

MULTIDIMENSIONAL CHALLENGES OF THE AGRICULTURAL SECTOR AT NATIONAL AND GLOBAL LEVELS

(Tantangan Multidimensi Sektor Pertanian di Tingkat Nasional dan Global)

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ABSTRACT

The diverse challenges faced by the agricultural sector make prioritization crucial. This approach allows stakeholders to focus on the most urgent and critical issues first before addressing lower priority ones. This study aims to analyze the main (priorities) challenges for the agricultural sector, both nationally and globally. This study employed a qualitative approach through a literature review of 100 studies published over the past 10 years (2013-2023). The findings identify 8 (eight) major challenges in the agricultural sector, namely climate change and risks of water deficits, energy, biodiversity and ecosystem services, social infrastructure, governance and policies, food supply chains, consumption patterns, and intensification of sustainable agriculture. This study concludes that achieving sustainable agriculture and food systems necessitates a robust and balanced understanding of both agronomy and ecology, enhancement of social capital through farmer and community participation, and policies that prioritize environmental preservation and human welfare while remaining unaffected by the political interests of a few parties.

Key words: agriculture, challenges, food, priorities, sustainability

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INTRODUCTION

Food production has increased significantly over the past five decades; however, the agricultural sector in Indonesia and globally still faces major challenges in meeting the food demands of a growing population, which is projected to reach 9.7 billion people by 2050 (Badan Pusat Statistik, 2023; Gerland et al., 2022). Addressing this rising demand without triggering significant price increases will require a 70 to 100% increase in food production, particularly in light of the intensifying effects of climate change and the depletion of energy resources (Tessari et al., 2016; Tomlinson, 2013). These projections raise several concerns, such as what policies are necessary to achieve such large-scale increases in production, and how to do so without exacerbating many of the existing problems in the agricultural sector.

The challenges facing the agricultural sector are becoming increasingly alarming due to rising purchasing power and shifts in consumption patterns in Indonesia and globally, as well as difficulties in food access and distribution in remote areas. Additionally, the pressure to meet

the Millennium Development Goals (MDGs) of reducing poverty and hunger (Fonseca et al., 2020; Hickel, 2016) further complicates the situation. Land use changes, particularly the shift from agricultural to non-agricultural purposes, have also become a key factor exacerbating issues within the agricultural sector (Crippa et al., 2021). This combination of factors creates increasingly multidimensional challenges, placing immense pressure on the sector to ensure food security sustainably, both economically and socially, as well as from an environmental perspective (Tian et al., 2018).

The agricultural sector faces increasingly multidimensional challenges due to the fluctuations in food prices, which disproportionately affect the poor, particularly during peak food price periods in 2007-2008 and 2010-2011 (Raleigh et al., 2015). Political/policy controversies and scientific debates have emerged regarding agriculture's role in carbon sequestration and biofuel emissions (Palmer, 2014). The agricultural sector is claimed to contribute one-third of global greenhouse gas emissions (21%), nearly double that of the transport sector, which

contributes only 14% (Crippa et al., 2021; Lamb et al., 2021). The multidimensional nature of the agricultural sector's challenges is further highlighted by international pressure for policies that increase production efficiency and promote more sustainable land use in both industrialized and developing nations (Osborn et al., 2015; Shideed et al., 2014). Therefore, the goals of the agricultural sector are no longer solely about maximizing productivity and achieving food self-sufficiency, but also optimizing production landscapes, rural development, environmental sustainability, and social justice, all of which are inherently difficult and/or multidimensional to achieve.

The United Nations' final report on the Millennium Development Goals (MDGs) claims that the initiative has been the most successful anti-poverty movement in history, citing the halving of global poverty and hunger since 1990. However, several studies challenge this claim. For instance, one study argues that the UN's assertions about reducing poverty and hunger are inaccurate (Hickel, 2016), while another suggests that many MDG targets remain unlikely to be met (Leal Filho et al., 2023). After 2015, there have been concerning trends. Global hunger has increased, with around 735 million people experiencing chronic hunger in 2022 (UN SDG Report, 2023), and over 2 billion people facing moderate to severe food insecurity (UN SDG Report, 2023).

The MDGs are accused of deliberately manipulating statistics to create an illusion of progress in poverty and hunger trends, whereas these trends have actually worsened (Bendell, 2022). The MDGs also use definitions of poverty and hunger that dramatically underestimate the scale of these humanitarian issues. In reality, around four billion people remain in poverty and approximately two billion suffer from hunger—numbers larger than any historical record and two to four times what the UN claims and expects the global community to believe (Bendell, 2022; Hickel, 2019). These facts have profound implications, indicating that the worsening trends in poverty and hunger highlight the significant challenges facing agriculture in ensuring food security, which demands serious attention.

In 2010, a study identified over 100 critical questions the agricultural sector must address to

achieve sustainability, including those related to increasing productivity without environmental degradation, integrating climate resilience, enabling equitable market access, promoting sustainable policy frameworks, and ensuring food system inclusivity (Pretty et al., 2010). A decade later, many of these questions remain relevant challenges for the agricultural sector (Pervez Bharucha et al., 2021). This persistence indicates that the number and complexity of sustainability challenges have not significantly diminished. Given the sector's limited resources and the urgency of global food security and climate concerns, it becomes imperative to identify and prioritize the most pressing challenges. Unlike previous studies that listed or broadly discussed numerous issues, this study offers a structured prioritization of key challenges both at the national and global levels, using a multi-criteria approach. This prioritization enables policymakers and stakeholders to allocate resources more effectively and develop targeted strategies for sustainable agricultural development.

This study aims to identify and prioritize the main challenges facing the agricultural sector at both national and global levels and to provide sustainable solutions. Specifically, the objectives of this research are to assess the socio-ecological challenges impacting agriculture, to analyze key governance and policy issues that affect sustainability in the sector, and to develop targeted strategies for addressing these challenges and promoting agricultural sustainability. By prioritizing these challenges, the study seeks to guide policymakers, stakeholders, and communities towards more effective agricultural development practices.

METHOD

This research was conducted from January to June 2024. This study is qualitative in nature, employing a Systematic Literature Review (SLR) approach. The SLR method was used to identify, evaluate, and synthesize existing research on challenges in the agricultural sector. To ensure transparency and replicability, the selection of literature followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol (see Figure 1).

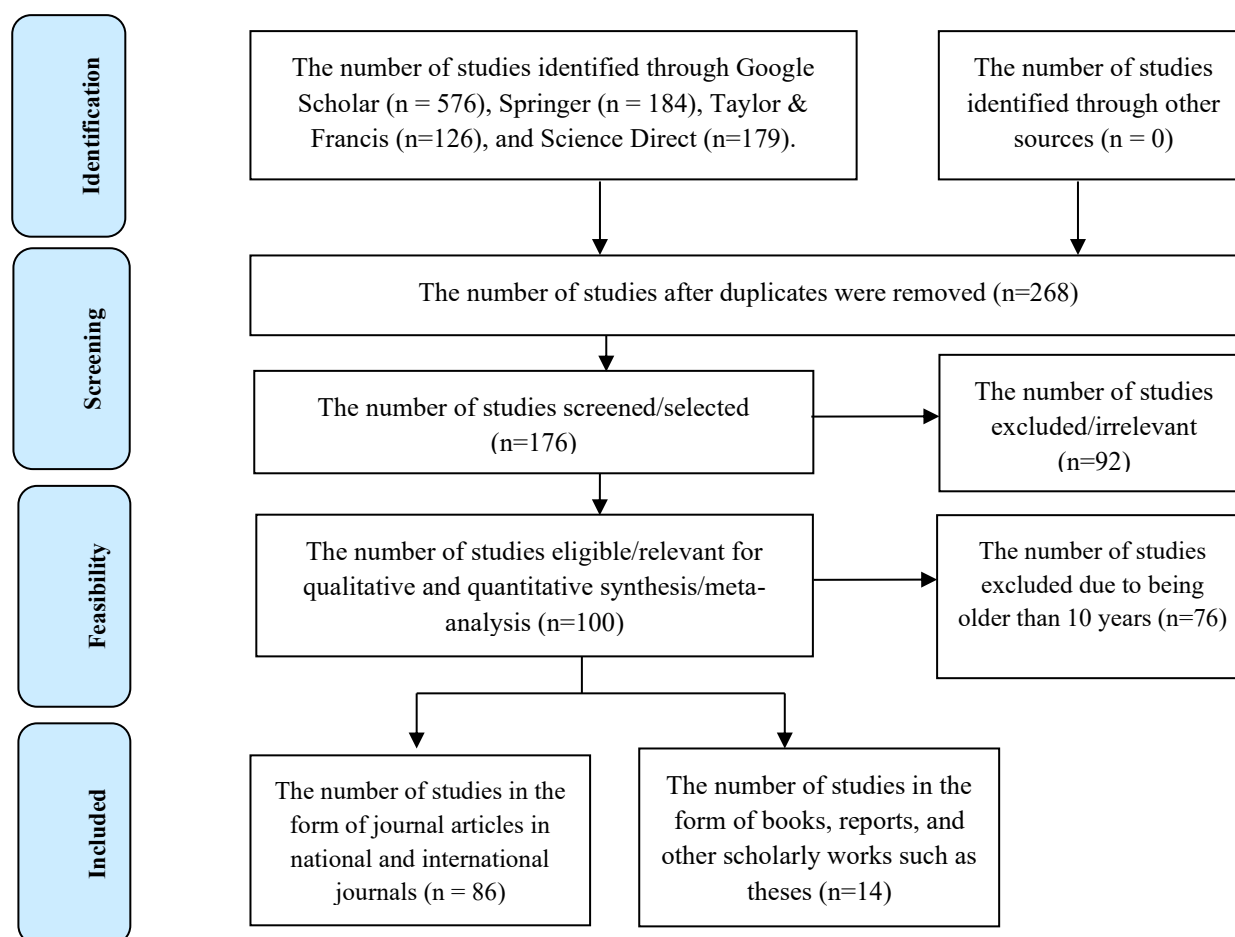


Figure 1. PRISMA Flow Diagram
Source: adapted from Moher et al. (2009)

Based on the PRISMA protocol, this research identified 100 studies relevant to the research objectives. These studies were published within the last 10 years (2013-2023), with the majority (86%) reported in scientific journal articles. The studies cover a range of topics and/or issues including climate change, land and water, food systems, crop agriculture, fisheries and livestock, community studies (poverty, gender), integrated pest management, social capital, conservation and environmental damage (pollution, greenhouse gas emissions), biodiversity, consumption and diet patterns, agricultural politics and economics, energy, agricultural innovation/technology, supply chains, farmer and rural organizations, and extension services. Some studies were published in other scholarly formats (e.g., books and reports) on

topics such as global agricultural value chains, population growth, meat consumption trends, Millennium Development Goals, women's participation in development, and global agricultural outlook.

RESULTS AND DISCUSSION

Based on the literature review, Figure 2 illustrates that the main challenges (priorities) in the agricultural sector stem from eight aspects: climate change and water deficit risks, energy, biodiversity and ecosystem services, social infrastructure, governance and policies, food supply chains, consumption patterns, and sustainable agricultural intensification.

Climate Change and Water Scarcity

Climate change projections indicate that the Earth will become warmer over the coming decades, but the impacts of rising temperatures on precipitation patterns remain uncertain (Schlaepfer et al., 2017). This suggests that while global temperatures are expected to increase, the effects on rainfall distribution are still unclear. Higher temperatures are likely to exacerbate evaporation and lengthen dry seasons in various regions. Increased evaporation and more frequent dry seasons contribute to rising temperatures and drought

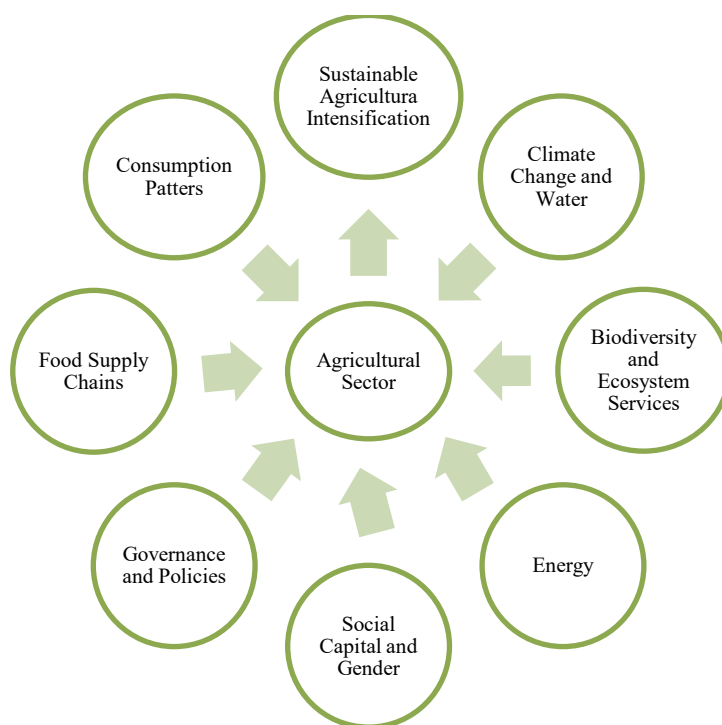


Figure 2. Main Challenges in the National and Global Agricultural Sector
Source: Literature Review

conditions worldwide. A study analyzing global drought conditions due to temperature increases of 1.5°C, 2°C, and 3°C reports that two-thirds of the global population will experience the impacts of progressive drought conditions (Naumann et al., 2018). For arid regions, the duration of global drought is projected to increase significantly from an average of 2 months (with less than a 1.5°C rise) to an average of 4.2 months (with temperatures nearing 3°C). If temperature increases continue, the risk of water deficits could increase fivefold in many parts of the world (Naumann et al., 2018; Tabari dan Willems, 2023; Tripathy et al., 2023). Countries in East and Southern Africa such as Ethiopia, Kenya, Malawi, Mozambique, Somalia, South Sudan, Zambia, and Zimbabwe have already been identified as highly vulnerable to these conditions (Nakamura, 2023). Similarly, countries in the Middle East and North Africa like Yemen, Palestine, Qatar, and Kuwait are experiencing extreme water stress due to intensified climate variability and limited freshwater resources (UNICEF Mena, 2023). Furthermore, more than 9,500 river basins across continents are facing increasing water scarcity risks as a result of climate-induced changes in hydrological patterns (Nakamura, 2023; Blöschl et al., 2023; Schewe et al., 2014).

One major cause of climate change is the emission of greenhouse gases (GHGs) from human activities

related to transportation, urban development, industrialization, energy sources, agriculture and food production systems, improper waste management, land use, and forestry (Hussain et al., 2019). The concentration of carbon dioxide (CO₂) in the atmosphere continues to rise, leading to increased GHG emissions (Moriarty dan Honnery, 2020). CO₂ emissions account for 54% of total GHG emissions, while methane, nitrogen oxides, carbon monoxide, and volatile organic compounds contribute 36%, 9%, 0.75%, and 0.3%, respectively (Hussain et al., 2019).

Climate change disrupts the physical, chemical, and ecological balance of oceans, with significant consequences for marine life (Sumaila dan Tai, 2020). Global warming leads to increased sea temperatures, which impairs the ocean's ability to absorb greenhouse gases (GHGs) (Scholes, 2016; Venegas et al., 2023). Rising sea temperatures threaten biodiversity not only at the surface but also progressively into deeper zones (Brito-Morales et al., 2020). The increase in sea temperatures results in heightened oxidative stress on certain fish species, which can lead to decreased cellular function, disease, and ultimately cell death (Almroth et al., 2015). This issue is exacerbated by overfishing, putting many commercially consumed and traded fish species at risk of near-extinction (Sumaila dan Tai, 2020). This has a significant impact on both national and global food security.

A study in Europe suggests that fish capture and/or exploitation needs to be reduced by 50–80% to restore the sustainability of current fish supplies (Froese et al., 2018). However, this alone is insufficient to ensure the sustainability of human food systems. Interventions are required at all levels, from production to consumption patterns, and management of conservation zones and entire river basins, focusing not only on fish supply sustainability but also on water resource efficiency (Hoekstra, 2014; Shi et al., 2024). In many countries, water resources are becoming increasingly scarce for agriculture due to rising competition for urban and industrial use (Flörke et al., 2018; Russo et al., 2014). Therefore, the need for improved management practices for crops, land, and water is becoming more urgent, particularly in light of climate change.

Biodiversity and Ecosystem Services

Agriculture, as an integral part of the food system, is often cited as a major driver of biodiversity loss in Indonesia and other countries, primarily due to habitat conversion such as forests and wetlands into agricultural land (Msofe et al., 2019; Pullanikkatil et al., 2016; Syahza et al., 2020). Similar cases can also be seen in African countries like Kenya and Tanzania, where the expansion of agricultural land into natural habitats has significantly threatened biodiversity. Increased agricultural efficiency also contributes to the decline of species that are symbiotic with agricultural landscapes, driven by the rising use of chemicals (e.g., pesticides, herbicides, and fertilizers) and landscape homogenization due to regional agricultural specialization (Adhikari, S., et al., 2019; Prokopová et al., 2019). In European and North American regions, for example, intensification practices have resulted in similar patterns of biodiversity loss despite different regulatory contexts. Furthermore, agriculture has become a significant cause of ecosystem service degradation (e.g., water pollution), increased greenhouse gas emissions, and reduced carbon sequestration (Adhikari, S., et al., 2019; Gao et al., 2018; Marques et al., 2019).

Livestock farming, as a sub-sector of agriculture, has the most substantial negative impact on terrestrial ecosystems and biodiversity in tropical countries. Indonesia, being one of the 17 megadiverse countries, is home to a high level of biodiversity and endemic species. To support livestock production until 2050, some megadiverse countries such as Brazil, Indonesia, and the

Democratic Republic of Congo are expected to need to expand agricultural land by 30–50%. Such large-scale land expansion will lead to the loss of many natural habitats and biodiversity, in addition to poaching, especially in Africa (Machovina et al., 2015).

Organic agriculture is often perceived as more sustainable than conventional agriculture. However, a global evaluation of this assumption found that, in terms of environmental and climate impact, organic farming causes less pollution compared to conventional farming per unit of land. Yet, this is not the case when measured per unit of product (Meemken dan Qaim, 2018). Organic farming, covering only about 1% of global agricultural land, has lower average yields, necessitating more land to match conventional farming yields (Meemken dan Qaim, 2018). This is especially evident in countries with large-scale organic sectors such as Germany, France, and the United States. Organic farming requires higher levels of farmer knowledge, and the knowledge gap increases as more farmers switch to organic practices. Expanding organic farming will lead to the loss of natural habitats and higher product prices, making food less affordable for poor consumers in developing countries such as India, Nigeria, and Bangladesh (Meemken dan Qaim, 2018).

Thus, the greatest challenge for the agricultural sector, in terms of biodiversity and ecosystem services, is finding the best solutions to increase food production without compromising biodiversity, ecosystem services, and community well-being. Appropriate technologies can be used to enhance agricultural intensity by optimizing the productivity of existing agricultural land, such as through the use of drought-resistant crop varieties. Therefore, the best solutions require a comprehensive understanding to balance intensification and extensification in sustainable food production.

Energi Needs

Energy demand is expected to rise significantly in the coming decades due to population growth. Agriculture is a major energy consumer, using energy directly through machinery and irrigation, and indirectly through inputs like fertilizers and pesticides (Molajou et al., 2021). For instance, in Indonesia, rising oil prices have had broad impacts on rural households, particularly among low-income families who struggle to afford fuel for

irrigation and farm machinery (Adnyani dan Sugiharti, 2019).

Globally, higher oil prices also increase the cost of agricultural inputs such as fertilizers, pesticides, and transportation, which can reduce productivity and push farmers to expand agricultural land, thus worsening environmental degradation (Koirala et al., 2015). The challenge of providing sufficient and affordable energy is especially pressing for smallholder farmers in developing countries who face limited access to reliable electricity. In response, some regions have turned to renewable energy. For example, in India, solar-powered cold storage technologies have been adopted to reduce post-harvest losses and expand market access, enhancing energy efficiency (IEA, 2025).

Meanwhile, the global electricity demand is projected to increase by about 4% per year through 2027, driven by industrialization, cooling demand, transport electrification, and data center growth. This surge will be largely met by renewables such as solar photovoltaic (PV), wind, and nuclear power. Solar PV alone is expected to account for around 50% of this growth, while nuclear power expansion is taking place in countries like France, Japan, China, India, and South Korea (IEA, 2025). The energy transition in developing and emerging economies including Indonesia, India, China, Kenya, and South Africa will be crucial in meeting rising energy needs while reducing carbon emissions (IEA, 2025; IEEJ, 2024). Therefore, the primary challenge is ensuring energy that is adequate, affordable, and sustainable for the agriculture sector, enabling increased food production without increasing greenhouse gas emissions. This requires the adoption of energy-efficient technologies and the expansion of renewable energy use (Masturi et al., 2021).

New Forms of Social Infrastructure (Social Capital and Gender

Social capital refers to the ability to facilitate collective action for mutual benefit, encompassing three primary dimensions: bonding, bridging, and linking (Rayamajhee dan Bohara, 2021). Bonding involves relationships within homogeneous groups, such as family, friends, and relatives, while bridging connects individuals or groups across different social divides. Linking refers to relationships with influential economic or political entities (Cofré-Bravo et al., 2019). A study in rural Indonesia by Nugroho dan Kurniawan (2018) explored the role of social capital in enhancing

farmers' access to government subsidies and agricultural technology. The study found that bonding social capital provided immediate support among family and community, while bridging ties to government agencies helped improve access to external resources. However, limited linking social capital with formal institutions was identified as a barrier to further economic opportunities.

Similar patterns have been observed in Maharashtra, India, where social capital significantly enhanced smallholder farmers' production efficiency and risk management through trust-based sharing of resources and collective action (Poli, 2015). In several sub-Saharan African countries, the absence of strong linking social capital has also been linked to low agricultural innovation uptake due to weak ties with research and government bodies (Ihalainen et al., 2021). Many collective resource management programs emphasize building social capital to facilitate cooperation and reduce transaction costs. Such programs use terms like community, participation, collectivity, decentralization, and joint management (Bell dan Newby, 2021; Mashlakov et al., 2021; Murunga et al., 2021). The common goal is to build trust, develop new norms, and form groups with high social cohesion (Serageldin dan Grootaert, 2017). The assumption is that individuals are more likely to engage in collective activities if they believe others will also participate and are less likely to engage in detrimental actions if they believe others will refrain (Cobigo dan Stuart, 2010).

A multi-country case study in Europe including Germany, Spain, Italy, Lithuania, Latvia, Denmark, highlights how social capital manifests differently across contexts but consistently contributes to the vitality of rural development and agricultural resilience (Rivera et al., 2018). Trust, cultural traditions, and community solidarity are central features enabling the implementation of participatory agricultural policies.

Historically, extension services aimed to bridge research results with farmers. However, support for such monolithic extension structures has waned due to their limited success in technology transfer and information flow. Many extension systems globally have been closed or underfunded, leading to a lack of institutions connecting farmers with external entities, especially markets (Ragasa et al., 2016). Participatory extension approaches have emerged in response, incorporating social capital concepts through initiatives like Farmer Field

Schools (FFS) and Agricultural Knowledge and Information Systems (AKIS) (Mariyono, 2018; Zahran et al., 2020). In addition to FFS and AKIS, social infrastructure involving farmers can include cooperatives, rural resource centers, business groups, interest groups, micro-credit groups, and water user groups (Meinzen-Dick et al., 2014).

In Indonesia and Uganda, FFS have shown notable success in strengthening farmers' social cohesion and trust, while in Brazil's semi-arid zones, farmer cooperatives and knowledge-sharing platforms have empowered rural women and improved their household livelihoods (Donà, 2022; Ihalainen et al., 2021). Participatory extension emphasizes farmer involvement in learning and applying technology within specific local contexts (agroecological, social, and economic) (Charatsari et al., 2020). Farmers learn best when encouraged to experiment, learn directly, and apply practices suited to their local conditions. Researchers also benefit from working participatively with farmers to ensure that crop and livestock varieties are developed according to local needs and norms. Farmer involvement is crucial in sustainable intensification practices, as recommendations often seem incompatible with local practices, such as introducing forage crops into maize systems, managing pests with trap plants, planting rice with wider spacing, and replacing plowing with conservation techniques like agroforestry (Barbeau et al., 2015; de Freitas dan Landers, 2014; Donggulo et al., 2017; Juniawan, 2021; Malahayatin dan Cahyono, 2017; Septariani et al., 2019; Yanti dan Halimi, 2022).

The challenge for agriculture in the context of social infrastructure is strengthening social capital to facilitate innovation/technology diffusion and enhance access to new markets by connecting farmer groups with external markets and processing industries (Rivera et al., 2019). Additionally, gender justice presents another critical challenge in agricultural social infrastructure development. Gender justice (the involvement of both men and women in development) is not only a political or ideological issue but also a matter of development effectiveness, ensuring benefits for the entire community (Donà, 2022). This is particularly evident in the province of Almería, Spain, where women's involvement in greenhouse horticulture has transformed gender roles and contributed to local economic growth (Odini, 2014). Likewise, in Indonesia's dairy sector, women's participation in farmer cooperatives has strengthened community

bonds, though leadership roles remain limited due to persistent gender norms (Ihalainen et al., 2021). Gender-sensitive agricultural research and development can transform community practices and improve role division between men and women (Ihalainen et al., 2021). Understanding barriers and opportunities for both genders in agriculture can enhance community contributions to agricultural productivity, food security, and poverty reduction (Kurniawanto dan Anggraini, 2019; Odini, 2014).

Governance and Policies

The development of agriculture as a central pillar in national development agendas presents substantial challenges in managing and aligning the diverse interests of formal and informal institutions, including government, the private sector, and civil society. These challenges stem from issues related to interconnections, responsibilities, processes, mechanisms, and institutional differences. Effective governance, economic investment, power dynamics, and policy-making are essential to addressing these challenges (Hinrichs, 2014). Smallholder farmers, in particular, require protection from risks and assurances regarding both their economic and social well-being. In this context, the state plays a pivotal role in shaping the adoption of new technologies and influencing policy decisions that can support their implementation.

For instance, in Indonesia, the rising fuel prices have significantly impacted smallholder households, particularly in their ability to purchase diesel for irrigation. This economic pressure has prompted local agricultural communities to explore and adopt renewable energy alternatives as a form of adaptation and resilience, reflecting how national energy policy and agricultural sustainability are deeply intertwined (Adnyani, et.al. 2019). The agricultural sector, which has been operational for over fifty years, is increasingly recognized as unsustainable, particularly in light of its health and environmental impacts, its failure to alleviate rural poverty in developing nations, and the power imbalances within the food value chain (De Schutter, 2017). Significant change is unlikely to result from government actions or private-sector initiatives alone. While community-driven innovations have proven beneficial, they often lack sufficient support and impact. Agricultural reforms, at both the national and global levels, can only achieve sustainable outcomes if there is robust

collaboration and democratic engagement among the three key actors: the government, private sector, and local communities (De Schutter, 2017).

In several countries across Africa and Asia, women's empowerment through the strengthening of social capital has been shown to enhance both productivity and community well-being, demonstrating the role of inclusive governance structures in fostering sustainable development (Ihalainen et al., 2021). This also highlights how targeted policy interventions can influence power dynamics within agricultural systems and encourage more equitable participation. Achieving the desired growth targets in food production requires comprehensive investments across various agricultural systems, from intensive systems necessitating substantial mechanization to small-scale farming. Critical questions revolve around the optimal mix of public and private investments, alongside active community participation. Investments should focus on areas such as irrigation and water management, rural infrastructure development, and the provision of agricultural financial services and extension services. These investments are vital for transitioning agricultural systems toward greater sustainability (De Schutter, 2017; van Berkum et al., 2018).

Food Supply Chains

Food supply chains (FSC) encompass all activities occurring between production points and consumption points. Since 1950, food supply chains have undergone fundamental changes, becoming increasingly global in scale (Fernandez-Stark dan Gereffi, 2019). This shift is characterized by rising production levels, an increase in manufactured products, and the concentration of various economic sectors. Managing food supply chains has become more complex, involving numerous stakeholders, including public, private, and civil society sectors (Baker et al., 2020). Over the past two decades, power within food supply chains has shifted towards food retail, predominantly controlled by large companies (Ferne dan Sparks, 2014). In the United States and most developed countries, the dominance of supermarkets as the main retail format has transformed food distribution systems. This shift has raised environmental and health concerns, especially due to supply chain strategies that prioritize year-round availability at low costs, often at the expense of sustainability (Pulker et al., 2018; García et al., 2022).

In contrast, in Indonesia, the fresh food supply chain including vegetables and fruits relies heavily on local farmers, distributors, traditional markets, and increasingly, supermarkets. However, the sector continues to face major challenges in terms of distribution efficiency and post-harvest losses, highlighting a persistent gap in supply chain modernization and infrastructure (Nugroho dan Kurniawan, 2018). The definition of 'sustainable food' remains highly necessary. Life cycle assessments and other technical actions are crucial for evaluating energy, carbon, water, and other environmental impacts (Cerutti et al., 2014; Houshyar dan Grundmann, 2017). However, social, economic, and ethical criteria must also be considered to determine the appropriate trade-offs (Baiano, 2020). The goal is to illustrate the relationship between consumption patterns and environmental and social impacts, encouraging all parties to take responsibility and change behaviors to develop more sustainable food supply chains (Notarnicola et al., 2017).

Consumption Patterns

Changes in food consumption patterns are influenced by rising purchasing power, shifting food preferences, easier access to global markets, and significant population growth over recent years, with projections for continued growth in the coming decades (Vicentini et al., 2016). Daily per capita calorie consumption has increased from 2280 kilocalories in the 1960s to 2800 kilocalories since the turn of the millennium (Habtmu Lemma, 2015).

As income levels rise in developing countries, global meat consumption has increased by 58% over 20 years, reaching 360 million tons by 2018 (Whitnall dan Pitts, 2019). The growth in global meat consumption is projected to continue, increasing by 14% by 2030 compared to the baseline period (2018-2020), primarily driven by income and population growth. The availability of protein from beef, pork, poultry, and lamb is projected to grow by 5.9%, 13.1%, 17.8%, and 15.7%, respectively, by 2030 (FAO dan OECD, 2021).

In China, per capita meat consumption has continued to rise, particularly for pork, which is projected to account for 70% of the global increase in pork consumption by 2030. For example, per capita beef consumption in China increased from 1.3 kg in 2020 to 1.5 kg in 2021, reflecting

changing dietary preferences in line with economic growth (FAO dan OECD, 2021; National Bureau of Statistics China, 2021). Changes in consumer preferences, along with aging and slower population growth in high-income countries, have led to a decrease in per capita consumption of red meat (such as beef and lamb) and a shift towards white meat (poultry) (FAO dan OECD, 2021). Consumers in high-income countries prefer poultry for its ease of preparation and perceive it as a healthier food option, while low-income consumers in developing countries prefer poultry due to its lower cost compared to red meat (FAO dan OECD, 2021).

Global poultry consumption is expected to account for 41% of all animal protein consumption by 2030, up by 2% compared to the baseline period (2018-2020). Other meat products have lower global shares: beef (20%), pork (34%), and lamb (5%). Per capita meat consumption in China is expected to rise, particularly for pork. China is projected to contribute 70% of the global increase in pork consumption from the baseline period to 2030. Global per capita meat consumption is projected to increase by 0.3% per year to 35.4 kg per year in retail weight equivalent by 2030. More than half of this increase is attributed to higher per capita poultry consumption (FAO dan OECD, 2021). This rise in meat consumption is expected to lead to an increase in meat production from 229 million tons in 1990 to 465 million tons by 2050, while milk production is projected to increase from 580 million tons to 1043 million tons (Lal, 2020).

Changes in consumption patterns combined with population growth have created predictions that agricultural production must significantly increase to meet future food needs. However, increased consumption of meat products and other animal-based products does not appear to provide the same health benefits as a balanced diet rich in grains and other plant-based products (Hemler dan Hu, 2019). The use of dairy and meat products (particularly red meat), sugar, and other high-fat ingredients characterizes modern processed foods. These products tend to lead to nutritional deficiencies and higher rates of obesity and related diseases such as type II diabetes and chronic heart conditions (Muscogiuri et al., 2022). The increased risk of serious diseases due to an unhealthy diet will, in turn, drive higher demand and expenditure on healthcare facilities, products, and services.

Sustainable Agricultural Intensification

The increase in agricultural production worldwide has helped millions escape poverty, reduce hunger, and provide a platform for economic growth in both rural and urban areas. This rise in production was largely driven by the Green Revolution, which began in the 1950s and expanded globally throughout the 1960s (Campagnolla et al., 2019). The Green Revolution introduced various advancements in agriculture, including new varieties, inputs, water management, and rural infrastructure (Campagnolla et al., 2019). However, despite these efforts more than 60 years ago, the Green Revolution has not succeeded in achieving a world free from hunger and poverty. Currently, around four billion people remain in poverty, with an additional two billion still suffering from hunger worldwide (Bendell, 2022; Hickel, 2019).

Experts agree that global food production must increase significantly to address hunger and help alleviate poverty. However, there is disagreement on the best way to achieve this goal. Some experts argue that agriculture should expand into new lands, but competition for land is becoming increasingly difficult and costly (due to competition with non-agricultural activities), especially if the priority is to protect biodiversity and the public goods provided by natural ecosystems (such as carbon storage in rainforests) (Baudron dan Giller, 2014). Others believe that the growth of food production must come through a more aggressive approach, doubling the efforts of the Green Revolution (Muthayya et al., 2014). Another group of experts supports the adoption of biotechnology or a shift towards organic farming systems (Fraser et al., 2016).

Despite differing opinions, one thing is clear: agriculture must produce more from the existing farmland. Agricultural production as a food source must be increased. The literature suggests three common ways to enhance agricultural yields: increasing yield per hectare, intensifying cropping (i.e., two or more crops per unit of land) and inputs (fertilizers), and shifting land use from low-value crops (or commodities) to crops with higher market prices (Shrestha et al., 2021; Shrestha dan Subedi, 2019). The challenge is that agriculture can have negative environmental impacts through the overuse of natural resources (either as inputs or as absorbers of waste and pollution). These impacts are referred to as negative externalities because they impose costs (which are generally

difficult to control) on market prices (de Roest et al., 2018).

Externalities are significant costs for many countries due to the trade-offs between ecological interests and economic demands (Xia et al., 2022). Some modern agricultural systems can significantly mitigate negative externalities, particularly regarding environmental issues (Rosa-Schleich et al., 2019). For example, a study in Brazil shows that crop diversification and the use of organic inputs can simultaneously improve productivity, soil health, and biodiversity conservation (Rosa-Schleich et al., 2019). In Indonesia, agricultural policy encourages sustainable intensification by focusing on increasing productivity on existing farmland while reducing the use of harmful chemical inputs (Ministry of Agriculture Indonesia, 2023).

Sustainable agricultural intensification is defined as producing more agricultural products from the same area of land while minimizing negative environmental impacts and simultaneously increasing contributions to natural resources and environmental services (Struik dan Kuyper, 2017). Sustainable agricultural systems, by definition, are more resilient to shocks and pressures. Productive and sustainable farming systems leverage technologies that create crop varieties and livestock breeds that offer the best productivity, depending on specific ecological and agronomic conditions. Therefore, sustainable agricultural intensification should be viewed as an analytical process for navigating and sorting through issues and concerns closely related to agronomy (Struik dan Kuyper, 2017).

Peter Jennings, a pioneer in the development of high-yield rice varieties during the first Green Revolution, has championed an "agronomic revolution" (Mohapatra dan Sahu, 2022). He recognized that the yield gaps between regions were caused by agronomic failures and that the future of agriculture depends heavily on the development of this science (Gulati dan Juneja, 2022). Agronomy refers to the management of crops and livestock under specific conditions. It is an applied science based on insights, knowledge, and expertise in physics, chemistry, biology, socio-culture, and economics. Key elements of agronomy as a science include inclusivity, comparative analysis through experimentation and modeling, asking the right questions (conceptualization), interpreting and evaluating information (frameworks), aggregation (models), application

(decision support), generalization and contextualization, extrapolation, and design (Struik dan Kuyper, 2017).

Agronomy needs to be developed to increase agricultural productivity, which has tended to stagnate. The skills and knowledge of agronomy must be passed down from generation to generation. However, one of the biggest challenges for agronomy is ensuring that it aligns with the demands of agroecology. Farmers are expected to invest in science and practices that provide the best combination of crop varieties and livestock breeds while remaining harmonious with ecological management and conservation contexts.

CONCLUSION

This research highlights the primary challenges faced by the agricultural sector, both globally and nationally, which are interconnected with socio-ecological, political, technological, and economic aspects. The key challenges include: first, climate change and water deficits, requiring better crop, soil, and water management; second, limited energy access for smallholder farmers; third, balancing food production with biodiversity and ecosystem services; fourth, strengthening social infrastructure, addressing gender equity, and improving market access; fifth, optimizing governance and policy for public-private investment and community involvement; sixth, creating sustainable food supply chains to balance consumption patterns with environmental and social impacts; seventh, adapting to changing consumption patterns driven by population growth, which affects food security and health; and eighth, enhancing sustainable agricultural intensification by aligning agronomic science with environmental conservation to boost production.

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