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A Review on Impact of Changing Climate on Agricultural Productivity of Meghalaya: A Solution Through Food Diversity

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Abstract:
Over the past few decades, the climate has undergone profound changes, marked by a notable increase in greenhouse gas emissions that have escalated the global average temperature. This shift has manifested in alterations such as the changing patterns of monsoons, rising maximum temperatures, and a surge in extreme weather events worldwide. As climate is a major component of agriculture so this changing climate possesses a serious threat. From the past research works it is found that climate change has a severe effect on rice, wheat cultivation in Kerala, Tamil Nadu, Karnataka and Punjab. Climate change also has an effect in vegetables, fruits farming, livestock including poultry. In north east India especially Meghalaya, the effects of climate change are reported mostly in Ri-Bhoi district and on rice cultivation. In compare to other parts of India the effects of climate change in Meghalaya are less but the trend is exhibiting a significant effect in near future. This paper reviewed the effect of climate change on agriculture in India with special reference to Meghalaya. The study also places emphasis on analyzing the pivotal role of indigenous food diversity in mitigating the imminent threat posed by climate change in Meghalaya. In this scenario the indigenous food diversity of the tribal community can play an important role in finding solutions. The traditional knowledge embedded with modern technologies is the key lesson to combat the effects of climate change.

Keywords: Climate Change, Agriculture, Indigenous Food Diversity, Food Security, Integrated Farming

1. INTRODUCTION TO CLIMATE CHANGE AND ITS EFFECT ON AGRICULTURE:

Climate change can be defined as a long-term change in the average weather patterns that have been observed over an extended period of time. The term is often used to describe the current global trend of increasing average temperatures and associated changes in precipitation, sea levels, and other climate-related factors. The concept of climate change can also depict as a shift in the climatological parameters from the long-term average of the recorded meteorological data, normally 30 years [1]. During the past few decades, a significant change in climate has been noticed which has altered the composition of the global atmosphere [2]. The concentration of greenhouses gases such as methane (CH_4), carbon dioxide (CO_2), and nitrous oxide (N_2O) have been increased by 150%, 40% and 20%, respectively since 1750 [3]. Human activities, such as the burning of fossil fuels (coal, oil, and natural gas), deforestation, and

industrial processes, have led to an increase in the concentration of greenhouse gases in the atmosphere which leads to climate change (Fig 1). The average global temperature has increased at an average rate of 0.15–0.20 ◦C per decade since 1975 [4]. The increasing temperature in the late 21st century and early 22nd century will cause frequent changes and shifts to the monsoon precipitation up to 70% below normal levels [5]. The Indian summer monsoon and also the Southeast Asian monsoon will also be delayed for this reason [6] (Fig 1a & 1b). On the other hand, increasing amount of rainfall in the monsoon has triggered major floods and landslides in some south East Asian countries [7]. In India climate change is also becoming a major threat. Increasing trend in annual rainfall and minimum temperature in parts in of Bihar, West Bengal and Gujarat. Kumar et al 2012 has reported that in Punjab the minimum temperature has increased over the past three decades in the range of 0.02- 0.07 ◦ C per year [8]. The effects of climate change are not similar in all the places throughout the country.

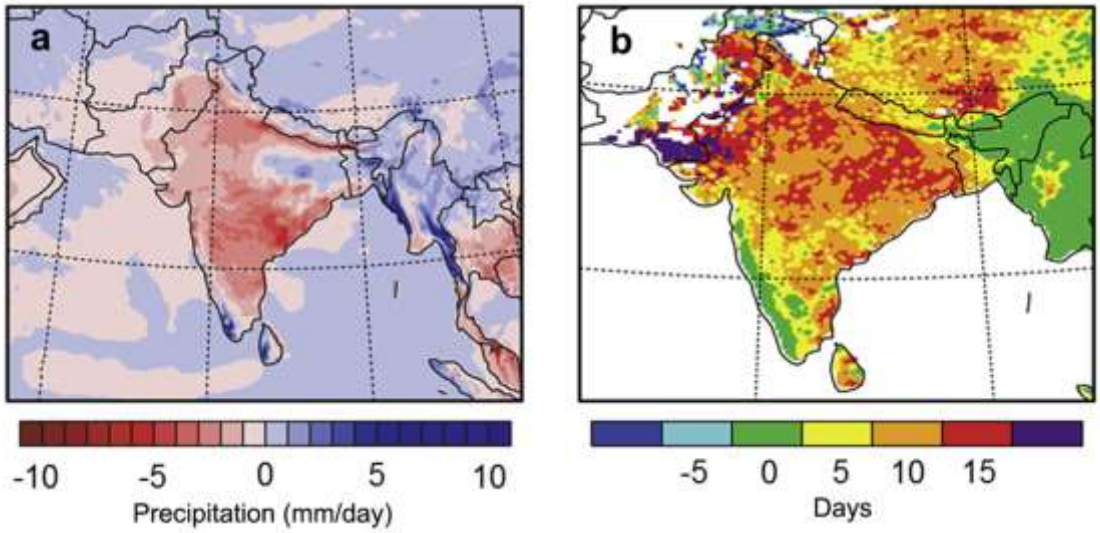

Figure 1 A) Future changes in summer convective precipitation in India. B) Future change in monsoon onset date in India [6].

A major component of agriculture is climate. While farmers used to face weather fluctuations from year-to-year variability, so there is a degree of adaptation to the local climate in the form of established process of farming, local farming practices, and individual experience. Climate change can therefore be expected to impact on agriculture, potentially threatening established aspects of farming systems but also providing opportunities for improvements. The major outcomes of climate change which possess a threat on agriculture are likely, temperature changes, changes in precipitation pattern, extreme weather events, shifts in pest and disease pattern, sea level rise, adaptation challenges, global food security. As climate varies through the global geographical regime the degree of impact will also varies from place to place. From the Himalayas to coastal south Asia, all the countries must be prepared to combat the effects of global warming on agriculture [9]. As predicted, the South Asian zones may experience a warming effect of 2° to 6° C during the 21st century [10]. Indian subcontinent is also vulnerable with all kind of existing climate change issues like floods, droughts, extreme events (cyclones, hurricanes), heat waves, melting of glaciers (fig 2).

Changing climate also affects the pathogens and diseases. The resistance ability of crops to specific diseases may be hampered due to warming or drought situation. Environmental stress induced mutation of organisms which increased the level of pathogenicity [11].

This paper focuses on the recent studies conducted in Meghalaya to find a systematic farming strategy against climate change.

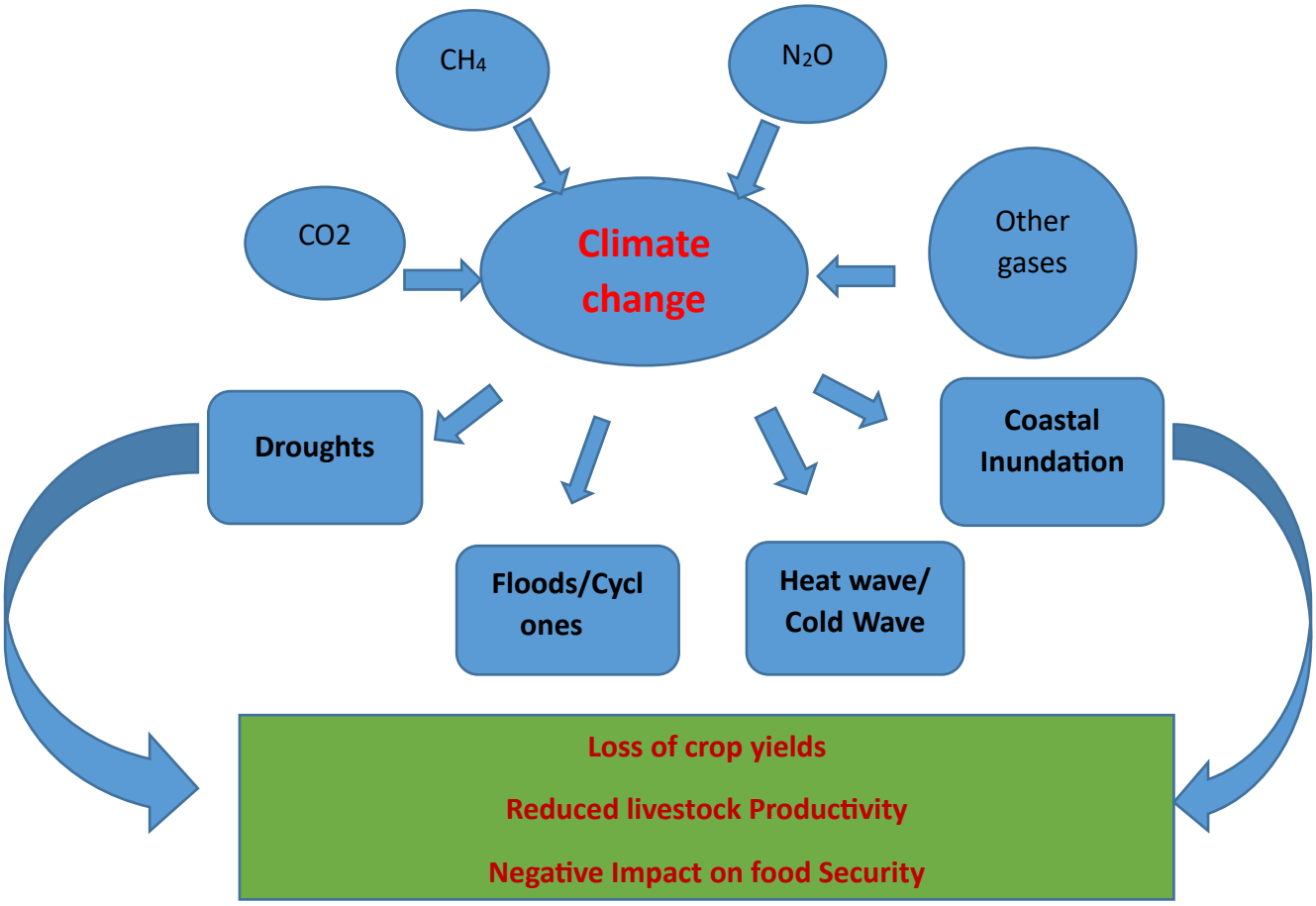

Figure. 2 Causes and impact of climate change on agriculture and allied sectors

2. FOOD SECURITY AND INDIA, ON THE LIGHT OF CLIMATE CHANGE:

India has a diverse and significant agricultural sector which contributes a significant portion to the Gross Domestic Product (GDP). India is known for its diverse agro-climatic conditions, leading to a wide variety of crops being cultivated across the country. Major crops include rice, wheat, pulses, sugarcane, cotton, oilseeds, and various fruits and vegetables. Indian agricultural sector is also affected by climate change in various aspects. It adversely affects the food security in four dimensions which are food availability, food accessibility, food utilization, and food system stability [12]. The major staple food crops of India like rice and wheat may face significant reduction in yield due to climatic variability which can affect the gross agricultural production by 2060 and affect the food security of more than one billion people of India {[13]; [12]}. The other significant studies which were conducted with rice and wheat are-

	Reference	Major findings
1.	Geethalakshmi et al. (2013) [14]	productivity of rice crop has declined up to 41% when the temperature reaches 40°C in Tamil Nadu
2.	Saseendran et al. (2000) [15]	increment in temperature up to 50°C can lead to a continuous decline in the yield of rice and every one-

		degree increment of temperature will lead up to 6% decline in yield in Kerala
3.	Hundal and Prabhjyot-Kaur (2007) [16]	An increase in minimum temperature up to 3.0°C above normal has led to declining in productivity of rice and wheat by 3% and 10%, respectively, in Punjab.
4.	Karim et al 1999 [17]	An increase in 4°C temperature would have severe impact on food grain production, especially for wheat production.
5.	Kumar et al 2011 [18]	decline in the irrigated area for maize, wheat, and mustard in northeastern and coastal regions and for rice, sorghum, and maize in Western Ghats of India may cause loss of production due to climate change
6	Kaul and Ram [19]	excessive rains and extreme variation in temperature have adversely affected the productivity of Jowar crop, thereby this has affected the incomes as well as food security of farming families in Karnataka

Apart from staple food, climate change also has severe effects on vegetable crops and fruits. Extreme high temperatures can cause very high transpiration losses in vegetable crops. It also limits fruit setting in citrus fruits [12]. Fruit setting stage of navel oranges is recorded to be severely affected by high temperatures during flowering [20]. Kumar and Kumar in 2007,[21] reported that the temperature enhancement at ripening stage causes fruit burning and cracking in litchi plantation. Increase in temperature also enhances moisture stress condition which leads to sunburn and cracking symptoms in fruit trees like apricot, cherries, and apples [12].

Climate change can have significant effects on livestock, impacting their health, productivity, and overall well-being. These effects can vary depending on the specific climatic conditions, the type of livestock, and the management practices in place. The micro climatic conditions has a specific role on the growth and development of any species. Species with their specific characters can govern by their adaptation and tolerance to the changes in their environment. But sometimes the magnitude of variations is larger than their adaptive capability. Thus global climate changes affect various factors which are associated with reproduction, health and adaptability of every animal. Higher temperatures abruptly change the animal's body physiology [22] such as rise in respiration rates (> 70- 80/minute), blood flow and body temperature (>102.5º F). Chowdhury and Monzur, 2016 [23] reported that in Bangladesh, because of heat stress, lack of forage and breeding strategies the livestock sector faced huge economic losses. Singh et al 2012 [24] reported that changes in weather conditions directly impact the production level of animal by 58 percent and reproduction by 63 percent. Heat stress effects more on dairy breeds than meat breeds. Among the dairy breeds also the higher milk producing breeds are more susceptible to heat stress than the low milk producing animals [25]. West, 2003 [27] stated that increase in temperature and temperature humidity index value beyond the critical threshold level reduces the dry matter intake and milk yield and also interrupts physiology of animal's body. Poultries are also sensitive to temperature fluctuations and heat

stress. Feed intake of poultries used to reduce due to heat stress, this leads to several results like less body weight and egg production, quality of meat and also reduces the thickness of eggshell and increases the egg breakage [28]. Vivekanandan et al 2009 [29] reported that the rise in temperature of 1◦C will affect the mortality of fish and its geographic distribution. The temperature rises of 0.37°C to 0.67° C alter the pattern of monsoon seasonal variations, eventually shifting the breeding period of Indian main carps from June to March in West Bengal and Orissa's fish hatcheries (DARE/ICAR Annual Report, 2008-09).

3. Meghalaya- the land of Diversified Indigenous food system:

Meghalaya is an agrarian state in North- eastern region where more or less 60% of the population are dependent on agriculture as livelihood [30]. Most of the region falls under high rainfall zone with sub-tropical type of climate. The eastern Himalayan diverse forest will be greatly challenged by the impact of climate change. Droughts and floods are the two extreme climatic conditions which arises time to time due to unpredictable rainfall. Rice occupied 95.21 per cent of the total net sown area (0.23 mha) in Meghalaya in 2013 [31]. In Meghalaya rice is grown mainly in Kharif season thus a slight change in the amount of rainfall in monsoon season will have a direct effect on rice production. Roy et al 2022,[32] in his study reported that Ri-bhoi is the most affected district from climate change. Whereas the change in rainfall is insignificant but the average temperature during a year was about (23 ± 4.4) °C and has increased significantly at the rate of 0.17°C per year. Ri-Bhoi District had maximum variability in average monthly temperature (2009-2013) among the districts, followed by Jaintia Hills and East Khasi Hills [32]. Thus, the rice cultivation of Ri-bhoi district has faced severe issues like decline in productivity of rice, shortage of water for irrigation, pest and disease infestation on rice crops. Chakraborty et al 2014 [33] reported a sharp increase in temperature in Umiam region. The calculated heat index from their study exhibits significant increase for most of the period of the year. The changes of temperature and humidity still is not a direct threat to human and cattle but it has created a perfect environment for the animal disease vectors like mosquitoes and pose greater indirect risk for the spread of the deadly disease [33]. Changing pattern of temperature and moisture could lead into insurgence of new pests.

Indigenous community of Meghalaya have a diversified source of food generation which includes the forest, water bodies, shifting cultivation fields (jhum), terrace farming or *bun*, home gardens, and valley-based paddy system. They farm various crops in jhum, bun, home gardens and valley-based paddy system. Apart from that wild plants and animals are also harvested from the forest. As practice of jhum cultivation involves moving from one place to another thus a new more intensive land use process has invented as bun method. In bun method, terraces are constructed that run across hill slopes and raised mounds are created on which crops are grown [34]. As food is also harvested from forests and water bodies which indicates that a single village have five or six food sources which makes their system highly diverse and resilient. The huge agrobiodiversity of Meghalaya is a result of the knowledge system of the indigenous communities. These traditional practices are also dynamic. With time some traditional practices are also improvised to cope with the changing environment. Like an improvised version of jhum cultivation is the bun process. From various studies the huge diversity of indigenous foods has been reported [35]. The most diverse villages were found in Ri Bhoi with an average of 252 food plants per village, followed by Garo Hills with 210, West Khasi Hills with 196, East Khasi Hills with 194 food plants, and finally Jaintia Hills with 175 food plants. Apart from individual food plants, the varieties within a specific food group and species diversity is also existed. For example, starchy staples (a group which includes cereals and tubers) in Marmain consist of eight species: Rice (which includes sticky rice), millet, taro/ Colocasia (white and

black), maize, potato, sweet potato and other wild tubers. Among them rice had the highest diversity with 41 varieties, which includes wetland and dry land, i.e., hill varieties. Similarly, the number of potato varieties ranged from five to 15 in the selected villages of East Khasi Hills. Another food source is the wild varieties of vegetables which grows along the paddy fields or sometimes the banks of the rivers which flows across the fields. The paddy fields are also home to various animals like rodents, amphibians which helps to eradicate pests. The undisturbed forest patches in most of the lands of Meghalaya has helped the farmers to conserve this diversity.

From a recent study conducted in west Garo Hills, it is found that the food diversity includes 39 crops farmed through Jhum system, four indigenous breeds of livestock, and a wide variety of wild edible plants. The huge food diversity which is a part of the culture of indigenous people also served the nutritional security. The various wild edible plants are collected from fringes of forest which ensures the conservation of biodiversity. The interference of agro biodiversity and the culture of the indigenous people of Meghalaya can be a resilient system to maintain the food security even in the light of climate change.

4. CONCLUSION

It has no doubts that Meghalaya is on the verge of climate change effects. But the biodiversity rich Indigenous people's food system of Meghalaya is crucial for climate change adaptation. The mixed cropping pattern, is crucial in the light of the challenges climate change is creating. The traditional knowledge system and practices has allowed for the high degree of diversity of land uses and species which is continuously being enriched. To combat the effects of climate changes the farmers must be properly trained and they should be aware about the proper implementations of the age old practices. In a recent study in NICRA farms the implementations of climate resilient technologies has resulted in increasing cropping intensity, annual savings, expenditure pattern and crop yield were significantly higher in comparison to before implementation of the intervention [36]. The climate change resilient system includes water harvesting structures, production of organic manure by vermicomposting, mulching in ginger & turmeric on raised bunds across the slope, low-cost polyhouse technology for multiple cropping, hanging rope practice of oyster mushroom cultivation etc. [36]. The yields of all the crops increases due to climate change resilient system implementations. Thus, the local farmers need more awareness and knowledge on these kinds of adaptations.

The effect of climate change varies throughout the country. Considering very low temperature in north eastern region the direct effect in crop field is still not significant. Although the monsoonal shift has already been started to affect the crop diversity and relative crop yield especially for the indigenous crops, fruits and vegetables of North eastern region. The slight change in temperature is already effecting the pest diversity and demands innovative pest control mechanism. In this scenario the reliance of multiple food sources by the north eastern tribes for ensuring the food security of the community might be an adaptable learning lesson for the rest of the world.

5. Conflict of Interest:

Authors have declared that no competing interests exist.

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