THE EFFECT OF CLIMATE CHANGE ON AGRICULTURAL PRODUCTION

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Abstract. Global warming and climate change problems are experienced because of the mixing of greenhouse gases which are formed as a result of human-induced activities such as the use of fossil fuels and deforestation, into the atmosphere. The sector where the adverse effects of climate change are most evident is the agricultural sector. Due to climate change, it causes various problems such as irregular rainfall, drought, water scarcity, soil degradation, and increase in diseases and pests in the agricultural sector. These problems cause low yield and low quality in agricultural production. While the need for food increases in a trend where there is a continuous increase in the world population and the decrease in agricultural areas, various studies and agreements have been made on the subject by scientists, national and international organizations on the seriousness of the negativities experienced due to climate change. In this study, studies to reduce the negative effects of climate change on agricultural production were explained.
Keywords: *climate change, global warming, greenhouse gas, agricultural production, food safety*

Introduction

There are many fields of study that require expertise in agricultural science and agriculture consists of complex events involving biological, physical, and chemical processes. Agricultural production can be adversely affected by many factors such as uncontrollable weather, climate, soil characteristics, diseases and pests, and environmental pollution. For this reason, not only expertise is sufficient for an efficient agricultural production, but also the cultivation conditions must be suitable for the demand. Thus, provided that the species and breeds of the plants and animals grown are also suitable, the most efficient production will be achieved if the growing conditions meet the optimum demands. However, achieving optimum conditions can be very difficult and costly. For this reason, for an efficient agricultural business, it is necessary to determine the changes in each component accurately and in a timely manner, and to decide on the applications to be made by considering possible interactions (Ozguven, 2023).

The mixing of greenhouse gases into the atmosphere caused by fossil fuel consumption raises the problem of global warming. It is known that because of the intense use of fossil fuels in the last century, the amount of CO^2 in the atmosphere increased from 270 ppm, which was the value before the industrial revolution, to 389 ppm. In addition, it is known that the average world surface temperature has increased by 0.8 °C with the effect of global warming. It is stated by experts that if the temperature increase reaches 4 °C, many parts of the world will become unsuitable for people to live in (Kasap et al., 2012). The Intergovernmental Panel on Climate Change

(IPCC) report predicts that climate changes such as heat waves, extreme temperatures, heavy rains, drought and tropical cyclones, longer warm seasons and shorter cold seasons will increase in all regions in the coming decades. IPCC scientists also point out that extreme temperature thresholds for agriculture and health would be exceeded more frequently (IPCC, 2021). It is estimated that the world population will reach 9.1 billion, 34% higher than today. To meet the food needs of the increasing world population, it is necessary to increase the amount of global food production by approximately 70% by 2050. For this, annual cereal production will need to increase from 2.1 billion to about 3 billion tons, and annual meat production will need to reach 470 million tons from 200 million tons (FAO, 2009).

Agricultural productivity must be high in order to meet the increasing demand for food. One of the most important factors affecting yield is irrigation. However, different parts of the world are experiencing varying degrees of water scarcity as a result of global climate change causing irregular rainfall. Among the causes of water scarcity are the scarcity of freshwater resources due to climatic conditions, population density and agricultural activities with intensive irrigation (Ozguven, 2023). The questions of what needs to be done to eradicate global hunger and feed the future world population are a major global societal challenge. To ensure the development of effective policies to ensure global food security, a good analysis of future outcomes and main drivers is required. In the global assessments, four broad indicators were used as the basis for measuring various dimensions of food security. These indicators are food demand, population at risk of hunger, food prices and childhood malnutrition (van Dijk et al., 2021).

The agricultural sector is adversely affected by economic, social, and structural problems as well as climate problems. Some of these problems are global market fluctuations, economic crises, drought, hurricanes, floods, and diseases resulting from climate change, the emergence of alternative uses of agricultural products such as biofuels, misuse of agricultural lands such as mining activities, reduction of natural resources such as water, migration of young population from villages to cities and increase in the elderly population in the village (Ozguven, 2018). There is also the problem of using agricultural products as feedstocks for biofuel production. For example, maize is used for ethanol in the USA, cane sugar in Brazil, vegetable oils and cereals are used to produce biodiesel and ethanol in the EU. If such trends continue, biofuels could be a major disruptor, possibly benefiting producers but hurting low-income consumers (Alexandratos and Bruinsma, 2012). In addition, the use of agricultural products in bioenergy production poses a risk for biodiversity and ecosystems. Examples of this are the destruction of tropical forests and the direct use of land for energy crops (especially sugarcane) (Saraçoğlu, 2010).

All these problems in the agricultural sector negatively affect the productivity and quality in agricultural production. Various studies and agreements have been made by scientists, national and international organizations against the negativities experienced due to climate change. The studies carried out to reduce the negative effects of climate change on agricultural production can be listed as follows: (1) climate-smart agriculture; (2) precision agriculture; (3) conservation of water resources; (4) precision irrigation applications; (5) reducing greenhouse gas emissions; (6) breeding of plant and animal; (7) conservation of biodiversity; and (8) international climate change legislation.

Discussion

Climate-smart agriculture

Climate-smart agriculture (CSA) is an integrated approach that studies food security and climate change challenges to increase productivity and income growth for farmers and foresters. Therefore, to help mitigate climate change, CSA works on building resilience, adapting and reducing or removing greenhouse gas emissions. CSA applications focus on reducing emissions in livestock production, reducing farm inputs (such as energy, fuels, pesticides, fertilizers) for more resource efficiency, or storing carbon in the soil (The World Bank, 2021). The purpose of CSA practices is to ensure sustainable food safety, increase revenues, reduce potential risks, adapt to climate change while capturing the benefits, and provide flexibility. It focuses on the combination of other innovations such as protected agriculture, agroecology, agroforestry, and the development of crop varieties with greater tolerance of diseases, pests, flooding, drought, and salinity (FAO, 2013). In CSA, sustainable livestock production is encouraged with mixed plant-livestock systems by fully integrating environmental and production targets. For example, it uses livestock manure to maintain soil fertility and rotation of pasture and forage plants to improve soil quality and reduce erosion. Agroforestry systems are also an important tool for sustainable food production while protecting the ecosystem, especially in regions prone to environmental degradation (FAO, 2017).

Precision agriculture

Precision agriculture (PA) technologies, combined with control, electronics, computer, and databases with account data, present an advanced system approach. Using global positioning system (GPS), geographic information system (GIS), variable rate application (VRA), and remote sensing (RS) technologies, PA technologies, contrary to common fixed-level application methods which are applied all the same way to the whole land, use variable-level input application methods determining land and plant characteristics of small sections (yield, soil structure, soil moisture, nutrient level of soil, plant requirements etc.). As a result, PA is agricultural production and management methods whose targets are more economic and more environmentally sensitive production. PA is the idea of doing the right thing, in the right place, at the right time. This idea is as old as agriculture. However, during the mechanization of agriculture in the 20th century, there was strong economic pressure to cultivate large fields with uniform agricultural practices. PA provides a way to automate site-specific applications using information technology; thus, making the site-specific application practical in commercial agriculture. PA includes all agricultural production practices that use information technologies (e.g., VRA, yield monitors, RS) to either tailor the use of inputs to achieve desired results or monitor those results (Bongiovanni and Lowenberg-DeBoer, 2004).

Thanks to the GPS, RS, GIS, VRA technologies in PA, the variability in different parts of the land can be easily determined, variability is mapped, and field-specific applications are performed depending on the variability. *Figure 1* shows soil variability maps of of potassium, phosphorus, magnesium and pH values prepared according to the soil analysis results of a field. In PA, these variability values are taken into consideration during fertilization, and fertilizer is applied at a variable rate needed by site-specific applications. Thanks to the VRA, it is possible to do fertilization, spraying,

and planting in specific amounts needed in the area, as well as to perform desired operations during the application, thanks to the sensor and control systems developed. Sustainable agriculture targets such as long-term income of the producer in agriculture, elimination of environmental problems caused by pesticide pollution, chemical fertilizer pollution and wrong irrigation can be achieved by the application of PA technologies. The benefits of PA are listed below (Ozguven, 2023): (1) effective fertilizer usage; (2) effective pesticide usage; (3) effective irrigation; (4) effective management; (5) contribution to food safety; (6) traceability; and (7) risk management.

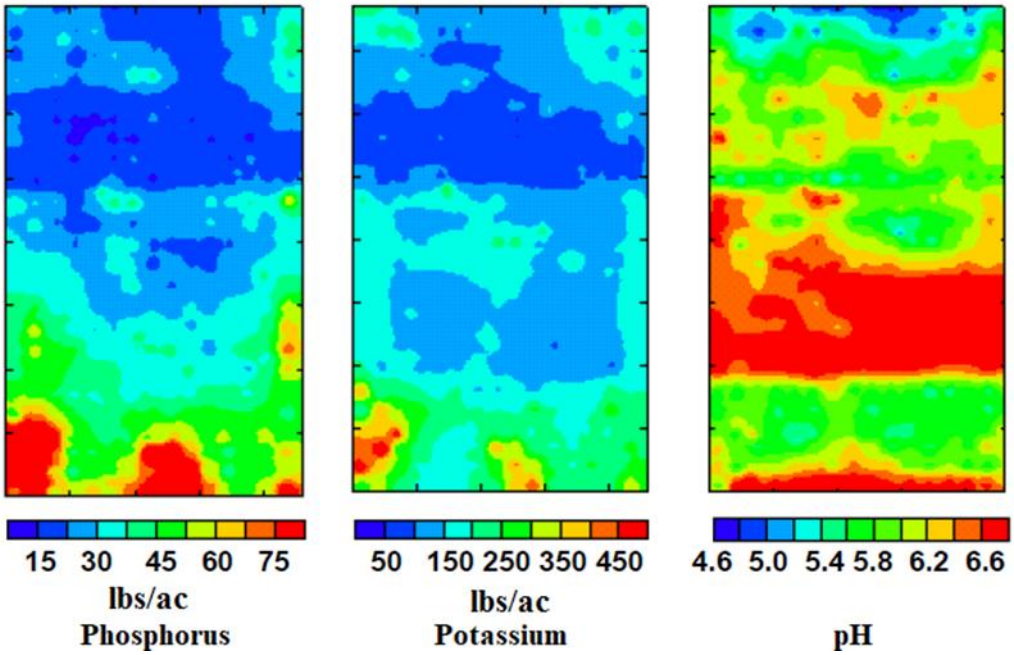

Figure 1. *An example of soil variability maps.*
Source: Davis et al. (1998).

Conservation of water resources

Water scarcity, the problem of access to water, is a critical constraint for agriculture in many parts of the world. More than 1.2 billion people, about one fifth of the world's human population, live in areas of physical water scarcity and cannot find enough water for their demands. About 1.6 billion people live in basins with water scarcity where human capacity or financial resources are insufficient to develop adequate water supplies (*Figure 2*). There is a possibility of increasing water scarcity and increasing complexity in the coming years. While increasing population is an important factor, there are other major causes of water problems. These include lack of interest to water and poverty, insufficient and incomplete investments, insufficient human capacity, ineffective institutions and mismanagement (IWMI, 2007).

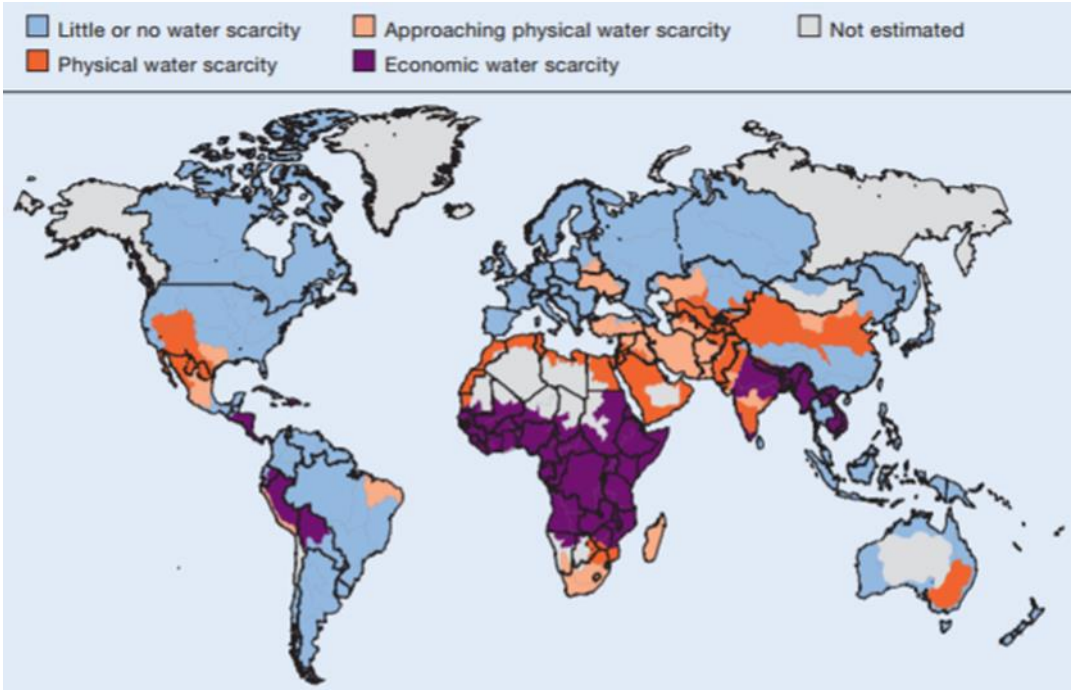

Figure 2. *Areas of physical and economic water scarcity.*
Source: IWMI (2007).

Precision irrigation (PI) systems use improved irrigation application and management technologies combined with advanced sensing, modeling, and control technologies to ensure the best irrigation performance. With PI, plant yield can be optimized through systematic collection and processing of plant and area information, and site-specific targets can be set. Thus, the amount of water can be applied at a variable rate according to soil type, plant type, topography, or field obstacles. With PI systems, real-time data obtained from the field can be analyzed continuously and effectively using advanced hardware and software and, enabling more accurate decisions to be made for irrigation management. In this way, it contributes to the protection of the environment by preventing unnecessary input use and waste of resources (Özgüven and Karaman, 2012). PA provides important contributions both in reducing the effect of drought and increasing food production. Thus, it is possible to minimize the advers effects of climate change on agricultural production and food safety. For example, with drones, it is possible to monitor irrigation practices in a very short time and to determine the effects of drought or flood and plant water status. Therefore, PI techniques contribute to improving water use and maximizing plant productivity (Ozguven, 2023). *Figure 3* shows the individual sprinkler-controlled PI pivot system allowing variable rate irrigation.

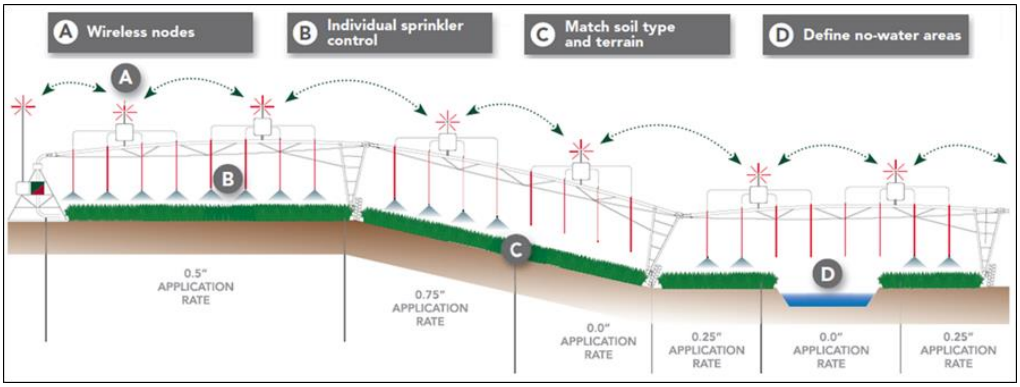

Figure 3. *Individual sprinkler control allowing PI.*

Reducing greenhouse gas emissions

Global warming is caused by the greenhouse effect created by greenhouse gases released into the atmosphere due to some human-induced misapplications. The largest source of greenhouse gas emissions is energy consumption and is responsible for 73% of greenhouse gas emissions worldwide. Other major areas producing greenhouse emissions are agricultural activities such as land use and land use change (12%), forestry activities such as deforestation (6.5%), chemicals, cement, and different industrial processes (5.6%), and wastes including sanitary landfills and wastewater (3.2%). The process of combating climate change is generally handled under two main headings as "mitigation" and "adaptation". Mitigation and adaptation are considered as two inseparable parts for results-oriented studies against climate change. The IPCC in 2007 summarized agriculture's mitigation practices as follows: (1) ensuring management of fields and pastures to increase soil carbon storage; (2) restoration of arable peat soils and degraded lands; (3) improved paddy farming techniques to reduce CH_4 emissions; (4) livestock and manure management; (5) improved nitrogen fertilizer application techniques to reduce N_2O emissions; and (6) shallow tillage farming practices.

Livestock production significantly increases emissions of agricultural greenhouse gases (CH_4, N_2O) and ammonia, which affect the climate, ecosystem and human health. The main reasons for this are fermentation in the digestive systems of ruminants, manure decomposition and over-application of (synthetic) fertiliser. CSA practices can further help farmers reduce their climate footprint while increasing productivity and saving costs. Extensive farming systems, optimising livestock diets and sustainable manure management can reduce on-farm emissions. PA tools can enable farmers to apply fertiliser more efficiently. Sustainable grazing methods that prevent CO2 emissions, store carbon in the soil and using local feed can reduce the need for external inputs such as fuel, pesticides and fertilizer (EIP-AGRI, 2021).

Breeding of plant and animal

It is expected that temperature, drought, CO_2 concentration, biotic-abiotic stress, heavy rainfall, and salinity in soils will increase with the effect of climate change and these factors will negatively affect plant and animal productivity. For example, extreme temperatures affect root and stem development, water and nutrient uptake, transpiration, photosynthesis, and respiration in plants, while adversely affect product yield (growth, meat, milk, egg production, etc.), reproductive physiology, metabolism, and immune

system in animals. For this reason, various breeding studies such as classical, biotechnological, and molecular genetics supported (eg. CRISPR gene technology) are being produced to create new plant varieties and animal breeds that meet different demands in terms of quality, resilience, and sustainability against these conditions. One of the main breeding strategies to adapt to climate changes is a more accurately matching phenology to the available moisture using the photoperiod-temperature response. Other strategies include increased access to a range of varieties with different growth times to escape or avoid predictable occurrences of stress during critical periods in crop life cycles, changing temperature optimums for crop growth and reemphasizing population breeding. Quality is not directly affected by natural selection, unlike yield and disease. Therefore, if quality is an important breeding goal, it is important to include high-quality parents in the crossbreeding design (Ceccarelli et al., 2010).

Conservation of biodiversity

Agricultural biodiversity is crucial for a safer food supply and for coping with the projected effects of climate change. The biodiversity can maintain or increase soil fertility and reduce the impact of pests and diseases. In addition, biodiversity is essential to increase productivity, enhance ecosystem functions, and ensure adaptability. Nowadays, concerns about high food prices and low food supply have made agriculture and agricultural production one of the most important international agenda items. The profound challenges faced in increased production to sustainably meet the needs of a growing population under changing climates have made biodiversity play a more important role (Frison et al., 2011). Gaba et al. (2015) focused on three ways to increase biodiversity. However, the researchers reported that there are many other possibilities. The first approach proposed in the study is to increase crop diversity by changing crops in rotations over time. Other suggested approaches of diversification include the use of cover crops, pest-trap, and pest-repellent crops, and diversifying agricultural landscapes. It is necessary to determine whether, how and when they can benefit agriculture, the environment and society at the same time (Gaba et al., 2015).

International climate change legislation

Studies on climate change on an international scale have been created as a result of studies carried out under the leadership of the United Nations and international organizations. It first started with the United Nations Conference on the Human Environment held in Stockholm in 1972. Then, the United Nations Conference on Environment and Development (UNCED) in 1992, the Kyoto Protocol in 1997 and Paris Agreement in 2015 signed. In these agreements, legal regulations aimed at limiting anthropogenic greenhouse gas emissions and decisions on international emission trade, technology and capital movements were taken. Frameworks and developments in international climate change legislation are listed as follow: (1) United Nations Conference on the Human Environment, Stockholm, in 5-16 June 1972; (2) Intergovernmental Panel on Climate Change (IPCC), Geneva, in 1988; (3) United Nations Conference on Environment and Development (UNCED), Earth Summit, Rio de Janeiro, in 3-14 June 1992; (4) United Nations Framework Convention on Climate Change (UNFCCC), on 21 March 1994; (5) Kyoto Protocol, Kyoto, on 11 December 1997; (6) Paris Agreement, Paris on 12 December 2015; (7) European Green Deal, on

12 December 2019; (8) European Climate Law, on 29 July 2021; and (9) IPCC Sixth Assessment Report, on 9 August 2021, 28 February 2022, 4 April 2022, 20 March 2023.

Many difficulties and uncertainties arising from the increase in the world population and climate change are challenging agricultural production. Reports of some important organizations such as the United Nations and FAO report that more challenging situations such as the global food supply problem may be experienced in the near future. In a world where the population is constantly increasing, it is necessary to increase agricultural productivity and produce quality and sufficient agricultural production in order to feed people. For example, using technologies such as precision agriculture can provide significant benefits such as variable rate application, but cannot fully cope with climate change because the climate cannot be controlled. For this reason, agricultural studies against climate change can be classified under several headings. These studies include the use of technology in agriculture, enhanced resilience, reduced greenhouse gas emissions, breeding of plant and animal, conservation of biodiversity, etc. In order to reduce the impact of climate change on the world and agriculture, it is necessary to expand the reduced greenhouse gas emissions studies worldwide and to concentrate more on academic and technical studies to increase agricultural productivity.

Conclusion

Agriculture is a necessary and strategic activity for the continuity of life, as it produces plant and animal nutrients for human nutrition, provides raw materials for sectors such as textiles and pharmaceuticals, and contributes to national and international economy and employment. While agricultural activities are already labor-intensive by tackling many difficulties, uncertainties and risks, the negative effects of climate change also need to be tackled. Due to climate change, various problems such as irregular precipitation, drought, water scarcity, soil degradation, increase in diseases and pests cause low yield and low quality in agricultural production. With the increase in the world population, the demand for food is constantly increasing, agricultural areas and natural resources are decreasing. Significantly felt adverse effects of climate change raise concerns about access to food. Various mitigation and adaptation studies have been determined by the United Nations and international organizations, and these studies have been recorded with various agreements and protocols. The level of global implementation of the identified mitigation and adaptation efforts will determine the degree of success in combating climate change

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Conflict of interest

The authors declare that there is no conflict of interest involve in this research study.

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