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TITLE: **IMPACT OF CLIMATE CHANGE ON FOOD SECURITY**
Research Paper

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ABSTRACT:

Food is a part of our day to day life without which life on earth would not exist for any living being. For a healthy human life, healthy edibles are essential. The food we eat depends upon the environment we live in and in turn has a direct link to climate. Therefore, climate plays a vital role in the agricultural or food sector. A change in climate may affect the entire food system. Due to climate change rapid increase in temperatures, precipitation patterns and other extreme events are already affecting food security. The interconnection between geophysical and human environment had resulted in the system of food that comes under food security. Production, processing, distribution, preparation and consumption of food are the outcome of such interconnection. To reduce food security and for the purpose of uplifting the food system it is necessary to encompass food availability, food accessibility, and food utilization. However, climate change and other environmental factors when combined impose great difficulty in reducing food security. On the other hand globalization and urbanization are also causing severe changes in food systems. The impact of climate change on food security differs from

place to place. In African countries, the major reason for food insecurity is climate with issue of short-lived shock. But in other countries like India, the factors include labor issue, ground water deficiency etc. Various socio-economic and bio-physical factors have also affected the cropping system and consequently the food system is unable to adapt to the changing climate. This paper shall look into the ways in which climate change has an impact on food security.

INTRODUCTION:

Climate change acts as threat for the sustainable development, eradication of poverty and food security. There are two ways in which climate change may affect food production. One is the direct way (water availability, diseases and pests) and another is indirect way (rise in temperature, increase in CO2, air pollution and other effects). Its impact on food is calculated based on the productivity of crops and amount of food they yield. Several researches have shown that high latitude regions have greater chances of getting affected by climate change (e.g., Alaska, Siberia and the Arctic). With the local knowledge it can be perceived that food yields in dry lands and High Mountain regions are affected the most by climate change (e.g. Africa, Asia and South America). In order to cope up with climate change, the system food production, distribution, and access should improve in its quality. It is also to be noted that in the process of improving the food system, sustainability should be given importance. It is estimated by IAEA that the world's population will increase one third by 2050 with developing countries having the highest increase.[1] The agricultural production has to grow 60% to meet the demands of the population with the current income and consumption rate. In order to achieve such production rate, agriculture should transform itself to systems that are more productive. Such transformation should not affect the natural resources.

LINK BETWEEN CLIMATE CHANGE AND FOOD SECURITY:

There lies a deep interconnection between climate change and agriculture. Around 21% of greenhouse gases are emitted globally from agriculture. Temperature and precipitation plays a vital role in agriculture due to which it is highly vulnerable to climate change. This climate change has a positive impact on the growing conditions in some regions but howsoever the negative impacts highly out way the positive. With climate change and rapid increase in population, the chances of food insecurity are high. In the year 2016 the food and agriculture organization (FAO) of the UN released a report which discussed in detail the impact that climate and agriculture have on each other. It stated the necessary actions to be taken to the protect agriculture and food security. The report was named as The State of Food and

[1] International atomic energy agency, food security and climate change, joint FAO/IAEA programme, nuclear techniques in food and agriculture, 2021, https://www.iaea.org/topics/food-security-and-climate-change.

Agriculture in 2016.[2] Under this report, major consideration was given farmers in the developing countries especially smallholder farmers who were highly vulnerable to climate change.

The greenhouse gases emitted from the agricultural sector include methane, carbon dioxide and nitrous oxide.[3] Deforestation and conversion of forests into cropland are the main reasons for emission of carbon dioxide. It is to be noted that the agricultural sector has the ability to control such emission.[4] There are certain programs conducted all over the world to create awareness about such emission. Several policies are also introduced by various governments.

By using lands extensively for production of rice leads to emission of methane. As rice crops take in lot of water, water efficient methods can reduce methane emission. Another major reason for methane emission is livestock. Methane production can be reduced from 14 to 41% by sustainable livestock production.[5]

Fertilizers act as a main factor for emission of nitrous oxide. In a report by FAO, it is stated that nitrogen from fertilizer is used for 50% of food production in the world. The damages caused by nitrogen to the environment are higher than benefits received from it. Nitrogen oxide has a potential of 265 times that of carbon dioxide in causing global warming which is why reduction in agricultural emission is currently essential.

It is necessary to address agricultural emissions so as to meet the standards in international climate agreements. In order to reduce emissions to a reasonable level, certain actions have to be taken by way of policy making, which include sustainable production in agriculture and policies for such sustainable development and check on policies that encourage unsustainable practice. For the purpose of controlling agricultural emissions, policies should be accepted and uphold regionally and globally. If actions and policies are not taken immediately, then 122 million people or more might suffer from extreme poverty.

LINK BETWEEN CLIMATE CHANGE AND FERTILITY RATE:

Climate change has an impact on the population growth. With temperature fluctuations and changing precipitation patterns, the fertility rate of a human is decreasing. Recent reports state

[2] Hunter, M.C., Smith, R.G., Schipanski, M.E., Atwood, L.W. and Mortensen, D.A., . Agriculture in 2050: recalibrating targets for sustainable intensification. Bioscience, volume *67* issue (4), 22/02/ 2017 pp.386-391. https://doi.org/10.1093/biosci/bix010

[3] Den Elzen, Michel GJ, Jos GJ Olivier, Niklas Höhne, and Greet Janssens-Maenhout. "Countries' contributions to climate change: effect of accounting for all greenhouse gases, recent trends, basic needs and technological progress." *Climatic Change* 121, no. 2 (2013): 397-412. https://link.springer.com/article/10.1007/s10584-013-0865-6

[4] Loo, J., Fady, B., Dawson, I., Vinceti, B. & Baldinelli, G. 2011. Climate change and forest genetic resources: state of knowledge, risks and opportunities. Commission on Genetic Resources for Food and Agriculture. Background Study Paper No. 56. Rome, FAO http://www.fao.org/ docrep/meeting/023/mb696e.pdf

[5] Blackburn, H. & Gollin, D. 2008 Animal genetic resource trade flows: the utilization of newly imported breeds and the gene flow of imported animals in the United States of America. Livestock Science, 120 (3): 240–247. https://www.sciencedirect.com/science/article/abs/pii/S1871141308002072

that birth rate after nine months of pregnancy reduces by higher temperature.[6] It is also stated that with an increase of 1 degree Celsius monthly would result in 1% fewer birth rate after nine months of pregnancy.[7] It is not only temperature that has an impact on fertility but also precipitation. It was found that, in the rural communities of Mexico, an increase in precipitation lead to increase in fertility 1.14 times in dry land communities over the wetland communities.[8] Because in dryland regions the environment was unfit for agricultural purpose and people would migrate for a short term in search of work. However in wetland, since the land was readily available for agriculture, people were full time involved in it.[9] In the past five years with high temperature persisting, women with farms gave less birth and made greater use of family planning. Climate change both long term and short term has different impact on fertility.[10] It was identified by a study which was made on 18 sub-Saharan African countries that long term and short term climate variability has an impact on fertility.[11] There is negative impact on fertility with temperature increase on both short & long term. However precipitation has different impact on different terms.

Climate change has an indirect effect on fertility through food production. There are demographic consequences because of food insecurity which in turn has limited impact fertility. Reduction in fertility rate may be one way to control population growth which comes up with inadequate food supply. Droughts and famine are the major reasons for such change in fertility rate. For example, there was a significant decline in conception rates in Ethiopia during the years of drought and famine between 1970 and 1980.[12] Similarly, fewer conceptions were reported during the months of January through May, when there were extreme food shortages in Finland due to the 1967–68 famine.[13] The historic famine in China from 1958 to 1961 had a

[6] Bakhtsiyarava M, Grace K, Nawrotzki RJ. Climate, birth weight, and agricultural livelihoods in Kenya and Mali. American Journal of Public Health. 2018; 108(S2):S144. https://ajph.aphapublications.org/doi/10.2105/AJPH.2017.304128

[7] Barreca A, Deschenes O, Guldi M. Maybe next month? Temperature shocks and dynamic adjustments in birth rates. Demography. 2018; 55(4):1269–1293. pmid:29968058, https://read.dukeupress.edu/demography/article/55/4/1269/167901/Maybe-Next-Month-Temperature-Shocks-and-Dynamic

[8] Simon DH. Exploring the influence of precipitation on fertility timing in rural Mexico. Population and Environment. 2017; 38(4):407–423. https://doi.org/10.1007/s11111-017-0281-3

[9] Lam D, Miron J. The effects of temperature on human fertility. Demography. 1996; 33(3):291–305. https://doi.org/10.2307/2061762 pmid:8875063

[10] Seiver D. Seasonality of fertility: New evidence. Population and Environment. 1989; 10(4):245–257. https://doi.org/10.1007/BF01255839

[11] Winkler-Dworak M. Food security, fertility differentials and land degradation in Sub-Saharan Africa: A dynamic framework. Vienna Yearbook of Population Research. 2004; 2:227–252. https://www.jstor.org/stable/23025444

[12] Lindstrom D, Berhanu B. The impact of war, famine, and economic decline on marital fertility in ethiopia. Demography. 1999; 36(2):247–261. https://doi.org/10.2307/2648112 pmid:10332615

[13] Fellman J, Eriksson AW. Regional, temporal, and seasonal variations in births and deaths: The effects of famines. Social Biology. 2001; 48(1–2):86–104. pmid:12194449 https://www.tandfonline.com/doi/abs/10.1080/19485565.2001.9989029

similar effect on fertility.[14] In a study in India, Pakistan, and Turkey, Finlay concludes that people have a "positive response" to child mortality;[15] people who have lost children in disasters prefer replacement[16] and view more children as insurance against expected risk.[17]

IMPACT OF CLIMATE CHANGE:

For over 100 years constant increase in temperature all over the world has led to climate change. This increase in temperature resulted in accumulation of mass amount of greenhouse gases, which lead to global warming. Various climate models were used to assess the surface temperature. The "Intergovernmental panel on climate change" has stated that by the 2100 the surface temperature will rise from 1.4 to 5.8 degree Celsius.[18] Climate change caused by human being out way the increase in surface temperature this includes melting of glaciers in Arctic, rise in sea level, increase in ocean temperature, emission of greenhouse gases, and other change of patterns in ecosystem.[19]

Heating of air has resulted in melting of glaciers due to which the sea level is rising. Because of the rise of sea level, heavy floods were witnessed in California (1999) and other western parts in India. Major coastal cities and harbors of today will be washed away if the sea level rises by 80-90 cm.[20] the finishing industry will face a huge hit. With constant flooding, agricultural lands might lose its fertility as a result famine may exist in third world countries. There has been an increase in drought and flood all over the world because of excess greenhouse gases. Hurricanes, pacific typhoons, tornadoes and local storm often damage crops and fields thereby causing food insecurity.

Change in air temperature and rainfall patterns have resulted in shift in seasons. Seasonal characters have changed, some seasons last longer than average and some seasons end in short span. Winters and summers are extreme than usual years. Indigenous farmers are dependent on

[14] shton B, Hill K, Piazza A, Zeitz R. Famine in China, 1958–61. Population and Development Review. 1984; 10(4):613–645. https://doi.org/10.2307/1973284

[15] Finlay EJ. Fertility response to natural disasters: The case of three high mortality earthquakes. 2009. World Bank Policy Research Working Paper, 4883. Available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1372960

[16] Nobles J, Frankenberg E, Thomas D. The effects of mortality on fertility: Population dynamics after a natural disaster. Demography. 2015; 52:15–38. pmid:25585644, https://read.dukeupress.edu/demography/article/52/1/15/169368/The-Effects-of-Mortality-on-Fertility-Population

[17] Cain M. Risk and insurance: Perspectives on fertility and agrarian change in India and Bangladesh. Population and Development Review. 1981; 7(3):435. https://doi.org/10.2307/1972559

[18] Fankhauser, S. Valuing Climate Change: The Economics of the Greenhouse. London: Earthscan Publications Ltd, 1995. https://www.taylorfrancis.com/books/mono/10.4324/9781315070582/valuing-climate-change-samuel-fankhauser

[19] Parry, M., C. Rosenzweig, A. Iglesias, F. Fischer, and M. Livermore. "Climate Change and World Food Security: A New Assessment." Global Environmental Change, 1999, 9: pp51-67. https://pure.iiasa.ac.at/id/eprint/5646/1/RR-99-12.pdf

[20] West, J.J. and H. Dowlatabadi. "On Assessing the Economic Impacts of Sea-Level Rise on Developed Coasts." In Climate Change and Risk, T.E. Downing, A.A. Olsthoorn, and R.S.J. Tol eds. New York: Routledge, 1999 pp. 205-220. https://www4.unfccc.int/sites/NWPStaging/Pages/item.aspx?ListItemId=22868&ListUrl=/sites/NWPStaging/Lists/MainDB

traditional knowledge to cope up with food production amidst climate change.[21]

Change in hydrological cycles has resulted in diminishing water resources. Areas with heavy rainfall are facing minimum to low and humid areas are transforming into arid area. Ground water has been depleted by extensive domestic and industrial use.[22]

With a shift in temperature and rainfall cycles, microbial organisms have multiplied. Pest or disease in plants, crops and animals have seen a surge. Due to which harvest is delayed or denied and has affected the food production.

Climate change leads to change in ecosystem. When several species shift from one place to another in search of a suitable climate, the biodiversity depending on them would not get there benefits. This might lead to change in ecosystem.[23]

IMPACT OF CLIMATE CHANGE ON FOOD SECURITY:

Human beings have the tendency to adapt themselves to changing environment. The socio-economic stresses laid by climate change have caused extreme drought and floods. As climate change is seen to affect the future, it is necessary to learn from past experience and gain knowledge from it. However, changes in climate variability will bring additional complications to many, especially those dependent on food systems that are particularly vulnerable to these additional stresses.[24]

Climate change disturbs the food system, which leads to food insecurity. Adapting different approaches to food system can reduce its vulnerability towards climate change. The approaches may include any methods in agronomic and fisheries, government policies, access to food, changes in societal values or pricing of products.[25]

Agricultural production is a result of extensification (generating products using the ecosystem) and intensification (production of more output in a specified land area). As there is depletion in natural ecosystem, intensification shall be of dominant use in the future. To meet the demand in future, crop grown in seasonal cycle should increase per unit area. Such increase can be achieved by combing three techniques namely, using herbicides to control weed, nitrogen

[21] White, A., M.G.R. Cannell, and A.D. Friend. "Climate Change Impacts on Ecosystems and the Terrestrial Carbon Sink: A New Assessment." Global Environmental Change , 1999 volume 9:S21-S30. https://researchportal.hw.ac.uk/en/publications/climate-change-impacts-on-ecosystems-and-the-terrestrial-carbon-s

[22] Brugère, C., & De Young, C. Assessing climate change vulnerability in fisheries and aquaculture: available methodologies and their relevance for the sector. FAO Fisheries and Aquaculture Technical Paper No. 597. Rome, FAO., 2017., https://www.fao.org/3/i4398e/i4398e.pdf

[23] Global Food Security Programme. 2015. Extreme weather and resilience of the global food system. Final Project Report from the UK-US Taskforce on Extreme Weather and Global Food System Resilience. UK 2015, http://www.foodsecurity.ac.uk/assets/pdfs/extreme-weather-resilienceof-global-food-system.pdf.

[24] Fischer, G, M. Shah, and H. van Velthuizen. Climate Change and Agricultural Vulnerability. Vienna: International Institute of Applied Systems Analysis., 2002, http://adapts.nl/perch/resources/climateagri.pdf

[25] Arnell, N. and C. Liu. 2001. "Hydrology and Water Resources." In Climate Change: Impacts, Adaptation, and Vulnerability, J. McCarthy, O. Canziani, N. Leary, D. Dokken, and K. White (eds.). New York: Cambridge University Press, pp. 191-234., 2001 https://library.harvard.edu/sites/default/files/static/collections/ipcc/docs/27_WGIITAR_FINAL.pdf

fertilizers with genotypes, expansion of irrigation.

All the attempts to adapt to the changing climate and environment, it is necessary to note that the attempts made against environmental degradation are done sustainably. Major source of CO2 was past extensification, therefore in order to control that the forest should be kept intact. Future technological development should anticipate facilitating crops with changing climate.[26]

DIRECT IMPACT OF CLIMATE CHANGE ON FOOD SECURITY:

1. **Global crops and climate change:**

Change in environment such as extreme heat and drought lays stress on naturally prevailing crop species. Crops can grow only in optimum temperature but with fluctuation in temperature the Plant physiology is influenced. Stress resistant plants are necessary against climate change. Scientists find it difficult to develop stress resistant plants. Plants respond in terms of genes, physiology and metabolism to climate stresses. The organs and tissues of the plants are damaged due to different stresses.[27] The stress in crops is triggered by reactive oxygen species (ROS) which is caused by the level of carbon dioxide in the leaf during drought. Due to ROS, the plant development, respiration and photosynthesis is disturbed. Heat and salt stress disarm cell building materials like carbohydrates, lipids, proteins and nucleic acid.[28] Hence for crop development ROS is necessary without crops may lose its potential.

In a study published by NASA in the journal 'nature food', it states that climate change caused due to the emission of greenhouse gases will affect the maize and wheat production by 2030. Increase in temperature, precipitation and shift in rainfall patterns are also some of the reasons for climate change. This climate change might distress certain crops like maize but at the same time help in the growth of other crops. The crop yields from maize may decline by 24% and wheat could increase by 17%. Overall, global warming and climate change both have some negative and positive effects on agricultural crops as well as on humans.[29]

2. **Fruits/vegetables production and climate change:**

Vegetable crops are sensitive to climate change. Since it is equally sensitive to agricultural crops, high temperature inflects stress on the crop.[30] Environmental extremes such as minimum availability of irrigation water, flooding, salinity, temperature, affect the vegetable crops

[26] Mendelsohn, R., W. Nordhaus, and D. Shaw. 1994. "The Impact of Global Warming on Agriculture: A Ricardian Analysis." American Economic Review 84(4):753-771. https://www.jstor.org/stable/2118029

[27] Pugh, T.A.M., climate analogues suggest limited potential for intensification of production on current croplands under climate change., volume 7., 1-8.,2016., https://www.nature.com/articles/ncomms12608

[28] Lizumi. T., crop production losses associated with anthropogenic climate change for 1981-2010 compared with preindustrial levels., int. j. Climatol., 38, 5405-5417., 2018 https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.5818

[29] Rosenweig c, coordinating AgMIP data and models across globe and regional scales for 1.5 C and 2.0C assessments., 2018., https://royalsocietypublishing.org/doi/full/10.1098/rsta.2016.0455

[30] Scheelbeek, P.F.D., effect of environmental changes on vegetable and legume yields and nutritional quality. 115., 6804 LP- 6809 https://www.pnas.org/content/115/26/6804.abstract

resulting in low yields. Rainfall is one the major factor affecting crop production. The quality and yield of the vegetables depend greatly on water but the drought constrains limit the productivity especially tomato production. Tomato is one such crop that intakes a lot of water but water scarcity stress the plants.[31]

Fluctuations in temperature affect the vegetables highly in tropical and arid area. High temperature causes a significant alteration in morphological, physiological, biochemical and molecular response of the plant and in turn affects the plant growth, development and yield.[32] The symptoms causing fruit set failure at high temperatures in tomato; this includes bud drop, abnormal flower development, poor pollen production, dehiscence, and viability, ovule abortion and poor viability, reduced carbohydrate availability, and other reproductive abnormalities.[33] At the pre-anthesis stage, due to high temperature tomato and pepper production will be affected. It also affects the red color in the chili fruit and causes flower drop. Germination of watermelon, cucumber and pumpkin seeds are put down at 42 and 45 degree Celsius. The fluctuations in temperature cause delay in the ripening of fruit and reduce their natural sweetness.

3. Livestock system and climate change:

The pastoralist and agro-pastoralist groups are most vulnerable to climate change. The size of the heard decreases due to climate stress thereby resulting in increased mortality and poor reproduction among animals. The frequent number of extreme hot days and heat waves strongly affect the farm animals. This would have an impact on food security and life of pastoralists who depend upon the products or other benefits from it. It can be overcome by adapting various approaches namely:

- By enforcing various schemes and policies. For e.g., giving compensation for the loss in livestock because of climate change.
- Generating incentives to pastoralists In to process of involving the them in market economy to create cash income
- Providing accessibility to food and service by developing a network system to support, when they are in position to access.

Thermotolerance acts as a method to select farm animals. Animal tolerance to heat can be

[31] Rippke, u., time scales of transformation climate change adaptation in sub-saharan African agriculture., 605-609., https://www.nature.com/articles/nclimate2947

[32] Tripathi., A., DK Tirupathi, N. Kumar, and G.S. Singh, 2016: paradigms of climate change impacts on some major food sources of the world: a review on current knowledge and future prospects., agriculture., ecosystem., environment., 216, 356-373, https://agris.fao.org/agris-search/search.do?recordID=US201600252050

[33] Gitay, H., S. Brown, W. Easterling, and B. Jallow. 2001. "Ecosystems and their Goods and Services" In Climate Change 2001: Impacts, Adaptation, and Vulnerability, J. McCarthy, O. Canziani, N. Leary, D. Dokken, and K. White (eds.). New York: Cambridge University Press, pp. 235-342. https://library.harvard.edu/sites/default/files/static/collections/ipcc/docs/27_WGIITAR_FINAL.pdf

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changed permanently through genetic selection which is a cost effective mechanism. However it can be challenging as well because of the problems created by heat stress and its response to heat tolerance and productivity. Phenotypic measures helps to determine heat-tolerant animals. These animals can be used in field conditions with low cost.[34]

In contrary, livestock act as a major cause for environmental degradation. Due to the emission of greenhouse gases such as methane and nitrous oxide, livestock greatly has an impact on climate change.

4. Aquaculture and climate change:

Fish and other aquatic organisms are very sensitive to their external environment. There body temperature depends upon the temperature of the water hence they are poikilothermic in nature. When the temperature of their surrounding increases they migrate to cooler areas where they regain their homeostasis. The migration, from shallow area to mid-sea area causes an imbalance in the coastal zones such as damages to coral reef, ocean acidification and other destructions. This could result in a downfall of fisheries by 40% in the near future.

Fishing would be difficult as regular sustainable fishing would become overfishing. The rise in temperature will increase the metabolic rate in aquatic organisms thereby reducing the growth and maximum size of the fish. Several fish species may go extinct due to the migration. Because of the higher potential of migration, terrestrial species show a higher rate (15-37%) of overall migration than marine species.[35] the species that is first going to be affected by rise in temperature in plankton. Secondly the sea birds and fishes that depend upon and slowly the aquatic ecosystem. With ocean acidification shrimps, oysters and corals will lack the ability to form the outer shell. It is predicted that in the coming decades, the temperature of the Indian seas shall increase by 1-3 degree Celsius.

5. Pests/Diseases and climate change:

The ecology and biology of insect pests are highly influenced by climate change. Greenhouse gasses such as carbon dioxide and nitrogen greatly help in multiplication of insects and pests. CO2 increases the sugar content in leaves and reduces the nitrogen content. Because of this the

[34] Jones, P.G. & Thornton, P.K. 2009. Croppers to livestock keepers: livelihood transitions to 2050 in Africa due to climate change. Environmental Science & Policy, 12(4): 427–437., https://www.climatelearningplatform.org/sites/default/files/resources/Jones%2BThornton_2009_Croppers%20to%20livestock%20keepers.pdf

[35] West, J.J. and H. Dowlatabadi. 1999. "On Assessing the Economic Impacts of Sea-Level Rise on Developed Coasts." In Climate Change and Risk, T.E. Downing, A.A. Olsthoorn, and R.S.J. Tol (eds.). New York: Routledge, pp. 205-220., https://www4.unfccc.int/sites/NWPStaging/Pages/item.aspx?ListItemId=22868&ListUrl=/sites/NWPStaging/Lists/MainDB

insects have to consume many leaves to meet their metabolic requirement thereby making a severe attack on crops and plants. With increased temperature, insects will survive in the winter with the help of CO2. The temperature also intrudes in the lifecycle of insects. High temperature results in increase of fecundity in insects leading to earlier completion of life cycle. Hence prolonged breeding increases reproduction by producing more pests than usual rate.[36]

The other side effect of high temperature is that the insects carry diseases such as pathogens and other natural enemies leading to the spread of diseases in crops. Increased temperatures will accelerate the development of cabbage maggot, onion maggot, European corn borer, Colorado potato beetle.[37] This gives an important implication that increase in temperature in the range of 1°C to 5°C would increase insect survival due to low winter mortality, increased population build-up, early infestations and resultant crop damage by insect-pests under global warming scenario.[38]

6. Soil erosion and climate change:

To meet the global demand of food for the growing population, agriculture must evolve. One of the important factors in agriculture is soil. Soil resources are limited and hence it is necessary to make significant use of it. Climate change acts as a threat to food security. Countries like India are at high risk with marginal and small farmers. With tropical climate which is affected by increase in temperature and poor coping system, food security is problematic.Though, climate change is a slow process involving relatively small changes in temperature and precipitation over long period of time, nevertheless these slow changes in climate influence the various soil processes particularly those related to soil fertility.[39]

The formation of a soil depends upon the temperature and precipitation. Climate change directly has an impact on soil formation. The moisture content, water balance and organic minerals in the soil are influenced by temperature change. The external factors affecting soil are temperature and precipitation and internal factors affecting are energy, hydrological and biological characters. The environmental change damaging the external factor will lead to alteration in internal factor.

[36] Jat MK, Tetarwal AS (2012) Effect of changing climate on the insect pest population National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate., https://repository.rothamsted.ac.uk/item/889y2/climate-change-impacts-on-insect-management-and-conservation-in-temperate-regions-can-they-be-predicted

[37] Newton AC, Johnson SN, Gregory PJ (2011) Implications of climate change for diseases, crop yields and food security. Euphytica 179: 3-18., https://link.springer.com/article/10.1007/s10681-011-0359-4

[38] Harrington R, Fleming RA, Woiwod IP (2010) Climate change impacts on insect management and conservation in temperate regions: can they be predicted?. Agricultural and Forest Entomology 3: 233-240., https://repository.rothamsted.ac.uk/item/889y2/climate-change-impacts-on-insect-management-and-conservation-in-temperate-regions-can-they-be-predicted

[39] Pendall E, Bridgham S, Hanson PJ, Hungate B, Kicklighter, et al. (2004) Below-ground process responses to elevated CO_2 and temperature: a discussion of observations, measurement methods, and models. New Phytol 162(2): 311-322.

Soil development is persuaded by many factors but by far the vital one climate change. The rocks and minerals in the soil are damaged due to temperature and lack of rainfall. The moisture level and CO2 is projected to have effects on soil properties that are substantial for fertility and productivity. The destruction energy increases by climate change because of which the soil loses its fertility. Hence mineral fertilizers are used heavily on food crops to artificially retain moisture.

The chemical properties in the soil add nutrients to the roots surface. With changed climate, the nutrients for root growth are tampered with no soil moisture and temperature. It has been suggested that climate change impacts on nutrient use efficiency is be primarily affected through direct impacts on root surface area and influx rate.[40]

INDIRECT IMPACT OF CLIMATE CHANGE ON FOOD SECURITY:

1. **Climate change on price rise and hunger:**

Extreme events in climate change can cause food insecurity. Droughts in crop producing regions were there major cause for price rise. It affects the price of food and the access to it. It is to be noted that urban poor spend 75% of their expenditure on food. When it comes to food there is a global connection for its consumption. Any extreme events in one region can cause food stress in various parts of the world. The low income countries are vulnerable towards food insecurity along with climate change. It would be difficult for them to adapt to sudden change in climate and it effect on financial resources. Because of climate stress, the price of rice increased by 217%, wheat by 136%, corn by 125% and soya beans by 107% between 2006 to 2008. In 2010, the floods in Pakistan inundated cropland and the severe heat wave and drought in Russia caused a grain embargo.[41]

2. **Climate change on human health:**

Climate change will also affect the nutrition in the food. When the harvest is extended during the lean season, food production and availability decreases. The protein, zinc and iron content of a crop are reduced due higher concentration of CO2. As a result, by 2050 an estimated additional 175 million people could be deficient in zinc and an additional 122 million people could experience protein deficiencies.[42] People in poverty who depend upon plants for their

[40] Brouder SM, Volenec JJ (2008) Impact of climate change on crop nutrient and water use Efficiencies. Physiologia Plantarum 133(4): 705-724.

[41] Dasgupta, P., Rural areas in: climate change: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working groups II to the fifth assessment report of the intergovernmental panel on climate change, Cambridge university press, Cambridge UK and New York, 613-657., http://www.ecoforumjournal.ro/index.php/eco/article/view/874

[42] Tol, R.S.J. and H. Dowlatabadi. 2002. "Vector-Borne Diseases, Development, and Climate Change." Integrated Environmental Assessment 2:173-181, Tol, R.S.J. and H. Dowlatabadi. 2002. "Vector-Borne Diseases, Development, and Climate Change." Integrated Environmental Assessment 2:173-181

daily nutrition would be affected. These impacts will be felt most keenly by people living in poverty, who depend heavily on plant sources for their nutrition. Poor people in Africa, the Middle East, and South and Southeast Asia are most at risk from the combination of these deficiencies and poor public health systems that may be unable to cope with the impact.[43] Apart from this the air quality affects the lungs of humans and water related illness spread rapidly in developing countries. The authors of a 2014 paper published in *JAMA* concluded that "Health is inextricably linked to climate change.[44] It is important for clinicians to understand this relationship in order to discuss associated health risks with their patients and to inform public policy."

3. Climate change on food quality:

In 2018, the intergovernmental panel for climate change (IPCC) in its report stated that it is highly time to sound alarm on global warming. It is predicted that with the same events continuing, by 2040 there will be extreme weather conditions, the sea levels would rise, there will be extinction of certain species, and decrease in food production.

Climate change is often associated with the weather conditions and environmental extremes. It is equated with food production but what we often forget is the quality of the food and the nutrition value.

Prior to 2015, the only method used to collect data on the impact of CO2 gas on nutrient content of the plants was to employ artificial growing conditions in many countries. But with the new technology of free-air CO2 enrichment (FACE) the influence of CO2 on crops are exposed in normal field conditions. This technology provides more accurate results on food quality. The data collected using FACE technology across three continents gave 10 times more accurate results than previous studies. It was found that the natural zinc, iron and protein content in the crops were affected because of CO2. It is also to be noted that reduce in food quality would amount to reduce in food quantity. [45]

4. Climate change on food stability:

According to various research studies, the areas in which the crop yields are predicted to

[43] US Geological Survey. What is the difference between global warming and climate change? https://www.usgs.gov/faqs/what-difference-between-global-warming-and-climate-change-1?qt-news_science_products=0#qt-news_science_products. Accessed August 22, 2019.
[44] Patz JA, Frumpkin H, Holloway T, et al. Climate change: challenges and opportunities for global health. *JAMA*. 2014:312(15):1565-1580.

[45] Timmerman, A., J. Oberhuber, A. Bacher, M. Esch, M. Latif, and E. Roeckner. 1999. "Increased El Niño Frequency in a Climate Model Forced by Future Greenhouse Warming." Nature 398:694-697., https://www.nature.com/articles/19505

decrease are the areas which are already facing food insecurity. There will a decline in aquatic foods positively and negatively. The catch around the coastal belt will decrease due climate change and organism migrating to deeper areas. Climate change not only affects the production capacity of food but also the income of the poor people and their ability to buy. The market risks, defects in supply and storage systems, the deficiency in agricultural stability, inadequate rural incomes and nutrition content act as a major challenge for food stability to the vulnerable and poor groups.[46]

Extreme climate conditions have an impact on the stability of food supply, its access and utilization. Stability of food supply will be impacted by changes in seasonality, increased variance of ecosystem productivity, increased supply risks and reduced supply predictability – issues that may also have large impacts on supply chain costs and retail prices (FAO, 2008). There is a threat to economic access to food. As price of the food the increases people depending upon agriculture with irregular income are highly vulnerable.

5. Climate change on global economy:

Climate change poses a greater threat to the world economy. The Paris agreement, Swiss re institute's new climate economic index states that by 2050, there would 18% decrease in the GDP of world economy due to climate change. If as predicted the temperature increases above 3 degree Celsius, the greatest economies of the world would be at distress. Firstly china would lose a quarter of its GDP (24%) to climate change, the US, UK and Canada would 10% each, Europe slightly higher might lose 11% of its GDP. However the countries that go through extreme losses are countries with minimum resources and those who are unable to mitigate the rise in temperature. Such countries include Malaysia, Thailand, Indonesia, and the Philippines.

The social and economic consequences of climate change are fluctuations in agricultural incomes, increase in prices, food markets, and trade and investment patterns. Climate extremes can reduce the income of farmers. It can abduct physical and productive capital from the yielders such as cattle. The investment capacity of people would diminish. At national level, the price of agricultural products would rise and would have a drastic impact on the population that spends major part of their budget on food. Thus environmental change triggers those countries which are agriculture-dependent and that agriculture constitutes as major part of their GDP and primary employment. Climatic shocks that impact a significant volume of worldwide

[46] Schneider, S., J. Sarukhan, J. Adejuwon, C. Azar, W. Baethgen, C. Hope, R. Moss, N. Leary, R. Richels, and J.P. van Ypersele. 2001. "Overview of Impacts, Adaptation, and Vulnerability to Climate Change." In Climate Change 2001: Impacts, Adaptation, and Vulnerability, J. McCarthy, O. Canziana, N. Leary, D. Dokken, and K. White (eds.). New York: Cambridge University Press, pp. 75-103. Schneider, S., J. Sarukhan, J. Adejuwon, C. Azar, W. Baethgen, C. Hope, R. Moss, N. Leary, R. Richels, and J.P. van Ypersele. 2001. "Overview of Impacts, Adaptation, and Vulnerability to Climate Change." In Climate Change 2001: Impacts, Adaptation, and Vulnerability, J. McCarthy, O. Canziana, N. Leary, D. Dokken, and K. White (eds.). New York: Cambridge University Press, pp. 75-103.

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production or an area of importance in terms of world markets have global consequences on markets:

(i) quantity and price effects, with increased tension on markets; and

(ii) impacts on bilateral contracts and/or import/export behavior, with disruption of trade patterns

METHODS TO IMPROVE FOOD SECURITY:

1. **Reduction of food loses and food waste:** food waste has an impact on the economy and environment. Economically, it can reduce the income of the farmers and lead to rise in prices. Food waste if not treated properly pollutes water resources and causes greenhouse gas emission thereby affecting the environment. If the current rate of food waste is cut by half then the world would need 1,314 trillion kilocalories less per year by 2050. For a sustainable future, global strategies should strive to reduce food loss and waste.
2. **Combining supply side and demand side:** the difference between demand and supply tends to increase in food price thereby creating inflation in the economy. The rise in prices of food products represents the beginning of a structural increase in near future. Due to increasing population in a short span, the food demand in increasing rapidly. There is a great demand for the food in countries like India and china. The supply side is also affected because of extreme climate conditions and other human activities and is unable to meet the demands. For a sustainable living it is necessary to integrate supply and demand by taking economical policies.
3. **Taking various measures and policies**: the food security policies have been developed in the recent decade to conserve the resources. The extensive importance was given to the right to adequate food, providing secure tenure. The policies mainly concentrate on three things namely, agriculture, trade and macroeconomics thereby neglecting climate change. Since climate change act as a threat to food security it is essential to take climate change into consideration while making policies. A multi-sectoral approach should be followed involving various sectors such as trade, forest, agriculture, environment etc. the policies framed should have link between the sectors and not contradictory. All the ecosystem factors should be kept involved in the decision making.
4. **Adaptive farming practices:** the technological development should reach to farmers who are currently unable to predict the fluctuations of extreme climate. The yielders should be well equipped about the farming before starting as to when to plant, what crop to cultivate and when to sow With changing climate, measures have to taken for

the crops to be resistant to the environmental changes. Multiple cropping could be adopted widely in the near future to cope up with the food insecurity.

5. **Technological advancement:** artificial intelligence of things (AIoT) can be used to combat climate change extensively. AIoT enables to collect data of the greenhouse gas emissions specifically carbon management. AIoT integration enables seamless sourcing of real-time activity level data and asset inventory data from a variety of systems. This provides an organization with the capability to efficiently structure, collect and transform data into reports for accurate emissions-monitoring and measurement, reducing overall efforts around data collection and enhancing data quality and report resolution. Abatement planning is a challenge primarily due to the lack of accurate measures for determining the emissions derived from certain processes and AIoT technology tackles this challenge by creating insights from real-time data to better predict process emissions.[47]

CONCLUSION:

Climate change affects the food system all around the world. It affects the dimensions of food security, starting from availability of food, access, utilization and food stability. The repercussions of climate change will be different in different regions. Hence to satisfy the needs of all the people is a task of the era. The most vulnerable people to vulnerable people to such changes are those who are already hunger and malnutrition. Reduced accessibility and stability of food to vulnerable groups is the serious issue on food security. The sustainable development goals 2030 by United Nations are the only step taken at the international to solve food crisis. However there are two ways, either of which can be implemented to combat climate change. Firstly, should try to control climate change through mitigating factors or develop ourselves and the environment to the changing climate. The annual occurrence of disaster has increase three time than that 1970s & 1980s. Drought has been major cause for food insecurity followed by floods, production cost, storm, pests and diseases and wildfire. Therefore as FAO stated, global investment must be made for resilience and disaster risk reduction, were countries should share data, statistics and information which acts as an evidence to reduce the climate extremes. Countries must adopt multi-sectoral system to anticipate, prevent, and prepare for global environment change. New innovations should arrive into practice without delay in regional countries. Above all the public-private partnership is essential to understand the change and be prepared to fight against it.

[47] Luiz Avelar, Strategy Director, Envision Digital, Envision Group, How Can Technology Help Combat Climate Change, world economic forum, 2021, https://www.weforum.org/agenda/2021/07/fight-climate-change-with-technology/

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