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Impact Of And Adaptation To Climate Change In Agriculture: A Systematic Review

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Abstract: Climate change and agriculture are interrelated global processes. A change in climate affects agricultural production in multiple ways. Rise in temperature increases the pest's vulnerability to different crops and change in rainfall pattern reduces water availability and also affects both the irrigated and rainfed farming activities. The aim of this review is to map published literature on impact of and adaptation to climate change in agriculture by categorising papers according to their focus on concept of climate change and variability, extreme weather events, rainfall variability, temperature variability, adaptation to climate change in agriculture and factors influencing the adaptation strategies. Systematic searches were conducted through 'Google scholar'. For this study only those journal's articles were considered which are available at 'Web of Science' and 'Scopus' databases. The study also includes reports which were published by international agencies since 1992. A total of 112 publications were retrieved, of which 58 met the inclusion criteria for the systematic review. These 58 publications were categorised and discussed thematically. A synthesis from various studies finds that inter-annual and seasonal variability of rainfall is a major cause of fluctuations in the production of agricultural crops and increasing temperature has negative effects on major agricultural crop production. The study also indicates that adaptations available to farmers vary according to the local conditions and the particular farming system. Access to agricultural extension, credit, land availability, farm income, education, family size, gender, age, farming experience, farm size, access to market, access to climate information and improved technologies are found as significant factors influencing adaptation practices.

Key words: adaptation, agriculture, climate change, rainfall, systematic review

1. INTRODUCTION

Climate change and climate variability are important because of their relationship and impact on agriculture and its allied activities. Important indicators of climate change are changes in temperature levels, changes in rainfall and weather patterns, an increase in the frequency of extreme weather events, sea-level rise, and change in the CO_2 level, etc., over a long period of time (WMO, 2017). Agriculture is the economic sector that is most vulnerable to climate change (Mendelsohn and Dinar, 2009; Nastis et al., 2012). It is susceptible to climate change because all agriculture depends on acceptable temperature ranges and rainfall patterns for raising crops and livestock. Changes in climate reduce agricultural productivity, both directly via the damage to standing crops and indirectly via their impact on cropping decisions (Trinh, 2021). Climate change impacts on agriculture have received considerable attention because it has a close relation to the food security and poverty status of a vast majority of the world (Dinar et al., 1998). It is likely to contribute substantially to food insecurity in the future, by increasing food prices and reducing food production.

The magnitude of the impacts of climate change depends on the vulnerability of individual nations and their adaptive capacity to face the consequences (Panda, 2013). The term Vulnerability is defined as the degree to which a system is susceptible and unable to cope with the adverse effects of climate change, including climate variability and extremes. Due to structural weaknesses and low levels of resilience and adaptive capacity, developing countries are considered to be more vulnerable to the impact of climate variability and change (Panda, 2013). Hence, it is important to understand the factors that give rise to greater or lesser adaptive capacity among households within a community and government interventions to target appropriate groups of people.

There are several international bodies to address the climate change issue. Some important organizations are: Earth System Governance Project (ESGP), Global Green Growth Institute (GGGI), Intergovernmental Panel on Climate Change (IPCC), International Union for Conservation of Nature (IUCN), United Nations Environment Programme (UNEP) and European Environment Agency (EEA). Many international conferences have been organized by international bodies and several treaties were signed regarding the climate change. The first major conference is the United Nations Framework Convention on Climate Change (UNFCCC), 1992 (known as Earth Summit) was signed by 154 countries at Rio. de Janerio to stabilize greenhouse gas concentration in the atmosphere. In 1995, the first Conference of Parities (COP1) to the UNFCCC was held in Berlin. The UNFCCC, 1997 (known as Keyoto Protocol), is an international agreement among industrialized nations, to lower greenhouse gas (GHG) emissions. It was mainly concerned with six GHGs: Carbon dioxide, Methane, Sulphur hexafluoride, Nitrous oxide, Pen fluorocarbons and Hydro fluorocarbons (UNFCCC, 1998). The UNFCCC, 2005 was took place in Montreal (Canada) with the main agenda to discuss the adverse effect of climate change on developing and least developed countries. The latest important agreement, Paris Agreement of UNFCCC in 2016 recognizes that climate change represents an urgent and potentially irreversible threat to human societies and the planet earth. There is a need for cooperation among all countries to design an effective and appropriate international response to accelerating the reduction of global greenhouse gas emissions (UNFCCC, 2016).

This piece of research work attempts to provide a review of literature on the impact of and adaptation to climate change in agriculture sector. The study also intends to discuss various adaptation practices as well as factors influencing the adaptation of farmers in response to climate change.

2. MATERIALS AND METHODS

2.1. Methods: Systematic searches were conducted through ‘Google scholar’. For this systematic review only those journal’s articles are considered which are available at ‘Web of Science’ and ‘Scopus’ databases. These two academic data basses were selected to capture a wide range of multi-disciplinary literature, literature related to economics and social sciences. The study also includes reports published by international agencies on climate change related issues since 1992 (i.e. after the first major conference of the UNFCCC in 1992, known as Earth Summit).

2.2. Search items: Search items mainly includes concept of climate change and climate variability, extreme weather events, rainfall and agricultural production, temperature and agricultural production, adaptation to climate change, factors influencing adaptation to climate change in agriculture and barriers to adaptation.

2.3. Inclusion criteria:

- Primary research papers and review articles with clearly described methods.
- Journals which are available at 'Web of Science' and 'Scopus' databases.
- Reports published by international agencies since 1992.
- Papers and reports published in English.
- Papers exploring the concept of climate change and climate variability.
- Papers on extreme weather events and their relation to agricultural production.
- Papers explaining the impact of rainfall variability on agricultural production.
- Papers explaining the impact of temperature variability on agricultural production.
- Papers explaining adaptation practices to climate change in agriculture and factors influence in adaptation strategies.

2.4. Exclusion Criteria:

- Commentaries, letters to the editor, conference abstract/proceedings.
- News articles.
- Papers and review articles with no clear methods.
- Non-English language papers.
- Papers and reports published before 1992.
- Reports published by local/national agencies.

3. RESULTS AND DISCUSSION

A total of 112 studies were retrieved for possible inclusion, of which 58 actually met the inclusion criteria. These 58 publications were categorised and discussed thematically as given below.

3.1. Concept of Climate Change and Variability: The Inter-Governmental Panel on Climate Change defines climate change as a change in climate that can be identified (using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer (IPCC, 2012). The United Nations Framework Convention on Climate Change (UNFCC) defines the term 'climate change' as "A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (UN, 1992). But a significant change in climate depends upon the underlying level of climate variability. So, it is very crucial to understand difference between climate change and climate variability (IPCC, 2007).

Climate variability indicates the variations in the mean state and other statistics of the climate at all spatial and temporal scales beyond that of individual weather events (IPCC, 2012, Safari, 2012). Variability may be internal variability i.e., internal process within the climate system or external variability i.e., variation in natural anthropogenic external forces. Climate variability is characterized in terms of "anomalies", where an anomaly is the difference between the instant state of the climate system and the climatology since the spatial structure of climate variability in the extra tropics is strongly seasonally dependent (Hurrell and Deser, 2010).

The term 'climate change' is different from 'climate variability'. Climate variability refers to variations in the mean states of weather in each temporal and spatial scale whereas climate change (or global climatic change) is defined as the persistence in those variations including its origin in natural physical processes and by the influence of anthropogenic factors (Cardenas et al., 2006).

3.2. Extreme Weather Events: Extreme weather events act as indicators for climate change. Using statistical models, a study demonstrates that the frequency of such events is relatively more dependent on any changes in the variability (more generally, the scale parameter) than in the mean (more generally, the location parameter) of climate (Katz and Brown, 1992). It has been shown in a study that heat waves, droughts, floods and cyclones are the important extreme weather events that hamper the livelihoods in Odisha, India (Mirza, 2003). Employing climate model simulations, another study of extreme events over France reveals that the high sensitivity of some statistics of climate extremes as a consequence of regional climate internal variability. The changes of wind-related extremes are also regionally dependent (Planton et al., 2008).
Impacts of extreme weather events (such as floods, droughts, cyclones, hail storm, thunderstorm, heat and cold waves) have been increasing on socio-economic conditions of people due to large growth of population as well as its migration towards urban areas which has led to greater vulnerability. As per WMO review of global losses from such extreme weather events is about US $ 50-100 billion annually with loss of life of about 2,50,000 in recent years (De et al., 2005). Combining panel data techniques with spatial analysis, a study finds that farmers increase their adoption of conservation tillage following abnormally dry conditions of the past growing seasons; however, abnormally wet conditions (e.g., floods) in the past growing seasons do not have a significant effect on the choice of tillage systems (Ding et al., 2009. Using Regression technique, another study finds that the effects of extreme weather events on wheat yields are time specific in that week in which an event occurred in Netherlands. High temperature events and rainfall events decrease crop yield and production (Powell and Reinhard, 2016).
Extreme weather events are emerging as a potential threat to food security and farmers livelihoods in India. It has been claimed by a study that a considerable proportion of the revenue is being spent in addressing the damages caused due to these events. Extreme precipitation (flood and drought) and temperature are crucial in causing detrimental impact on crop yield and production. Particularly, the impacts of extreme events will be more in rainfed agriculture due to inter annual precipitation variability over the growing season in terms of crop yield and yield quality (Swaminathan and Rengalakshmi, 2016). Through a review of literature, another study highlighted that extreme weather events affect populations at large, caused substantial economic losses and exerted an unequal effect on the vulnerable social groups i.e., sharecroppers, small and marginal farmers, backward communities, wage labourers, landless labourers, rickshaw pullers and vendors as the nature of work is susceptible to the effects of extreme weather events in which they are engaged (Patel and Pati, 2019).

3.3. Rainfall variability and Crop production: Employing correlation and multiple regression analyses, a study finds that seasonal rainfall is important determinant of crop yields in Nigeria. However, inter-annual changes in the yield of maize and rice were less sensitive to rainfall variability (Adejuwon, 2005). Using 'unit root test', it is indicated that shifting crop cycle is not fruitful due to un-predictive changes of rainfall for Paddy Farming in Malaysia because all crop cycles are affected in a similar way (Alam et al., 2011). Based on a plot level panel data set from Ethiopia, another study indicates that the level of riskiness of crop portfolio

is partly motivated by rainfall variability, particularly that of annual and summer rainfall (Bezabih and Falco, 2012). However, employing a multiple regression analysis and Monte Carlo simulation approach, another study finds that drought and extreme rainfall negatively affect rice yield (harvest per hectare) in predominantly rain fed areas during 1966–2002 in India. Drought has a much greater impact than extreme rainfall (Auffhammer et al., 2012). It has been found by a study that variation in cotton yields is related to the rainfall distribution within the rainfall season, with dry spells and seasonal dry days in southern Mali. In the driest districts, maize yields are positively correlated with rainfall (Traore et al., 2013).
Using correlation analysis, a study shows that the rainfall has a strong positive association with maize and beans production at Hai District in Kilimanjaro Region of Tanzania (Munishi et al. 2013). The IPCC has assessed that change in precipitation or melting snow and ice alters hydrological systems which affects water resources in terms of both quantity and quality. Therefore, negative impacts on crop yields have been observed in many regions (IPCC. 2014). Using a time varying ARCH model, another study shows that exponential deviation on amount of rainfall leads to negative effects on the deviation in crop output in Uganda (Mwaura and Okoboi, 2014). Employing correlation analysis, a study indicates that any significant change in climatic conditions (Rainfall and temperature) will not only challenge the food production of North West India but also challenge the country's food security situation (Ahlawat & Kaur, 2015). Using correlation analysis, another study shows a negative relationship between crop yield and dry spells in the North- Western semi-arid zone of Nigeria (Yamusa et al., 2015). It is indicated by a study that crop production and cultivated area are positively correlated with rainfall in in the central highlands of Ethiopia (Alemayehu and Bewket, 2016). Using Ricardian approach, a study finds that rainfall has a negative effect on tea and it is estimated that climate change will adversely affect agriculture in 2020, 2030 and 2040 having greater effects in the tea sector in Kenya (Ochieng et al, 2016).
Employing regression analysis, a study shows that rainfall variability is harmful to autumn and winter rice yield in Assam, India. For summer rice, it is positive but statistically insignificant (Nath and Mandal, 2018). Using correlation coefficient technique, another study observed that crops in the region of Kashmir Himalayas have different associations with rainfall, and as a result, area under some crops has increased while under certain other crops it has witnessed a contraction (Batool et al., 2019). Based on a systematic review, a study finds that unpredictable and decrease in rainfall reduces agricultural production in the worldwide (Karki et al., 2019). Applying Correlation and multiple linear regressions, another study show that deficit in rainfall has a negative impact on the crop yield and livelihoods of smallholder subsistence farmers in Kalahandi, Bolangir, and Koraput districts of the south-western part of Odisha, India (Panda et al., 2019).

3.4. Temperature variability and crop production: Using simulation technique, a study shows that average predicted yield from crops decreases with increasing temperature variability where in growing-season temperatures are below the optimum specified in the crop model for photosynthesis or biomass accumulation in Georgia. However, increasing within year variability of temperature has little impact on year-to-year variability of yield (Riha et al., 1996). On the other hand, applying CERES RICE crop simulation model, another study shows that in Indian Punjab warming scenarios will have an adverse effect on rice production through the advancement in maturity (Mathauda et al., 2000). A study finds that increase in temperature affects crop production and crop choice throughout Europe, with increasing frequency of droughts negatively affecting crop yield in southern and central Europe (Olesen et al., 2011). Using linear regression model, another study indicates that seasonal temperature increases have the most important impact on crop yields. By 2050, projected seasonal temperature increases by 2̊ C reduce average maize, sorghum, and rice yields by 13%, 8.8%, and 7.6% respectively in Tanzania (Rowhani et al., 2011). It has been shown by a study that temperature had an inverse relationship with maize and beans yields at Hai District in Kilimanjaro Region of Tanzania (Munishi et al. 2013). The UNFCCC reported that rise in temperatures will cause shifts in crop growing seasons which affects food security in developing countries (UNFCCC, 2007). Using OLS technique, a study observed a significant negative impact of temperature on rice yield in India (Gupta et al., 2014). Using Ricardian approach, a study finds that the rise of annual temperature will hurt farms both in the north or south China. Net farm revenues vary with farms in the north and the south being adversely affected by a rise in the temperature (Wang et al., 2014).

Employing panel data approach with garden fixed effects, a study indicates that an increase in average temperatures as expected with global warming will reduce the productivity of tea plantations in Assam, other things remaining stable (Duncan et al., 2016). Using correlation analysis, a study finds that crop production and cultivated area are negatively related with maximum and minimum temperatures in the central highlands of Ethiopia except Basona Werana district (Alemayehu and Bewket, 2016). Using a random effects specification, a study shows interactions between temperature and SPEI (standardized precipitation evapotranspiration index) led to a stronger temperature sensitivity of the global maize and wheat yields in dry situation than normal conditions, and no temperature sensitivity of global soybean yields for wet, compared to normal conditions. Using state-level data, USA yields of maize and soybeans were found more sensitive to temperature in dry than normal conditions, and soybean yields were less sensitive to temperature in wet than normal conditions (Matiu et al., 2017). Applying regression analysis, another study suggests that an increase in temperature variability is beneficial to autumn and winter rice yield in Assam. For summer rice, it is positive but statistically insignificant (Nath and Mandal, 2018). It has been reported by WMO that rises in global temperature and changes in rainfall patterns have already affected terrestrial ecosystems such as forests and grasslands, as well as agricultural lands and crop yields. Between 2006 and 2016, agriculture (crops, livestock, forestry, fisheries and aquaculture) in developing countries accounted for an estimated 26% of total loss and damage incurred during medium- and large-scale climate-related disasters (WMO, 2019).

3.5. Adaptation to Climate Change in Agriculture: Employing crop simulation model, a study finds that changes in sowing date and hybrid selection can reduce the negative impact of potential warming on maize yield during the next century. Changes in cropping pattern, irrigation, and agricultural land use can be additional alternative options for adaptation in agriculture in Bulgaria (Alexandrov and Hoogenboom, 2000). Using a multinomial choice model to a cross-sectional survey of over 8000 farms from 11 African countries, another study indicates that specialized crop cultivation (mono-cropping) is the agricultural practice most vulnerable to climate change in Africa. Warming condition, especially in summer, poses the highest risk. Irrigation, multiple cropping and integration of livestock were suggested to cope up with climate variability (Hassan and Nhemachena, 2008). Applying a multinomial logit model, a study reveals that climate change influences the choice of crops among Chinese farmers. A marginal increase in temperature increases the chance that farmers choose maize and especially cotton and decreases the chance they will choose vegetables and potatoes. A marginal increase in precipitation increases the chance that farmers choose wheat and decreases the chance they choose rice, soybeans, oil crops, and especially vegetables (Wang et al., 2010).

Using Cost benefit analysis, a study argued that private adaptations are likely to be efficient in developing countries because the benefits and cost accrue to the decision maker (Mendelsohn, 2012). Based on the same methods of analysis, another study observes that water-saving irrigation is cost-effective in coping with climate change in China. It is beneficial for climate change mitigation, adaptation, and sustainable economic development (Zou et al., 2013). A study also reveals that irrigation is one of the key adaption measures to dealing with climate change in China (Wang et al., 2014).

Employing simulation techniques and regression models, a study finds that while adaptation can mitigate adverse effects of climate change under cost-effective terms, climate change may create winners and losers depending on their agricultural activity and location (Georgopolou et al., 2017). Employing a livelihood-based index that assigned weights to different individual strategies based on their marginal contributions to a household's livelihood, a study shows that farmers' attitudes strongly favoured introduction of new crops, changes in crop varieties, and changes in planting times in East Africa. Farmers disfavoured soil, land, and water management practices (Shikuku et al., 2017).

Through a content analysis and group information, a study claims that farmers in India are though aware of long-term changes in climatic factors (e.g., temperature and rainfall), they are unable to identify these changes as climate change. They take some traditional measures like changing their agricultural and farming practices in response to climate change. These includes changes in sowing and harvest timing, cultivation of crops of short duration varieties, inter-cropping, changes in cropping pattern, investment in irrigation and agroforestry (Tripathi and Mishra, 2017). Using panel data approach with a fixed-effects strategy, another study finds that farmers adjust their irrigation investments and their crop portfolios in response to the medium-run rainfall variation. However, adaptation only recovers a small fraction of the profits that farmers have lost due to adverse climate variation (Taraz, 2017). Another study revealed the existence of farmers' choices of agricultural activities including coffee production, poultry production and productions of fruits (e.g. mango and papaya) which were seen as the means of adaptation mechanism and mitigation practices against fluctuated rainfall and water scarcity in Sadi Chanka District of Kellem Wolega, Oromia, Ethiopia (Eticha et al., 2021).

3.6. Factors influencing the adaptation of farmers in response to climate change: Through logit regression technique, a study reveals that annual income, access to irrigation, access to credit facility and landholding size of the farming households are the major factors which influence their behaviour to adapt to climate change in Odisha, India (Mishra and Sahu, 2014). Employing Multiple regression technique, it has been identified by a study that the determinants of farm-level adaptation are agricultural extension, access to Mahatma Gandhi National Rural Employment Guarantee Scheme, received crop loss compensation and access to informal credit in Odisha, India (Bahinipati et al., 2015). Using propensity score matching (PSM) approach, a study shows that young farmers and farmers with higher levels of education are more likely to use adaptation practices. The number of adaptation practices used is e positively associated with education, male household heads, land size, household size, extension services, access to credit and wealth (Ali and Erenstein, 2016). Through a descriptive analysis, another study indicates that the farmers' perception and adaptation measures regarding climate change depends on location specific factors. The adaptation decisions of farmers are mainly influenced by family size, cultivated land size, education level, age and gender of the head of household, number of crop failures in the past, changes in temperature and precipitation, experience of farming, non-farm income, income from livestock, extension advice, farm-home distance climate information, duration of food shortage etc. (Asrat and Simane, 2018).

Employing principal component analysis, a study reveals that three components play major role in the farmers' decisions on adaptation methods, namely, farm production practices, farm financial management, and government programs and insurance. Analysis shows that these factors accounted for 50%, 25%, and 40% of the adaptation responses, respectively (Azadi et al., 2018). Another study also specified that access to agricultural extension, credit; land and improved technologies are highly significant to climate change adaptations. Demographic and socio-economic factors, which represent the status and economic condition of farm households, also received considerable attention (Dang et al., 2019). Using logit model, a study shows that factors affecting rural farming households' adaptation to climate variability are gender, age, heat wave, employment status, strong high wind occasional experience and cell phone (Mtintsilana and Akinyemi, 2021).

4. CONCLUSION

Agriculture is inherently sensitive to climate conditions. Many impact studies have shown the vulnerability of the agricultural sector to climate change (Mendelsohn and Dinar, 2009; Nastis et al., 2012). This paper presents an overview of impact of and adaptation to climate change in agriculture sector through a systematic review of literature. It has been observed that inter-annual and seasonal variability of rainfall is a major cause of fluctuations in the production agricultural crops and increasing temperature has negative effects on agricultural crop production. However, the impacts of climatic variables on agricultural productivity vary from economic condition of countries, regions and over a period of time. To minimise the losses of agricultural production due to climate change, appropriate adaptation strategies should be adopted. Adaptations available to farmers vary according to the local conditions and the particular farming system. In this paper, the majority of our reviewed studies have investigated the impacts of resources, services and technologies on farmers' adaptive responses. This implies the significance of financial and technical support in promoting adaptation. Further, most of the reviewed studies were conducted in developing countries. As a result, access to agricultural extension, credit, land availability, family labour availability, farm income, education, family size, gender, age, livestock ownership, farming experience, frequency of contact with extension agents, farm size, access to market, access to climate information, improved technologies, availability of cell phone, demographic and socio-economic factors are seen highly significant.

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