CURRENT APPROACHES IN AGRICULTURAL RESEARCH

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Res. Asst. Cihat GEDİK



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CONTENTS

PREFACE
Prof. Dr. Bahadır SAYINCI
Res. Asst. Cihat GEDİK……...……....1

CHAPTER 1
WAXY MAIZE (*Zea mays* L. ssp. *ceratina*) BOTANICAL, MORPHOLOGICAL AND PHYSIOLOGICAL CHARACTERISTICS
Prof. Dr. Abdullah ÖKTEM
M.Sc. Agr. Eng. Şehmüs ATAKUL ……...……3

CHAPTER 2
THE CONTRIBUTION OF MEDICINAL AND AROMATIC PLANTS TO THE ECOLOGICAL AND AGRICULTURAL FUNCTIONS OF BEE PASTURES
Assoc. Prof. Dr. Doğan ARSLAN ……23

CHAPTER 3
THE CONCEPT OF BEE PASTURE IN THE CONTEXT OF MEDİCİNAL AND AROMATIC PLANTS AND THE FORAGING AREAS OF BEES
Assoc. Prof. Dr. Doğan ARSLAN…….……33

CHAPTER 4
EVALUATION FOR THE LAST TEN YEARS (2015-2024) AND NEXT YEARS (2025-2030) OF CHANGES IN AGRICULTURAL MECHANIZATION LEVEL OF BİNGÖL PROVINCE
Asst. Prof. Dr. Muhittin Murat TURGUT…….43

CHAPTER 5
DESIGN-ORIENTED EVALUATION OF THERMOPLASTIC MATERIALS USED IN AGRICULTURAL MACHINERY SYSTEMS
Dr. Mustafa ÇOMAKLI
Prof. Dr. Bahadır SAYINCI
Res. Asst. Cihat GEDİK……..……61

CHAPTER 6
THE RISING VALUE AND ADVANTAGES OF BLUEBERRY (*Vaccinium spp.*) IN THE EASTERN BLACK SEA REGION UNSURLAR
Prof. Dr. Mustafa AKBULUT
Res. Asst. Şefik Tunahan ÇENGEL …….…….……93

CHAPTER 7
SUSTAINABILITY AND FOOD SECURITY: ENTANGLED CHALLENGES OF CLIMATE CHANGE
Asst. Prof. Yasemin ERGÜNER …….107

CHAPTER 8
AN ANALYSIS OF CHANGES IN SUGAR BEET PRODUCTION AND FOREIGN TRADE IN TURKEY
Assoc. Prof. Dr. Ali Rahmi KAYA
Asst. Prof. Dr. Tahsin BEYCİOĞLU …….121

CHAPTER 9
MICROBIOME-ASSİSTED PLANT PROTECTION IN MEDICINAL AND AROMATIC PLANTS: USE OF PLANT PROBIOTICS AND BIOCONTROL STRATEGIES
Assoc. Prof. Dr. Muhammed Akif AÇIKGÖZ
Asst. Prof. Dr. Seçil EKER …….137

CHAPTER 7

SUSTAINABILITY AND FOOD SECURITY: ENTANGLED CHALLENGES OF CLIMATE CHANGE

Asst. Prof. Yasemin ERGÜNER[1]

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1. INTRODUCTION

Climate change is is considered the greatest challenge facing our planet, due to its interlinked and cascading impacts. It affects the essential interactions among air, water, and soil, fundamentally threatening the sustainability of natural ecosystems and human societies.

The world's population is expected to reach around 10 billion by 2050. Agriculture faces a crucial responsibility under climate change: sustainably feeding exploding global population and ensuring of agro-based industries. According to the World Resources Institute (WRI, 2025), currently, nearly 800 million people worldwide experience hunger. Institute also indicates that to meet food demands by 2050, we must compensate a 56% difference between current supply and future needs.

The impacts of climate change on food security poses a major global concern, with multifaceted implications on ecological systems, human health, economic stability, and geopolitical dynamics. Shifts in temperature and rainfall patterns along with rising sea levels, and the increased frequency of extreme weather events are reducing crop and livestock productivity. These changes lead to food and water scarcity, price volatility and market shocks that consequently hindering every dimension of the agricultural supply chain. Anticipated worsening impacts putting global food security and the livelihoods of hundreds of millions of people at risk and driving migration flows, principally toward urban areas (Adger et al., 2020).

At the same time, unsustainable agricultural systems are among the principal drivers of global ecosystem degradation and galvanizing climate change. Agriculture has dominates around 40% of Earth’s ice-free ecosystems (Yang et al., 2024) by encompassing nearly 50% of the world's vegetated land and accounting for 70% of freshwater withdrawals (FAO, 2025a), a significant contributor to deforestation

especially in tropical regions (WRI, 2025) and agrifood systems account for about one-third of total greenhouse gas emissions (Crippa et al., 2021).

The agricultural sectors, which include crop and livestock production, forestry, fisheries and aquaculture, are a major contributor to global greenhouse gas emissions and other environmental pressures, including air, water and soil pollution, habitat degradation, deforestation, biodiversity loss and the emergence of zoonotic and food-borne diseases. (WHO, 2025) In turn, climate change is jeopardizing food security and the resilience of agrifood supply chains, with climate-induced natural hazards leading to production losses that exacerbate vulnerability in agroeconomies and undermine rural development.

As demand for agricultural commodities is projected to increase substantially (by 35–56% between 2010 and 2050), (van Dijk et al., 2021) pressure is intensifying to further intensify production systems or expand cropland through land-use change. While such responses may increase short-term food output, they are also likely to accelerate conversion of natural ecosystems, resulting in biodiversity loss and degradation of critical ecosystem services, including soil fertility, water regulation, and climate regulation. These land-use dynamics increase exposure and vulnerability of poor and marginalized populations, thereby amplifying long-term social, ecological, and food-system risks.

Food consumption patterns and production methods have profound implications for both human and ecosystems health. Each lifecycle phases of agrifood systems —including production, processing, transport, distribution, preparation, consumption, and waste management—generates greenhouse gas emissions that contribute to climate change. These emissions originate from on-farm crop and livestock production, land-use change associated with deforestation, biomass burning, and peatland degradation, as well as post-production

activities across the agrifood supply chain, including processing, trade, distribution, consumption and waste disposal (Dussi, M. C., 2025). A growing number of studies indicate that the impact of the global agrifood system on climate change increases substantially when pre- and post-production processes across supply chain logistics, food processing and retail, consumption patterns, and waste management are taken into account. When all agrifood system activities are collectively considered, total emissions are estimated to represent approximately 20–40% of global anthropogenic greenhouse gas emissions (UNIDO, 2025; Mandouri et al., 2025; Crippa et al, 2021).

The agricultural sector faces two interlinked challenges: sustainably increasing productivity to meet rising global food demand, and addressing climate change by reducing greenhouse gas emissions and enhancing adaptive capacity and resilience of production systems. Since the adoption of the United Nations Sustainable Development Goals (SDGs) in 2015 under the 2030 Agenda, there has been growing recognition that transforming agrifood systems is essential for reducing environmental pressures while enhancing food security under climate change. As a result, agricultural sustainability has become a central focus of international policy agendas, including the UN Food Systems Summits, the UN Framework Convention on Climate Change Conferences of the Parties (COPs), and the IPCC Sixth Assessment Report (AR6). Enhancing sustainable agriculture within the broader food system framework requires strategic policies to simultaneously advance climate mitigation and adaptation, safeguard biodiversity and natural resources, and improve public health, while strengthening the resilience and long-term sustainability of agrifood systems.

1.1 Ensuring sustainability in agrifood systems

Sustainable development is based on three fundamental pillars: social, economic and environmental. Sustainability in agriculture defined as "food system practices that contribute to long-term regeneration of natural, social, and economic systems, ensuring the food needs of the present generations are met without compromising food needs of future generations" (HLPE, 2020).

Sustainable agriculture constitutes a fundamental component of food security and sustainable development, directly contributing to the achievement of multiple SDGs related to climate change mitigation and food security. Specifically, it supports poverty reduction through the creation of resilient and diversified livelihoods (SDG 1: No Poverty); advances food security and improved nutrition through the promotion of sustainable agricultural practices (SDG 2: Zero Hunger); reduces health risks by minimizing the use of harmful chemicals (SDG 3: Good Health and Well-Being); enhances the efficient and responsible use of natural resources (SDG 12: Responsible Consumption and Production); and strengthens the resilience of agricultural ecosystems and rural communities in the context of climate change (SDG 13: Climate Action).

Sustainable agricultural development has a crucial role in achieving food security, improving livelihoods, and safeguarding natural resources. Sustainable agricultural development seeks to enhance productivity while maintaining soil health, improving the efficiency of water and energy use, conserving agricultural biodiversity, reinforcing rural resilience and promoting equity and social well-being (FAO, 2016b). Achieving these objectives requires a holistic consideration of agrifood system. Such an approach integrates coherent strategies across agricultural sectors and throughout all stages of the agrifood value chain, while managing trade-offs among the economic, social, and environmental dimensions of sustainability. Integrated approaches of

sustainable agriculture can reduce natural resource depletion, improve the efficiency of natural and financial resource use, and strengthen agricultural food supply chains. Sustainable agricultural development offers a cost-effective pathway to enhance equity, particularly in developing countries, by delivering targeted benefits to small-scale farmers and increasing the resilience of communities most vulnerable to climate-induced risks (UNICEF, 2025).

Transitioning to sustainable agricultural production systems and food value chains requires coordinated action by all stakeholders, including local communities and governments, civil society, and the private sector and green entrepreneurship across the design and implementation of policies, programmes, and investments.

Current strategies for sustainability in agriculture remain insufficient to enable a transition to sustainable agrifood systems. This situation poses a major threat to agricultural communities, especially in developing countries, which are already suffering from poverty, hunger, and malnutrition. Measures such as reducing meat consumption and shifting to plant-based diets like legumes, fruits, and vegetables, decreasing food waste and improving food production through innovative technologies are common components of agrifood system change. However, solely, these measures do not address the deeper institutional, policy, and economic factors that drive unsustainable agrifood systems (McGreevy et. al, 2022). This determination highlights the importance of the IPCC's AR6 discussion of degrowth as a transformative approach for advancing sustainable agrifood systems, emphasizing the need to integrate both socio-economic and ecological sustainability.

Sustainable agricultural practices can contribute to mitigating climate change by enhancing soil carbon sequestration such as reduced tillage, improved grazing management, the restoration of organic soils

and restoration of degraded lands. These sustainable management practices include diversified farming systems such as crop rotation, agroforestry, inter cropping, embedding natural habitats, and mixed crop and livestock farming. In extensively managed systems, often characterized by low input agrochemicals, and high diversity croplands with low yields, crop production could be strengthened through conserving agricultural biodiversity by rotating mixed crops and plantings densities, vegetation strips or through agroforestry systems. Intensively managed systems on the other hand, often signified by large tracts of monocultures managed with high agrochemicals, could be diversified through mixed plantings, agroforestry systems including diversified home gardens, boundary planting that involves use of hedgerows or tree breaks, embedding natural habitats e.g., vegetation strips, and diversifying landscapes surrounding croplands.

An increasing body of evidence suggests that sustainable agricultural practices are associated with over 10 % increase in food production (Beillouin et al., 2021; Zhao, 2022), improved economic outcomes over 20% (Himmelstein et al., 2016; Sánchez et al., 2022), around 19% reduced groundwater depletion (Yang et al., 2021; Wang, S. et al., 2023), enhanced carbon mitigation about 11% (Tamburini et al., 2020) and significant gains-over 20%- in biodiversity conservation (Bowman et al., 2013; Mauser et al., 2015; Rosa-Schleich et al., 2019; Jones et al., 2021; Beillouin et al., 2021; Zhao, 2022).

Another promising strategies for agricultural sustainability is ‘climate-smart agriculture’. UN Food and Agriculture Organization (FAO) introduced the concept of climate-smart agriculture in 2010. FAO promotes climate-smart agriculture to transform agricultural production systems and food value chains to support sustainable development and ensure food security under climate change. Climate-smart agriculture provides a framework for stakeholders at all levels to identify agricultural strategies adapted to local conditions, supporting more

productive and sustainable agrifood systems including crops and livestocks, forestry, fisheries, and aquaculture (FAO, 2025b).

Objectives of climate-smart agriculture involves improving productivity and livelihoods in a sustainable manner, building resilience and adaptive capacity to climate change, and reducing or removing greenhouse gas emissions where possible. More than 30 countries—predominantly in sub-Saharan Africa—explicitly reference climate-smart agriculture in their Intended Nationally Determined Contributions (INDCs) submitted to the UNFCCC, while many others highlight the strategic role of agriculture in climate action. In line with Türkiye's INDCs, the Ministry of Agriculture and Forestry launched the World Bank–financed Türkiye Smart Climate and Competitive Agricultural Growth Project (TUCSAP) in 2023. With a budget of over TRY 9.17 billion, TUCSAP seeks to enhance the productivity, competitiveness, and climate resilience of the agricultural sector by supporting around 43,000 farmers in adopting smart agriculture technologies (GrowTech, 2023).

1.2 Ensuring food security in agrifood systems

According to the latest State of Food Security and Nutrition in the World (SOFI, 2025) report by the UN World Food Programme, an estimated 8.2% of the global population—approximately 673 million people across Africa, Asia, and Latin America—experienced hunger in 2024. Of these, around 343 million people faced acute food insecurity. Moreover, approximately 2.3 billion people experienced moderate or severe food insecurity, while 2.6 billion were unable to afford a healthy diet. Projections under climate change indicate that hunger will persist, with an estimated 512 million people still affected by 2030. Food insecurity remains disproportionately higher in rural areas than in urban settings and continues to affect women and children most severely. Conflict, climate variability and weather extremes, and economic shocks