiness in Developing and Emerging Economie*.
- Parfitt, Julian, Barthel, M. and Macnaughton, S. 2010. Food waste within food supply chains: quantification and potential for change to 2050.*Philosophical Transactions of the Royal Society of London B: Biological Sciences*Vol. 365 (1554). pp: 3065–3081.
- Parker, Douglas D., and Zilberman, D. (1996). The use of information services: The case of CIMIS.” *Agribusiness*. Vol.12(3). pp: 209–218.
- Paustian, K. A., Andre´n, O., Janzen, H.H., Lal, R., Smith, P., Tian, G. and Woome, P.L. (1997) Agricultural soils as a sink to mitigate CO<sub>2</sub> emissions. *Soil Use Manag*. Vol.13. pp:230–244.
- Pulido, J.S. and Bocco, G. (2003). The traditional farming system of a Mexican indigenous community: the case of Nuevo San Juan Parangaricutiro, Michoaca´n, Mexico. *Geoderma* 111:249–265
- Raghuvanshi, R., Ansari, A.M. and Amardeep (2017). A Study of Farmers’ Awareness About Climate Change and Adaptation Practices in India. *International Journal of Applied Agricultural Sciences*. Vol.3(6). pp: 154–160.
- Ravi Kumar K, Nain M.S., Singh Rashmi, Chahal, V.P. and Bana R.S (2015). Analysis of farmers’ communication network and factors of Knowledge regarding agro metrological parameters. *Indian Journal of Agricultural Sciences*, 85(12),1592-96.
- Richards, M. and Sander, B. O. 2014. Implementation guidance for policymakers and investors. CCAFS report.
- Sandor, J.A. and Furbee, L. (1996). Indigenous knowledge and classification of soils in the Andes of southern Peru. *Soil Sci Soc Am J*. Vol. 60. pp: 1502–1512.
- Sapkota, T.B., Jat, M.L., Aryal, J.P., Jat, R.K. and Arun, K.C.2015. Climate change adaptation, greenhouse gas mitigation and economic profitability of conservation agriculture: some examples from cereal systems of Indo-Gangetic Plains. *J. Integr. Agric*. Vol. 14. pp: 1524–1533.
- Sarkar, S. and Padaria, (2010). Farmers awareness and risk perception about climate change in coastal Ecosystem of west Bengal.*Indian research journal of extension education*. Vol.10(2). pp: 32-38.
- Scheffran, J., Marmar, E. and Sow, P. 2012. Migration as a contribution to resilience and innovation in climate adaptation: social networks and co-development in Northwest Africa. *Applied Geography*. Vol. 33. pp: 119-127.
- Shitu A. G., Nain M. S., and Singh Rashmi (2018). Developing Extension Model for Smallholder Farmers uptake of Precision Conservation Agricultural Practices in Developing Nations: Learning from Rice-Wheat System of Africa and India. *Current Science*, 114(4),814-825.
- Singh, G.S., Ram, S.C. and Kuniyal, J.C. (1997a) Changing traditional land use patterns in the Great Himalayas: a case study of Lahaul Valley. *J Environ Syst*Vol. 25. pp: 195–211.
- Singh, R. and Singh, G.S. (2017). Traditional agriculture: a climate-smart approach for sustainable food production. *Energ. Ecol. Environ*.Vol. 2(5). pp:296–316. DOI 10.1007/s40974-017-0074-7.
- Singh, R., Erenstein, O., Saharawat, Y.S., Chaudhary, N. and Jat, M.L. 2012. Adoption analysis of resource-conserving technologies in rice–wheat cropping system of South Asia. *Indian J. Agric. Sci*. Vol.82. pp: 405–409.
- Sogani, R. 2011. Documentation of climate change perceptions and adaptation practices in Uttarakhand. Northern India, 2011. 33p. Available on <http://www.panap.net/sites/default/files/06-CC-Phase1-BBA.pdf> assessed on 9/10/2014.
- Stern, N.H. 2007. *The Economics of Climate Change : The Stern Review*. Cambridge, UK; New York: Cambridge University Press.
- Waterfield, G. and Zilberman, D. 2012.Pest management in food systems: An economic perspective. *Annual Review of Environment and Resources*. Vol.37. pp: 223–245.
- Woods, B.A., Nielsen, H. O., Pedersen, A. B. and Kristofersson, D. (2017). Farmers’ perceptions of climate change and their likely responses in Danish agriculture. *Land Use Policy*. Vol.65. pp:109–120.
- Zhang, Y., Min, Q., Li, H., He, L., Zhang, C. and Yang, L. (2017a). A conservation approach of globally important agricultural heritage systems (GIAHS): improving traditional agricultural patterns and promoting scale–production. *Sustainability*. Vol. 9(2). pp:295.
- Zilberman, D., Lipper, L., McCarthy, N. and Gordon, B. (2018). Innovation in Response to Climate Change. *Climate Smart Agriculture Building Resilience to Climate Change*. FAO.