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IMPACT OF CLIMATE CHANGE ON AGRICULTURE

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ABSTRACT

The article reviews different opinions on Climate modeling to understand the relationship between Climate change and Agriculture. The primary objective of this review is to better understand the potential impacts created by Climate Change on different aspects of Agriculture. The growth, productivity and yields of crops and livestock, senescence of crops, nutritional values of grains, crops and livestock were negatively influenced by climate change. Climate models are developed based on social, economic and environmental factors associated with change in climate. Different successful climate models have been analyzed and compared for making good choice for further studies. Still, appropriate and precise climate model needs to be developed that provides accurate information about the relationship of Climate change and Agriculture.

Keywords: Climate change, Agriculture, Climate models, Crop productivity, Livestock.

1. INTRODUCTION

Technically, Climate Change has gained its attention among scientific community in another term called Global Warming. Though both terms refer the same, Climate Change is the term which is widely preferred by scientific community majorly. Climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture in human welfare, concern has been expressed by federal agencies and others regarding the potential effects of climate change on agricultural productivity. Interest in this issue has motivated a substantial body of research on climate change and agriculture over the past decade [1]. Climate change is expected to influence crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems. However, the nature of these biophysical effects and the human responses to them are complex and uncertain. For example, crop and livestock yields are directly affected by changes in climatic factors such as temperature and precipitation and the frequency and severity of extreme events like droughts, floods, and wind storms. In addition, carbon dioxide is fundamental for plant production; rising concentrations have the potential to enhance the productivity of agroecosystems [2].

Agriculture is the most common industry which is being affected by adverse climate change. Several literature evidences that adverse climate change creates great negative impact on both cropping and livestock processes [3][2]. Especially, rural lands and Agrarian as well as forest ecosystems are more affected by such climate change [4][5]. Different domains under Agriculture are affected by climate change which includes the productivity of crops and livestocks, profitability due to sudden decrease in production and employment as well. Due to the instable production of crops and livestocks, fluctuating food prices, etc., Food security has been under threat because of adverse climate change [6][7]. As there are different social, economic and biophysical factors are involved in affecting Food systems, the adaptation towards climate change is not seem to be uniform. [7].

However, Agriculture is not just about production of food and food materials, it also manages renewable natural resources available in the environment, manages and protects the landscape, helps in conserving the biodiversity and contributes mainly in maintaining social and economic activities involving both marginal as well as rural areas. Climate change affects every aspect of Agricultural functions [9].

The growth of crops is dependent on certain physical factors such as temperature, humidity, solar radiation, rainfall, etc. These factors are dependent on climate patterns and their variations according to different seasons. After the revolution of industries, humans pose greatest threat in changing Global climate by inducing the emission of great volume of greenhouse gases which affects the overall temperature of Globe, hydrological regimes and variability of climate worldwide. Agricultural conditions, supply of food and Food security are found to have great impact due to Climate Change [10]. The impacts created by Climate change on Agriculture could be biological, physical, ecological, economical, etc like as follows:

- Shifting of climatic and agricultural zones nearer to poles.
- As temperature rises abnormally, production patterns are changed adversely.
- As the level of carbon dioxide is found higher in the atmosphere, the productivity of Agricultural industry might be boosted.
- Rainfall patterns are always changed.
- Poor becomes poorer and landless people suffer still [11].

Though there are different factors that induce climate change, Agriculture is also an important hindering factor for climate change. Agricultural sources are responsible for 25% of emissions of carbon dioxide. Rest of carbon dioxide is emitted from various other human activities like deforestation, exploitation of fossil fuel based manures,

combustion of biomass, etc. 70% of atmospheric nitrous oxides are resulted from domestic ruminants, catching of fires in forests, cultivation of rice cultivars in wetlands, waste products, etc. Agriculture is majorly responsible for increased greenhouse gases concentration which leads to Climate change. This report was given by the Intergovernmental Panel on Climate Change [3].

Different ways in which Agriculture is contributing for the emission of greenhouse gases as follow: a) Due to decreased forest area with increased fields to make houses and apartments, carbon dioxide is emitted in most temperate regions; b) Emission of ethane as a result of cultivating rice and enteric fermentation among cattle and c) Emission of nitrous oxides resulting from the usage of fertilizers. Several agricultural processes emit methane, nitrous oxide and carbon dioxide in the percentage of 54%, 80% and 25% respectively. As both Agriculture and Climate change are interlinked, the yields and productivity of crops, biodiversity and usage of water are highly influenced. This review deals with several impacts created by adverse climate change on Agricultural processes. It also explains certain models for measuring the impacts [12].

2. EFFECTS OF CLIMATE CHANGE ON AGRICULTURE

The following are the effects created by Climate change on Agricultural processes. 1) Water cycle that includes processes like evaporation, condensation, precipitation, etc. When any processes in such water cycle become problematic, then that adversely induces change in climate. Therefore, climate change will ultimately induce increased drought and flood conditions that might affect agricultural fields. When drought conditions are increased, it induces the loss of soil fertility while flood induces the loss of actual soil from its upper layer. 2) Similar to water cycle problems, increase in average global temperature would be another potential problem [13]. The emission of greenhouse gases has impact on increase in global temperature which adversely affecting the water cycle. Therefore, these physical factors are inter-linked to each other. 3) For the past 50 years, the concentration of carbon dioxide has increased to 450 parts per million by volume (ppmv) [14]. 4) Some crops have the threat of getting extinct due to climate change. In simple words, Crop biodiversity is being affected by change in climate. 5) Due to high demands for Agricultural products and raw materials and the effect of climate change on their productivity, their prices would go higher and higher when compared to meat prices. This is greatly influencing the lifestyle of common people who rely on meat rather than vegetables and fruits, resulting in greater Food insecurity [15].

3. METHODS USED FOR PREDICTING IMPACTS OF CLIMATE CHANGE

3.1 Considerations for Modeling

There are different environmental, social and economic factors which are inter connected for developing models to understand the relationship of Climate change with Agriculture. These issues are analyzed better as in the following. Some plants grow better in high and warm temperatures while some other plants cannot tolerate slight high temperatures as well. The latter ones are ultimately been damaged either directly by high temperatures or indirectly by the influence of temperature on water availability. According to current status on global warming, in next 100 years the global temperature could be increased up to 5.8 degree Celsius. Climate models based on temperatures would be dependent on evaporation as well as precipitation part of water cycle. Emission of carbon dioxide from household, industries and Agriculture would be another issue for increase in temperature. These are environmental factors that negatively influence Agriculture by changing climate adversely [15].

Agriculture has been one of the major industries that boost up the economy of many developing countries. Agriculture adapts to environmental crisis through several adaptation processes through self-regulatory strategies [17]. There are three levels of adaptation seen with Agriculture namely, a) Adaptation that happens at the level of farms, b) Adaptation that happens at the level of Nations and c) Adaptation that happens at the level of Globe. At the level of farms, there are several numbers of farmers who need to adapt well in choosing the crop types according to changes in climate. With the advancement in technology and availability of detailed information on different conditions, adaptation is quite successful for farmers. At the National level, the price ranges for these Agricultural products go higher as and when their productions are highly limited by climate change. This has got the direct impact in terms of Food insecurity. When considering the adaptation of Agriculture at the level of considering Globe as one, we need to understand a fact that effects of Agriculture because of climate change would be different for different countries. Price ranges would also be different in different countries depending on the availability and local national scenario. Some countries might be benefitted while some might be affected very badly [18][19][20][21].

Irrespective of any of these three levels mentioned above, certain policies and planned adaptation insist on developing strategies for overcoming several issues related to social and economic aspects of Agriculture impacted by climate change. Simply, any model that has been developed for studying climate change impacts on Agriculture should considerably include climatic variables, increase in temperature, increased greenhouse gas emissions, rainfall pattern changes, etc. It should also include the impact of fluctuated price ranges of Agricultural products in different places worldwide and the demands for food products [22].

3.2 Mitigation Policies

The current impacts of climate change depend on mitigation policies that intend in reducing emissions of greenhouse gases and in identifying appropriate adaptation protocols

that is focused in containing agricultural losses related to both market goods as well as services involved in environment. When the economic aspects of how climate change is influencing Agriculture are assessed, these strategies can easily be figured out. However, there are many practical complications arise when it is planned for assessment. There are not even data available frequently for assessment. In addition to this, there are different skills required for achieving so [16]. Some of the other factors include the following:

- Aspects related to climate as well as other climate changing environment inductions,
- Aspects related to biological and physiology of plants,
- Aspects related to technical, social and economic factors,
- Adaptation of Agriculture with Climate change,
- Adaptation to fluctuating price ranges in different nations at different levels,
- Feedback on altered climatic conditions, etc. [22].

The potential for mitigation economically with respect to agriculture is purely dependent on carbon rates and mitigation policies being followed. It is also been estimated that the potential of economy which is found to be 36% of carbon rates that are up to $25 per carbon dioxide equivalent [23][24]. According to the results of USEPA (2006), strategies involved in the cultivation of rice showed the highest potentials in terms of economy and greatly involved in reducing emissions of greenhouse gases in many developing countries [25][23][24]. Different conditions that help in realizing the potentials of mitigation policies include the following. Understanding the role of potentials of mitigation economically which is being limited by poor incentives to invest in areas of excessive greenhouse gas emissions would be more challenging. Due to limited access for carbons from the market required for agricultural sector, the prices for food and food related products have gone higher [14].

There are about six policy principles that have been suggested including

- Best policy principles as well as responses from institutions always will help in enhancing the flow of information, incentive costs as well as flexibility of technology.
- Policies proposed and governing institutions should help in promoting the development of economy and in reducing poverty completely. This will always help in improving adaptation in Agriculture that results in effective mitigation policies.
- Poor will always be poor, even sometime become poorer.
- Increased availability of existing technology or options should be taken care of.
- Local responses are highly important for adaptation in agriculture made after mitigation policies.
- Trading is very essential that affects both mitigation policies and adaptation in agriculture [26].

3.3 Climate Models

There are certain factors which determine the choice of climate models which are as follows: a) Required level of analysis, b) Analysis scale (whether it is temporal or spatial), c) The phenomenon that is used in measuring the climate change [27][28] as well as livestock [2][30][31] and d) Dimensions of Agriculture including social, environmental, biological and economic factors [22].

Table -1: Principal models used to estimate the effects of climate change on Agriculture

Model	Brief Description	Advantages	Limitations
Crop Simulation	This model restricts analysis to crop physiology, simulate and compare crop productivity for different climatic conditions	It is based on a deep understanding of agronomic science. It is suitable to integrate effects of Carbon dioxide fertilization. It is calibrated to local condition.	Analysis is focused on biological and ecological consequences of Climate change on crops and soil. Economic dimensions are not considered. This model can be coupled with other models to treat economic dimension better. In the traditional formulation adaptation is not considered and farmer's management practice is considered fixed. Some researches consider adaptation exogenously. It does not consider crop's switching. It is crop and site specific. It was calibrated for the main grains and for a limited number of places.
Production	Yields sensitivity to	Easy to estimate. It is	Crop specific social and

Function	climate is estimated assessing a empirical production function that links water, soil, climate and economic input to yields for specific crops. The effect of climate change is assessed by considering yield variations comparing two alternative scenarios. Future climate scenarios are usually simulated using a GCM.	possible to measure the effects of weather on yields over time.	economic dimensions of agriculture are considered of secondary importance. This model can be coupled with other models to treat economic dimension better. Assumption of the 'dumb-farmer' hypothesis (farmer adaptation strategies are not considered). Calibrated for a specific context; if the location is not representative, can provide biased predictions
Ricardian	This model treats the full range of farmer adaptation strategies as a black box by performing a cross-sectional regression of land values or net revenues on climate normal and other control variable. Climate normal are calculated as averages in a long-term scenario (usually 30 years). The effects of climate change are assessed in terms of farm outcome variations, comparing the current situation to simulated scenarios.	Does not assume the 'Dumb-farmer' hypothesis. Easy to estimate possible to consider spatial correlations and to analyze panel data. Possible to elicit farmer adaptation in estimation if a multinomial logit model (eg a structural Ricardian model) is used	Omitted variable such as unobservable farm and farmer characteristics could lead to bias of unknown sign and magnitude. In the traditional formulation, farmer adaptation strategies are considered but not explicitly treated. In the traditional formulation, the role of irrigation is not considered. More recently, this variable was included among regressors. However, it is not treated endogenously and multicollinearity problems are not adequately considered. Analysis is focused on economic dimension of agriculture and only indirectly on other dimension (eg biological and social). Assumes a partial equilibrium model and does not consider relationship with other sectors. Assumes output and input prices constancy and does not measure adjustment costs.
PMP	This is an economic management model estimated by solving a mathematical -optimization problem using farm data. The	Useful for assessing economic effects of climate change, especially in simulation of irrigation-farmer adaptation options and/or water	Difficult to estimate often difficult to find data on technical coefficients and limiting production factors. Assumes simulated farmer strategies not

	pay-off function can be formulated considering the profit (to be maximized) or the cost (to be minimized). The latter, known as Positive Mathematical Programming, surpasses traditional limitations of linear-programming methods such as unavailability of detailed information on relationship between inputs and yields through dual function cost.	policies, including water markets and irrigation efficiency improvement	obtained from observed choices in specific climate scenarios
GEM	These look at economy as a complex of interdependent components (eg industry, production factors, institutions)	Assumes a general economic equilibrium, considering all economic sectors. Captures economy-wide and global changes such as those linked to input and output prices. Provides information	Difficult to estimate aggregates into one single entity sectors that are different in economic and spatial characteristics. Production factors including irrigation water are considered in model as undifferentiated inputs. Difficult to analyze farmer adaptation strategies. Does not allow consideration of details of studies phenomena.
		on effect of climate change in different regions. Measures effect of climate change on other economic sectors.	
IAM	These are based on the joint use of general circulation model, crop growing, soil usage and economic models. These models integrate different skills and competencies.	Analysis simultaneously considers all agricultural dimensions. Generates useful information for policymakers.	Difficult to estimate. These models can be very complex. In some cases, required date are not available. Interaction between agriculture and land use with climate are only partially treatable. Accuracy of model is subject to treatment of complex interaction between different factors, especially concerning water usage and availability. Productivity is treated as an exogenous variable.

*Source: Salvo et al, 2013

Table 2 describes different characteristics that are mostly commonly considered for making climate models to measure the relationship between climate change and Agriculture [22].

Table -2: Comparison on the characteristics of different Climate modesls

Model	Object of the Analysis	Temporal Scale	Geographical Scale	Climate Change manifestation	Agricultural Dimension			References
					Biological	Social	Economic	
Crop simulation	A specific crop	Short time	Local	Weather annual fluctuation	Treated	Not treated in the traditional formulation. It is possible to treat it exogenously.	Not treated in the traditional formulation. However it is possible to couple this model with larger model frameworks that consider economy.	[32][33]
Production function	A specific crop, a group of crops or a particular ecosystem	Both short term and long term	All possibilities	All possibilities	Not explicitly treated	Treated in a secondary manner.	In the traditional formulation treated in a secondary manner. Some studies estimate and economic production function. Others couple this model with larger model	[34][35][36]

							frameworks that consider economy.	
Ricardian	The whole agricultural sector or a particular branch or crop	Long term	All levels, providing enough climatic variability is assured	Global warming and precipitations decreasing	Not explicity treated	Ricardian	The whole agricultural sector or a particular branch or crop	Long term
Econometric model	The whole agricultural sector or a particular branch or crop	Both short term and long term	All levels, especially local, national or regional	All possibilities	This depends on the model formulation	Econometric model	The whole agricultural sector or a particular branch or crop	Both short term and long term
PMP (Production – Function Model)	The whole agricultural sector or a particular branch	Both short term and long term	All levels, especially local, national or regional	All possibilities	Not explicitly treated in the traditional formulation. Some researchers treat it explicitly coupling this model with a crop simulation model	PMP (Production – Function Model)	The whole agricultural sector or a particular branch	Both short term and long term
GEMs (General Equilibrium Model)	The whole agricultural sector or a particular	Long term	All levels, especially national or higher	All possibilities	Not explicitly treated	Not explicitly treated	Treated	[48][49][50][51][52]

	branch if appropriately for mulated							
IAMs (Integrated Assessment Models)	The whole agricultural sector or a particular branch if appropriately for mulated	Long term	All levels, especially national or higher	Global warming and precipitations decreasing	Treated	Treated	Treated	[53][54]

*Source: Salvo et al, 2013

4. POTENTIAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURE

The following are the remarkable impacts created by climate change on Agriculture:

1. The effect of change in temperature: The growth of crops and its duration are all dependent on temperature. When temperature is said to be increased, it ultimately speeds up the development and growth of moderate plants. Otherwise, for other plants the result will be changed. For instance, in annual crops when the temperature is increased it results in the shortening of time duration between processes like sowing as well as harvesting. When growth is shortened at any stage, it ultimately affects the productivity of crops and senescence might be expected too early [2].

2. The effect of increased carbon dioxide content in atmosphere: Due to several reasons like deforestation, etc., carbon dioxide levels are found to be continuously increasing. Carbon dioxide is actually important for the growth and development of plants. However, there are certain serious negative consequences happen within plants during their growth when carbon dioxide concentration shoots up. According to the knowledge of photosynthesis, when carbon dioxide levels go up it should ultimately end up in increased photosynthetic rate, which is technically referred as "carbon dioxide fertilization". Recently, the level of carbon dioxide found in atmosphere is measured as 380 parts per million when compared to oxygen which is 210000ppm. This indicates that majority of times plants actually starve from the availability of carbon dioxide. Studies confirmed the fact that when carbon dioxide concentration increases, it results in development of less stomata on plants [55] which ultimately reduces the usage of water [56].

3. Effect on food quality: When carbon dioxide level goes up, it has positive consequences on rice cultivars by increasing the amylose content in every grain [57]. However, in these rice grains the amounts of zinc and iron would be relatively lower [58]. Similarly, when temperature and carbon dioxide are found to be higher, then the protein concentration in grains would decrease ultimately [59]. This clearly shows that with the increase in carbon dioxide concentration the plants grow with decreased contents of micronutrients [60]. These rice grains will cause deficiency diseases in animals who consume these plants; especially herbivores are very much affected [61]. It is also been proven that with increased carbon dioxide concentrations, plants uptake low amount of nitrogen. With declined nitrogen content, there is always reduced productivity of animals found in sheep.

4. How climate changes impact Agricultural surfaces: Climate changes induce the transformation of frozen lands into more of arable land, especially in high latitude regions. The rise in sea levels is expected to increase by 2100 in the near future. When sea level has risen, the agricultural lands would be filled with seawater which would result in Food insecurity the most. South East Asian countries would be suffering the most when continuous sea level rise happens in near future. Especially, countries like Bangladesh, Vietnam, India, etc are expected to face great loss of Agricultural lands when such rise in sea levels happen [22].

5. Effect in Soil Erosion and Soil Fertility: Change in climate will adversely affect the hydrological cycle (Water cycle) and its processes. When any of the processes of water cycle is disturbed, that negatively influences the rainfall patterns. When vigorous water cycle happens, it induces increased precipitation patterns. Due to more run off of water sources that come from increased precipitation patterns, the upper portion of the soil has been washed off. This results in soil erosion, which is the washing off upper layer of soil that contains necessary nutrients, water and food for plants to grow comfortably. This upper layer of soil

will help the plants to firmly attach with the ground. Therefore, with the loss of such layer, soil fertility will also be affected greatly [62].

6. Effect on Livestock: Livestock and their activities resulted from processes like deforestation (the process of cutting off forests to make use of forest lands to use for human kind) and exploitation of energy from fossil fuel based materials, are still increasing above 18% [63]. Production of livestock has taken its position of around 70% among all agricultural lands and over 30% among surfaces of land available on Earth [62].

5. FUTURE PROJECTIONS

In IPCC's 4th Assesement Report, Schneider et al (2007) had given future projections on the potential effects of change in climate towards Agriculture. It was predicted that the overall global average temperature might increase up to 3 degrees Celsius that might affect the productivity of crops greatly [62].

5.1 Food Insecurity

The great impact of climate change on Agriculture ultimately results in Food insecurity. Future projections identified that by the year 2080, the hunger would decline globally than in the year 2006. This could have been achieved by the development of globe with respect to its social and economic values. Cline (2008) mentioned in his study that there were no steps taken in reducing the emission of greenhouse gases which ultimately leads to increase in global warming. This would ultimately affect Agriculture negatively and people from different countries would suffer, especially developing countries in particular [64].

6. CONCLUSIONS

The measurement of relationship between climate change and Agriculture were perfectly dependent on various factors and climate models. There are various reasons why these climate models are found complex where some of them include the following. Sufficient data for modeling are not available from nature. Lack of skilled manpower in overcoming complications that arise during climate modeling is another challenging factor. Relevant roles are well played by different aspects including social, economic, geographical and agricultural mitigation policies. For a successful valid climate model, it should include the variability in climate both temporally and spatially. In addition, it should include other external factors like future projections or predictions, what role played by agriculture on climate change, etc.

For assessing any factors involved in climate change, climate models should be chosen appropriately. However, choosing the right model would be difficult as understanding of climate models is always complex and complicated. The wrong choice in climate models would ultimately result in false positive results which would increase the variability in unexplained manner that worsens the situation even more. This article was a little attempt to understand how two parameters climate change and agriculture are linked together and how the former influences the latter. Different successful climate models have been well explained in this review, which were tabulated as well.

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