International Journal of Research in Social Sciences
Vol. 8 Issue 10, October 2018,
ISSN: 2249-2496 Impact Factor: 7.081
Journal Homepage: http://www.ijmra.us, Email: editorijmie@gmail.com
Double-Blind Peer Reviewed Refereed Open Access International Journal - Included in the International Serial Directories Indexed & Listed at: Ulrich's Periodicals Directory ©, U.S.A., Open J-Gage as well as in Cabell's Directories of Publishing Opportunities, U.S.A

METHODS AND TECHNIQUES OF ADAPTATION IN AGRICULTURE IN THE CONTEXT OF CLIMATE CHANGE

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Abstract

According to World Meteorological Organization, climate change can adversely impact global environment, agricultural productivity and the quality of human life. More importantly in India, it is difficult for farmers to carry on farming in the increased temperatures and changing climate scenario. This paper deals with bio physical, and socio economic impact of climate change on agriculture. It outlines the climate change impact scenario in Indian agriculture. This paper makes a special note on various agriculture adaptation policies and adaptation options in agriculture in the context of climate change. This paper concludes with some interesting findings along with policy suggestions.

Introduction

Climate change is already affecting agriculture, with effects unevenly distributed across the world. Future climate change will likely negatively affect crop production in low latitude countries, while effects in northern latitudes may be positive or negative. Climate change will probably increase the risk of food insecurity for some vulnerable groups, such as the poor. Animal agriculture is also responsible for greenhouse gas production of CO2 and a percentage of the world's methane, and future land infertility, and the displacement of local species. Agriculture contributes to climate change both by anthropogenic emissions of greenhouse gases and by the conversion of non-agricultural land such as forests into agricultural land. Agriculture, forestry and land-use change contributed around 20 to 25% to global annual emissions in 2010.

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A range of policies can reduce the risk of negative climate change impacts on agriculture and greenhouse gas emissions from the agriculture sector .

Biophysical impact of climate change on agriculture

As per the report by OECD (2009) the bio physical impacts of climate change on agriculture can be observed in the following ways, physiological effects on cultivated crops, pasture, forests, fish, rangeland and livestock both in terms of quantity and quality, changes in the quantity and quality of land, soil and water resources, increased weed and pest challenges, alien invasive species, sea level rise, changes to ocean salinity and sea temperature rise causing fish to inhabit different ranges.

Socio-economic impact of climate change on agriculture

It is evident from the report of OECD (2009) that the socio economic impact of climate change on agriculture can be observed in terms of changes in yields and production, reduced gross domestic product (GDP) from agriculture in the long term, greater fluctuations in world market prices, changes in geographical distribution of trade, increased number of people at risk of hunger and food insecurity and migration and civil unrest.

Climate change scenario in Indian agriculture

Agriculture is one of the largest contributors to India's GDP, approximately 20 %. It is the main source of livelihood for almost 60 % of the country's total population. The impacts of climate change on agriculture will therefore be severely felt in India. GoI (2011) Guiteras (2007) and OECD (2002) projected that under the scenario of a 2.5 °C to 4.9 °C temperature rise in India, rice yields will drop by 32 %-40 % and wheat yields by 41 %-52 %. This would cause GDP to fall by 1.8 %-3.4 %. Despite the gloomy predictions about the negative impacts for India's agricultural sector, climate change is generally also expected to bring opportunities. IFPRI (2009) and UNFCCC (2009) reported that production gains through the CO^2 fertilization effect or the expansion of cultivated land to higher altitudes and northern latitudes. However, it must be noted that to date all climate change projections have been accompanied by uncertainty — not primarily concerning trends but extent.

Research studies on impact of climate change on agriculture in India

Many research studies have been conducted to analyze the impact of climate change on agriculture in India. Such studies have pointed out the various impact of climate change on agriculture in different settings. Some of the studies are cited here. These include Naresh Soora, et.al., (2013) carried out a simulation analysis using the InfoCrop-rice model to quantify impacts and adaptation gains, as well as to identify vulnerable regions for irrigated and rain fed rice cultivation in future climates in India. S. Naresh Kumar and P.K. Aggarwal (2013) reported that impact of climate change on coconut, a plantation crop, is challenging. However, the development of a simulation model has enabled the process.

Prabhat Barnwal and Koji Kotani (2013) examined the case of rice yield in Andhra Pradesh, India, an important state producing rice as a main crop but reported to be vulnerable to climate change. K N Ninan and Satyasiba Bedamatta (2012) assessed the impact of climate change on Indian agriculture covering a cross section of crops, seasons and regions based on existing literature. S. Mahendra Dev (2011) identified climate change related threats and vulnerabilities associated with agriculture as a sector and agriculture as people's livelihoods exposure, sensitivity, and adaptive capacity.

K.S. Kavi Kumar (2009) reported that climate change impact studies on agriculture are broadly based on agronomic-economic approach and Ricardian approach. Rao, (2011) reported that the impact of climate change in the form of climate variability like floods and droughts adversely affected food and plantation crops to a large extent. Sreenivas et al., (2005) conducted field experiment during kharif and rabi seasons to study the effect of weather parameters on grain yield of low land rice. Sreekanth, P.D., et al., (2004) have observed that crop yield loss varied between 10 and 100% in the case of horticultural and seasonal crops when there was a cold wave from December 2002 to January 2003 in some parts of Jammu, Punjab, Haryana, Himachal Pradesh, Bihar, Uttar Pradesh and north Eastern States. Rao et al., (2001) reported that excess rainfall throughout the crop growing period is not conducive and it adversely affects crop yield though rice is a water loving crop. Soto et al., (2000) conducted an off-farm research to find out the effect of shade structures on coffee grain yield and assessing the potential use of associated plant species.

Impact of Climate change on Crop:

A rise in atmospheric carbon dioxide to 550 ppm under controlled environment conditions enhanced the yields of wheat, chickpea, green gram, pigeon pea, soybean, tomato and potato between 14% and 27%. These enhancements were largely due to the increase in the number of storage organs. In most of the crops, this was accompanied by a small reduction from 2 to 10% in the protein content.

In plantation crops like coconut, areca nut and cocoa, increased CO2 led to higher biomass. In the case of rice - hybrid and its parental lines – elevated CO2 positively affected a few grain quality traits such as head recovery, test weight, proportion of high density grains and germination characteristics but adversely affected traits like aroma, gelatinization temperature, protein and micronutrient contents. Sunflower hybrids grown under elevated CO2 conditions inside open top chambers, showed a significant increase in biomass (61-68%) and grain yield (36-70%) but the quality of the produce was adversely affected in terms of protein and micro-nutrient contents.

The magnitude of the impact of climate change on wheat production in India, assessed through simulation studies, indicated that an increase in 1oC in mean temperature, associated with CO2 increase, would not cause any significant loss if simple adaptation strategies such as change in planting date and varieties are used. The benefits of such simple adaptation strategies, however, gradually decrease as temperature increases to 5oC. In the absence of adaptation and CO2 fertilization benefits, a 1oC increase in temperature alone could lead to a decrease of 6 million tones of wheat production. This loss is likely to increase to 27.5 million tones in case of a 5oC increase in mean temperature.

Cotton is an important cash crop, which is mostly grown under rain-fed conditions, making it more vulnerable to precipitation. The model results indicate that climate change and the consequent increased temperature and altered pattern of precipitation might decrease the cotton yield of northern India to a greater extent than the southern region. The impact of climate change on rain-fed cotton, which covers more than 65 to 70% of area and depends on the monsoon is likely to be minimum, possibly because of marginal increase in rain. Moreover, the stimulating

effect of CO2 could offset the negative impact of climate on cotton production. Thus, at the national level, cotton production is unlikely to change with climate change.

Adaptive measures such as changing planting time may further boost cotton production. Potato, a tuber, is widely consumed in India. It was found that, without adaptation, the total potato production in India, under the impact of climate change, might decline by 2.61% and 15.32% in the years 2020 and 2050, respectively. The impacts on productivity and production varied among different agro-ecological zones. Plantation crops: Using a validated coconut simulation model, the impact of elevated temperature and CO2 on coconut yields was simulated for different agro-climatic zones. Overall results indicate that coconut yields are likely to be positively influenced by increase in CO2 and increase in temperature of up to 2 - 3°C.

Cocoa, another plantation crop, is grown as the intercrop either under areca nut or coconut. Being a shade-crop, cocoa is influenced only indirectly by the increase in atmospheric temperature. The crop is maintained in irrigated conditions and is presently confined to limited pockets in the southern states of Karnataka and Kerala. Analysis indicated that a rise in temperature by 1oC should be beneficial for crop productivity. The improvement is likely to be about 100 kg of dry beans/ha. The cocoa growing foothills of the Western Ghats of Karnataka are more likely to benefit than central Kerala. However, crop management and irrigation supply should be maintained or improved to exploit this benefit. Further, an increase in temperature beyond 3°C is likely to reduce cocoa yields.

Vegetables and Fruits: Significant effects of increased climatic variability, if changes occur during critical periods in growth, have been observed on short season crops such as vegetables. Such crops have limited time to adapt to adverse environments. Among the vegetable crops, onion and tomato are important commercial crops grown across the country. However, the productivity levels are very low compared to major producing countries. This problem of lower productivity will be further compounded under climate change scenarios as the major onion and tomato growing regions are under tropical conditions and prevailing temperature conditions are already high. Onion and tomato are sensitive to environmental extremes.

The impact of climate change on grapes would be determined by the impact on rainfall during the months of February to April, when the berries mature. In severe conditions, rainfall during the month of October, could increase the incidence of Downey mildew disease on leaves and flower clusters. The increase in minimum temperature during fruit maturation plays an important role in the anthocyanin, total phenol, total flavanoids and total acidity content of the berries, which ultimately affect the quality. Another fruit, the productivity of which is heavily linked with climatic variations, is apple. Analysis of current and future climatic scenarios model have revealed that Himalayan ecosystems will suffer from reduced winter precipitation (January-June) in sub-tropical zones, high temperature during winters and summers, change in seasonal rainfall patterns and significant reduction in snowfall.

Agriculture adaptation policies

It could be noted that many climate change adaptation policies have been identified for the agricultural sector. Smith and Lenhart (1996), note that policies include efficient water allocation, promoting seed research and changes to subsidies and taxes. As per the report by OECD (2009), Policy options for adaptation in agriculture depend on promotion of research in agriculture. In adaptation option, developing crop and livestock technologies in the form of better heat and drought-resistant crops, enhancing seed banks, encouraging the transfer or adoption of locally important innovations by the way of water harvesting systems and making use of complementarities between public and private agricultural research. It can be done through promotion of crop and livestock diversification and agro biodiversity. It could be noted that avoiding monocultures and reducing the risk of crop failure by advising farmers to grow drought-resistant food crops such as cassava, millet, or sorghum could be done by the way of adoption of technologies. In agriculture adaptation, modernizing farm operations and using adapted seeds depends upon increasing efficiency of water infrastructure and water use.

In agriculture adaptation, providing opportunities to reduce direct dependence on natural factors such as precipitation and runoff and reducing vulnerability to climatic variations and natural disasters and Improving irrigation systems could be done by the way of disperisng information on conservation management practices. In agriculture adaptation, protecting fields from water and wind erosion, using management practices that reduce dependence on irrigation in order to

decrease water consumption without reducing crop yields and changing tillage practices in the form of zero tillage on formerly overused/depleted land can be done by the way of providing agricultural extension services.

In agriculture adaptation, improving knowledge on agricultural crop and livestock management and on drought and flood management depends upon promotion of investments in agriculture. In agriculture increasing productivity and improving management practices could be done by the way of investment in better information and forecasts. In agriculture adaptation, improving communication technologies in order to improve access to and handling of information, refining modeling techniques that bring high-quality short-term forecasts to many parts of the world and supporting the diffusion of information to help interpret forecasts in terms of their agronomic and economic implications can be done by the way of promoting food reserves and reduce post harvest losses.

India's National Mission for Sustainable Agriculture

The National Mission for Sustainable Agriculture is one of the eight missions in India's National Action Plan on Climate Change. It stresses the crucial role of agriculture in India's economy by the way of promoting livelihood security for its people, since the agriculture sector supports more than half the country's population of over 1 billion people. The mission focuses on four areas that are relevant for the endeavors of India's agricultural sector to adapt to climate change: dry land agriculture, risk management, access to information and use of biotechnology
The adaptation in dry land agriculture could be done in the form of priority actions for dry land agriculture with particular relevance to adaptation will be in the form of developing drought and pest-resistant crop varieties; improving methods to conserve soil and water; conducting stakeholder consultations, conducting training workshops and demonstration exercises to help farming communities share and disseminating agro-climatic information and providing financial support to enable farmers to invest in and adopt relevant technologies to overcome climate-related stresses.

Some of the priority actions in the field of agricultural risk management are required. These include strengthening current agricultural and weather insurance mechanisms;

development and validation of weather derivative models by insurance providers, ensuring access to archived and current weather data; creating web-enabled, regional language based services to facilitate weather-based insurance; developing geographical information systems and remote sensing based methodologies for detailed soil resource mapping and land use planning at the level of a watershed or river basin; mapping vulnerable eco-regions and pest and disease hotspots and developing and implementing region-specific contingency plans based on vulnerability and risk scenarios.

Adaptation options in agriculture

It is essential to have selection criteria that help decision-makers to identify which adaptation strategies or measures to implement and when to implement them. This is particularly the case if one takes into consideration the fact that the process of choosing the right adaptation options is happening in the uncertain environment of climate projections and continuous change. Leary et al. (2007) note that subsistence farmers in rural areas, who generally have low adaptive capacity, many of the choices will require putting in enormous effort. Hence 'choosing wrong can be costly, even deadly'. According to Leary et al. (2007), criteria for the selection of adaptation measures might be: economic and social benefits; consistency with development objectives; environmental impacts and spill-over effects and cultural acceptance and social feasibility.

It could be noted that prioritizing adaptation measures implies defining and applying criteria that help to decide when to implement an appropriate adaptation option. Consequently, anticipatory, i.e. planned, adaptation would be particularly favorable in cases where future impacts are potentially catastrophic or irreversible. It is evident from the work of Rosegrant et al. (2008) that, it might make sense to defer adaptation in cases where it would be very costly. In any case, the 'adaptation measure that yields the greatest benefit' should always be chosen. With regards to agriculture, benefits are generally related to the farmer's income, in terms of increased agricultural yields. According to Kumar (2008), introduction of adapted crop varieties and species in terms of water-efficient crops is the best option. Further, the decision on which practice to choose should be well matched with the farmers' given capacities, with respect to the financial resources available.

Technical options at farm level

It is important that adaptation measures are site-specific and fit the given conditions. Management-based adaptation practices related to livestock systems are subdivided into inputs, water and animal management. It is difficult to distinguish between good agricultural practices and 'pure' climate change adaptation options. Good agricultural practices often derive from efforts and experience that farmers acquire over time in adapting to different climatic conditions – be it short or long-term changes in weather and climate.

Arid and semi arid region

It is evident from the report of GOI (2011) that in arid and semi arid region cropping system should be based on drought-tolerant crops such as millet instead of corn and varieties. The crop management in Arid and semi arid region aims at enhancing crop rotation practices and changing cropping patterns. The livestock system in this region should use supplementary feeds and concentrates. In Arid and semi arid region, animal management should continuously matching stock rates with pasture production, changing grassland cutting frequency and restricting extensive livestock farming.

Humid region

GOI (2011) points out that in humid region cropping system should be based on early maturing varieties. The crop management in humid region aims at improving seed storage. The livestock system in this region should use adapted livestock breeds. In humid region, animal management should enhance animal welfare, in the form of vaccinating animals to protect them and reduce the spread of disease.

Coastal region

It is observed from the report of GOI (2011) that in coastal region cropping system should be based on salt- tolerant varieties. The crop management in Coastal region aims at integrating trees and bushes to reduce water runoff and erosion and to provide flood protection. The livestock system in coastal region should be in the form of constructing livestock shelters. In Coastal region, animal management should be based on moving herds from waterlogged fields.

Mountain region

It is evident from the report of GOI (2011) that in mountain region cropping system should be based on crop diversification, in the form off-season crops, short season crops and fruit cultivation. The crop management in Mountain region aims at maintaining agro biodiversity to conserve frost tolerant species and varieties, and applying soil and water conservation measures, in the form of contour cropping and terracing. The livestock system in this region should use supplementary feeds. In Mountain region, animal management should be continuously matching stock rate with pasture production, increasing feed reserves, designating special areas for livestock grazing, protecting and steep slopes by avoiding overgrazing so that that the vegetation cover remains stable.

Animal management in agriculture adaptation

Semi-arid and arid areas are particularly vulnerable ecosystems. Nomadic and semi-nomadic livestock keeping based on extensive grazing systems can make the best of what these ecosystems provide. Overgrazing, can lead to desertification. It is thus vital to ensure that stocking rates do not exceed the carrying capacity of the grasslands. This also refers to allowing the pastures sufficient time to recover between grazing periods, which may require frequent herd movement over long distances. The composition of the herds grazing on these pastures is another important factor: goats are the most nimble species of grazing livestock and can live on land inaccessible to other animals. However, as a result of their bite depth and the fact that they eat a very wide range of food, they also pose a threat to many plants. As per the report by World Bank (2003) the soil surface can be damaged not only by overgrazing but also by cattle trampling. The soil is exposed and becomes susceptible to wind erosion.

India's National Initiative on Climate Resilient Agriculture

In December 2010, a new scheme called the National Initiative on Climate Resilient Agriculture with a budget of 3,500 million Indian rupees was approved by the Indian cabinet to deal with the issue of climate change impacts on agriculture. The objective of this scheme is capacity building of scientists and other stakeholders in climate-resilient agricultural research in combination with the application of research results through awareness training and exchange visits.

It can be said that a lot of research on adaptation in agriculture has been carried out so far but putting it into practice remains the great challenge. Agricultural extension also known as agricultural advisory or extension services plays a crucial role in promoting agricultural productivity, increasing food security, improving rural livelihoods, and promoting agriculture as an engine for pro-poor economic growth. Farmers in India that largely depend on agriculture mainly use traditional methods that were handed down by their ancestors. Generally, these methods were well adapted to the more or less stable conditions of the past.

The increasing changes in climate conditions, farmers have to adapt their cultivation and harvest management methods. To achieve this, they may make use of innovations in terms of new cultivation methods or knowledge about traditional practices that have been virtually forgotten. In this context it could be noted that about well adapted crop varieties. Agricultural extension services and improved agricultural education are essential here. They enable farmers to gain systematic knowledge that will help them to respond to short and long-term environmental changes and to challenges posed by the global food and agricultural system. Smit and Skinner (2002) note that adopting technological innovations is one of the most frequently advocated strategies for agricultural adaptation to climate change.

With the increase in extreme weather events such as droughts, floods and exceptionally strong winds that often affect entire regions, traditional risk management strategies and social safety nets are often no longer able to counteract the resulting negative impacts. Within a comprehensive risk management strategy that includes diversification of agricultural activities and income, agricultural insurance can help people to cope with the financial losses incurred as a result of weather extremes. Insurances support farmers in their adaptation process and prevent them from falling into absolute poverty. Apart from stabilizing household incomes by reducing the economic risk, insurance can also enhance farmers' willingness to adapt, to make use of innovations and invest in new technologies. Additional credit insurance schemes may increase the creditworthiness of farmers applying for loans and thus support investment in agricultural production.

In India farmers have long been exposed to many kinds of environmental changes and have developed coping strategies, but the extent of future hazards often exceeds their adaptive capacity. The fact that many of them are marginalized worsens their situation. As per the report by CARE International (2009) many community-based initiatives first address the issue of vulnerability assessment to understand communities' risks and vulnerabilities towards climate change before suggesting measures for adaptation. In rural areas, however, where community income is mainly derived from farming, the focus of activities often lies on adapting existing farming practices to a changing climate. Farmers' field schools constitute a practical group-based approach to train farmers. They involve groups of farmers learning hands-on agricultural adaptation measures. They meet regularly and are guided by a trainer to discuss relevant agricultural topics and different adaptation measures. What is even more important: they also work together to apply their newly acquired knowledge in the field. Orindi and Eriksen (2005), note that implementing adaptation strategies at local community level, mainstreaming such strategies within national development measures requires coordination across all levels of management and policy-making.

Agriculture, Water Management adaptation options

The options for action in agricultural water management that are conceived to help farmers to cope with the impacts of climate change are discussed here

Increased flexibility of operations can be promoted through technical infrastructure, cropping patterns and water management measures. This enables quick and easy adjustments in water availability by adding water for irrigation or draining as part of an adaptive water management system. Adaption of production systems could be made available in coastal areas, in the form of salt water intrusion due to the rise of the sea level that will cause salinisation and necessitate adapted production systems with plants that have a higher salt tolerance.

Implementation of new cultivation methods could be made into action by the way of ridges, terraces or planting holes of new cultivation methods that help to catch or drain surface water. In combination with improved land management practices in terms of agro forestry, this contributes to a reduction in soil erosion and improved livelihoods.

Availability of historical and prognostic data is needed for adaptation option. The importance of data management related to water resources and their future dynamics must be given increased attention in the form of using new technologies, such as remote sensing.

Consumer awareness and conservation are needed in climate change adaptation in the form of clear water use rights and pricing will lead to more sustain able and considerate consumption and help to conserve the diminishing sources of freshwater.

More attention to demand management is needed in climate change adaptation by the way of options to increase water supply by greater water extraction from rivers, springs and groundwater or by storing seasonal excess water in large reservoirs will decrease in the long run. Instead, attempts to promote demand management by inducing farmers to use water more efficiently and to prevent non-beneficial losses will have to be given priority.

Identification practical solutions for existing needs in rural areas, where the vast majority of the populations are subsistence farmers, the focus will still be on the water supply side. Smith et al. (2007), note that building small water storage facilities or rebuilding traditional ones will help small farmers to make their living.

It could be noted that optimizing fertilizer input, can increase water use efficiency of crops and, hence, save water which is often a main necessity for adaptation in agriculture. This can be relevant in cases where higher temperatures associated with climate change are reducing water availability or increasing evopotranspiration rates. But, since fertilizer use also leads to nitrous oxide emissions from soils, the application of fertilizer, including timing, need to be managed well. Producing different forms of bioenergy or wood on cropland could have a similar effect. If less cropland is available for food production, productivity on the remaining land has to be increased, which may again lead to higher nitrous oxide emissions. However, both bioenergy production and forestry, particularly agroforestry, have a great deal of potential for synergy with agricultural adaptation.

Conclusion

It could be seen clearly from the above discussion that the impact of climate change on agriculture is a serious problem. The climate change has been affecting the food production and food security. The sustainability of food production depends on climate change adaptation, and mitigation measures to overcome the negative impact of climate change on agriculture. Many adaptation policies and programmes have been implemented by the government of India. However the impact of such programmes has not reached the farmers in many isolated and remote areas. Hence there is a need to disseminate the climate change adaptation policies and programmes to the farm households through agriculture extension programmes. The climate change has different types of impact on different crops and their length of growing season and yield potential. There is a need of specific agro climatic regional planning towards practicing cropping pattern on a par with changing climate scenario.

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