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Addressing Food System Transformation, Food Security, and Deforestation in Indonesia

Challenges and Opportunities

David Laborde

Elsa Olivetti

Valeria Piñeiro

Nelson Illescas

Markets, Trade, and Institutions Division

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AUTHORS

David Laborde (david.laborde@fao.org) is a Director in the Agrifood Economics and Policy Division (ESA) at the Food and Agriculture Organization of the United Nations (FAO), Rome.

Elsa Olivettie (elsa.olivetti@fao.org) is an Economist in the FAO's ESA Division, Rome.

Valeria Piñeiro (v.pineiro@cgiar.org) is the Acting Head of the Latin American Region and Senior Research Coordinator at the International Food Policy Research Institute (IFPRI), Washington, DC.

Nelson Illescas (nel.illescas@gmail.com) is the Director of the International Agricultural Negotiations Institute Foundation (INAI), Buenos Aires, Argentina.

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ABSTRACT

This study identifies food system interventions with high transformational potential for Indonesia by utilizing the MIRAGRODEP a multi-region, multisector computable general equilibrium model to analyze policy scenarios. Our findings reveal a range of economic, social, and environmental impacts. Initiatives such as social safety nets and food stamps can enhance affordability, while repurposing farm subsidies can improve socio-economic sustainability. Comprehensive policy packages that include social safety nets, repurposing agricultural supports, environmental regulation and investment in sustainable production, can lead to substantial GDP growth, poverty reduction, and dietary enhancements. However, each intervention presents distinct trade-offs between economic gains and environmental implications. This analysis underscores the need for a holistic policy approach when trying to achieve multiple sustainability goals. Implementing a blend of policies designed to promote environmental, social, and economic sustainability simultaneously could drive Indonesia towards a sustainable and resilient food system, addressing the complex interplay between economic development, environmental conservation, and improved nutrition.

Keywords: food system, social safety net, repurposing, sustainable production

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1 Introduction

Indonesia, faces significant challenges in ensuring food security, promoting sustainable food systems, and addressing deforestation. With a population of 272 million, the country strives to transform its food system, improve nutrition, and protect its vast tropical forests. This article explores the key initiatives undertaken by the Indonesian government, the impact of these initiatives on food security, and the challenges posed by deforestation.

As the largest economy in Southeast Asia and a major exporter of agricultural products, Indonesia is closely linked with the global economy. Food policy research in this context must account for international market dynamics along with national considerations. By utilizing the MIRAGRODEP multi-region, multisector computable general equilibrium model, this paper delves into three central policy goals and associated interventions:

- Improving Diets: This scenario focuses on implementing a social safety net program associated with food stamps. The objective is to bridge the affordability gap between households' per capita income and the expenses of a nutritious diet. This move aims to induce a shift towards healthier diets and reduce undernourishment.
- Sustainable Augmentation of Food Availability: This scenario takes on the task of enhancing the socio-economic and environmental sustainability of the agri-food supply. The approach involves repurposing farm subsidies, directing them towards directly supporting farmers' earnings. A special emphasis lies on nurturing nutritious and low-emission products.
- Strengthening the Environment and Pioneering Low Carbon Development: This scenario encompasses a spectrum of interventions geared towards the preservation of forests, the reinforcement of climate resilience, and the advocacy of low carbon development. It encompasses policies spanning from the regulation of land use, the reduction of food waste and loss, to initiatives promoting climate mitigation.

Spanning these scenarios, this study undertakes an evaluation of their economic, social, and environmental implications. This assessment entails a comparative analysis against a business-as-usual baseline, taking into account variables such as GDP growth, the reduction of poverty, dietary enhancements, emissions, and forest coverage.

Of critical importance, this paper places under scrutiny the inherent trade-offs within each scenario. While certain interventions excel in specific aspects, they might present limitations in other dimensions. This report strives to establish a well-rounded perspective on potential outcomes and challenges associated with diverse policy approaches. Embedded within a meticulously structured framework, the report then embarks on an expedition into the realm of scenario analysis. This meticulous journey systematically explores an array of policy interventions, unraveling the cascading consequences they might engender. This all-encompassing exploration scrutinizes the economic ripples, shifts in agricultural production paradigms, ramifications on poverty dynamics, dietary inclinations, and ecological implications. Implicit trade-offs are meticulously probed, with extracted insights providing the bedrock for the subsequent formulation of policy recommendations.

2 Lessons from previous research

In Nurhasan et al. (2021), the authors discuss the interlinkages between food, nutrition, and the environment in Indonesia, and the role of national food policies in addressing the challenges in these sectors. They argue that Indonesia's food system is unsustainable and that it is contributing to both malnutrition and environmental degradation. The authors identify several key problems with Indonesia's food system,

including: a focus on a few high-value commodities, such as rice, at the expense of dietary diversity; a reliance on monocropping, which has a harmful impact on the environment; a lack of support for local food production practices; and a top-down approach to food policy that does not consider the needs of local communities.

The authors consider that Indonesia needs to move towards a more sustainable food system, based on principles such as: a focus on delivering healthy and diverse diets, more support for local food production practices that are environmentally sustainable, embracing of local cultures and values, a re-evaluation of centralized and top-down food policies, and the avoidance of overly focusing on the production of rice.

The authors conclude by arguing that Indonesia has the potential to develop a sustainable food system that is both healthy and environmentally friendly. However, they acknowledge that this will require a significant shift in the way that food is produced and consumed in the country.

Meanwhile, as part of its process of transforming its food system, Indonesia began its process of national dialogues ahead of the United Nations Food Systems Summit (UNFSS)[1]. The country implemented the guidelines of the UNFSS, which entail the development of five Global Action Tracks. These include: (1) Ensuring access to safe and nutritious food for all, with the aim of enabling individuals to attain nourishment and good health while progressively realizing the right to food; (2) Shifting to sustainable consumption patterns, which promote and create demand for healthy and sustainable diets while reducing waste; (3) Boosting nature-positive production at sufficient scale, which involves taking action on climate change, reducing emissions and increasing carbon capture, regenerating and protecting critical ecosystems, reducing food loss and energy usage, all without undermining health or nutritious diets; (4) Advancing equitable livelihoods and value distribution, which encompasses raising incomes, distributing risk, expanding inclusion, promoting full and productive employment, and ensuring decent work for all; and (5) Building resilience to vulnerabilities, shocks, and stress, which entails ensuring the continued functionality of healthy and sustainable food systems.

For each Action Track, the dialogue identified Game-changing Solutions, which are specific actions that can be taken to achieve the objectives of the Action Track. The Game-changing Solutions identified in the National Food Systems Summit Dialogue in Indonesia provide a roadmap for how to transform food systems in the country. Even though these solutions were ambitious, but they were considered essential if Indonesia was to achieve its goal of ensuring food security and nutrition for all.

Creating sustainable food systems and combating deforestation are critical challenges in Indonesia. Valuable lessons can be learned from previous research about food systems transformation, providing insights into effective strategies and actions. This section presents key lessons learned and provides context for implementing these lessons in Indonesia's specific circumstances.

2.1 Improving Nutrition in Indonesia

Lesson 1: Nutrition education and awareness campaigns can raise awareness about healthy dietary practices, balanced nutrition, and the benefits of consuming nourishing foods. Implementing comprehensive educational programs in educational institutions can educate students about healthy dietary habits. Additionally, conducting public awareness campaigns through diverse media platforms is often effective for promoting the advantages associated with healthy diets.

Lesson 2: Establishing regulations that ensure transparent and accurate information on product packaging, including nutritional facts, ingredient lists, and prominent warning labels for products high in sugar,

[1] Indonesia strategic national pathway for food systems transformation, August 2021.

sodium, or fat content, can change consumer preferences in favor of more healthy diets while incentivizing healthier food production and preventing misinformation. . These regulations should encompass accurate nutrient information and restrictions on misleading health claims.

Lesson 3: Encouraging the consumption of locally produced and traditional foods is important for promoting sustainable and nutritious diets. This may involve establishing farmers' markets and promoting community-supported agriculture initiatives that connect consumers with local farmers and grant them access to fresh, locally sourced foods.

Lesson 4: Collaboration with the food industry to reformulate processed foods, reduce unhealthy ingredients, and increase the availability of healthier alternatives can improve access and affordability of healthy diets. Efforts can be made to encourage food manufacturers to voluntarily reformulate their products to decrease salt, sugar, and unhealthy fats content through incentivized programs. Furthermore, other effective strategies include promoting the availability and affordability of healthier food options in schools, workplaces, and public institutions.

2.2 Promoting Sustainable Increases in Food Availability

Lesson 1: Encouraging investments in agricultural research and development, technology adoption, and infrastructure enhancements is essential to bolster productivity and efficiency in food production. Providing financial support and grants to farmers to facilitate the adoption of modern agricultural technologies, such as precision farming, smart irrigation systems, and efficient machinery, is crucial. Additionally, establishing research and development centers to facilitate the development of high-yield and climate-resilient crop varieties should be prioritized.

Lesson 2: Supporting small-scale farmers with financial incentives, training, and access to resources is necessary to improve productivity, diversify crops, and adopt sustainable farming practices. Offering microfinance programs, agricultural training initiatives, and extension services can enhance small-scale farmers' access to credit, knowledge, and resources. Facilitating the formation of farmer cooperatives and networks can strengthen their collective bargaining power and market access.

Lesson 3: Developing robust and resilient supply chains is crucial to minimize post-harvest losses, enhance storage and transportation facilities, and ensure efficient food distribution from farms to consumers. Investments in cold storage facilities, transportation infrastructure, and efficient logistics systems are vital to reducing post-harvest losses and ensuring the timely delivery of perishable goods. Encouraging the growth of agro-processing industries can add value to agricultural products while mitigating wastage.

Lesson 4: Creating favorable market conditions, including fair pricing and trade regulations, stimulates agricultural growth, incentivizes sustainable practices, and promotes food security. Implementing policies that incorporate price stabilization mechanisms, fair trade practices, and risk-sharing instruments can safeguard farmers from price volatility and market uncertainties. The introduction of tax incentives for sustainable farming practices and environmentally friendly technologies is also recommended.

2.3 Reinforcing Environmental Sustainability, Bolstering Climate Resilience, and Fostering Low-carbon Development

Lesson 1: Implementing measures to enhance the resilience of agricultural systems against climate change impacts is crucial. Promoting the utilization of climate-resistant crop varieties and sustainable agricultural practices such as agroforestry, conservation agriculture, and water-efficient irrigation systems is necessary. Supporting the establishment of climate-smart villages or model farms that exemplify resilient farming techniques is advised.

Lesson 2: Advocating for sustainable land management practices, including reforestation, soil conservation, and water management techniques, is vital to preserving ecosystems, safeguarding biodiversity, and

maintaining essential ecosystem services. Implementation of reforestation programs to restore degraded lands and conserve biodiversity is paramount. Encouraging the adoption of agroecological approaches that minimize the use of chemical inputs and promote natural pest control is also vital. Furthermore, the establishment of protected areas and wildlife corridors can contribute to ecosystem conservation and resilience.

Lesson 3: Strengthening Forest governance and enforcing existing laws are essential in avoiding deforestation. Promoting sustainable land use planning, supporting conservation and restoration programs, improving law enforcement and monitoring, encouraging sustainable farming practices, fostering international cooperation, raising public awareness, promoting sustainable trade and certification, addressing socioeconomic drivers, and investing in research and innovation are all crucial components of efforts to protect forests and combat deforestation.

Lesson 4: Encouraging the adoption of renewable energy sources in the agricultural sector helps reduce greenhouse gas emissions and decrease reliance on fossil fuels. Providing financial incentives, such as feed-in tariffs or tax credits, for farmers to install renewable energy systems, such as solar panels or biogas digesters, is important. Moreover, promoting the adoption of renewable energy solutions in agro-processing facilities and decentralized energy generation in rural areas is recommended.

Lesson 5: Ensuring policy coherence and coordination across various sectors, including agriculture, environment, energy, and finance, is necessary for holistically addressing climate change and environmental challenges. The establishment of inter-ministerial committees or task forces can facilitate policy coordination and harmonization. Developing cross-sectoral initiatives that foster collaboration and knowledge sharing among stakeholders, such as public-private partnerships and multi-stakeholder platforms, is recommended.

It is noteworthy that the implementation of these policy requirements necessitates the engagement of multiple stakeholders, including government agencies, private sector entities, civil society organizations, and local communities. This collaborative approach ensures a comprehensive and inclusive endeavor towards attaining the desired policy goals.

3 Food System Transformation in Indonesia

The Indonesian government has prioritized food system transformation as a national policy objective. This transformation aims to enhance food quality and access, promote sustainable production, and achieve the Sustainable Development Goals (SDGs). Under the Medium-term National Development Plan 2020-2024 (RPJMN), specific programs have been developed to increase the availability, access, and quality of food, improve human resource development, and strengthen the sustainability of agricultural resources. These programs address the dynamic challenges faced at the global, national, and local levels.

3.1 Food security

Food security is a critical concern for Indonesia, given its position as the largest economy in Southeast Asia and the fourth most populous country globally. Based on the 1996 World Food Summit, Food security is defined as ensuring that all individuals have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and preferences for an active and healthy life. However, Indonesia faces various challenges in achieving food security for its population of 275 million people (UNDESA, 2022).

Despite rapid economic growth and significant investments in social development, Indonesia still experiences high prevalence rates of undernourishment, stunting, wasting, overweight, obesity, and micronutrient deficiencies. Recent estimates indicate that although the prevalence of undernourishment has decreased from an average of 19.3% in 2004-2006 to 5.9 % in 2020-2022, approximately 16.2 million

people in Indonesia are still undernourished. Additionally, about 13.4 million Indonesians face moderate or severe food insecurity in 2020-2022 (FAO, 2023b).

Child malnutrition is a pressing concern in Indonesia, with more than 30% of children under 5 years experiencing stunting in 2022, indicating chronic undernutrition. This condition can have long-term consequences for physical and cognitive development, as well as future health and productivity. Furthermore, in 2022, about 10.2% of children under 5 years are wasted, indicating acute undernutrition and increasing the risk of mortality and morbidity (FAO, 2023b).

In addition to malnutrition, Indonesia also struggles with micronutrient deficiencies and challenges in achieving healthy diets. A significant proportion of the population, approximately 193.7 million Indonesians, cannot afford a healthy diet, which affects about 70.8% of the total population in 2021 (FAO, 2023a). These challenges in achieving food security and nutrition are exacerbated by natural disasters, climate change impacts, and the COVID-19 pandemic, particularly affecting vulnerable groups such as children and women (Malau et al., 2021; McCarthy et al., 2020).

Efforts are being made to address these challenges and achieve food security. The government has implemented various policies and interventions to enhance the nutritional quality of Indonesian diets. These include nutrition education and awareness campaigns, food labeling and marketing regulations, promotion of local and traditional foods, and collaboration with the food industry to reformulate processed foods and increase the availability of healthier alternatives. Additionally, initiatives such as agricultural investment and innovation, support for smallholder farmers, strengthening supply chains, and market incentives and policies have been introduced to promote sustainable increases in food availability.

3.2 Combating Deforestation

Indonesia possesses vast and biologically diverse tropical forests that provide essential benefits to human health and well-being. Forests offer edible products, environmental services such as freshwater resources, flood control, soil fertility, microclimate regulation, and habitats for biodiversity. Consequently, addressing deforestation and preventing environmental degradation is crucial for supporting food production and maintaining ecosystem services (FAO, 2020).

According to data from Global Forest Watch (GFW), Indonesia's forest cover in the year 2000 was estimated at 139 million hectares, representing 74% of the total land area. Of this, 21.7 million hectares were designated as plantations, while 28.4 million hectares were non-forest areas. Primary forests, characterized as old-growth forests with high carbon stock and biodiversity, accounted for 93.8 million hectares, covering over 50% of Indonesia's land area (World Resources Institute, 2023).

Over the past 20 years, Indonesia has experienced a net loss of tree cover, with a loss of 9 million hectares and a gain of 4.88 million hectares, resulting in a net loss of 4.12 million hectares. Moreover, the total tree cover loss since 2000 amounts to 28.6 million hectares, resulting in approximately 19.7 gigatons of carbon emissions. Commodity production has been the primary driver of deforestation, contributing to approximately 96% of the overall forest loss. However, recent years have seen a deceleration in the rate of deforestation.

While primary forests have been affected by deforestation, it is important to note that most of the forest loss has occurred in areas classified as secondary forests rather than primary forests. The regional distribution of tree cover loss reveals that Riau and Kalimantan regions have experienced significant deforestation, accounting for a substantial portion of the overall tree cover loss in Indonesia.

Indonesia's vast tropical forests are essential for biodiversity, climate regulation, and food production. However, deforestation poses a significant threat to these forests and their ecosystem services. The Indonesian government recognizes the importance of addressing deforestation and has implemented measures to protect forests and promote sustainable land use. These measures include strengthening forest governance, enforcing existing laws, promoting sustainable land use planning, supporting conservation and

restoration programs, improving law enforcement and monitoring, encouraging sustainable farming practices, fostering international cooperation, raising public awareness, promoting sustainable trade and certification, addressing socioeconomic drivers, and investing in research and innovation. These efforts aim to protect forests, promote responsible land use, combat illegal activities, empower local communities, and address the underlying causes of deforestation.

4 Methodology

4.1 Introduction

The MIRAGRODEP model is a multi-region, multisector computable general equilibrium model (CGE model). It builds on the widely used MIRAGE multisector, CGE model of the global economy (Decreux & Valin, 2007). By capturing international economic linkages through international trade in goods and services, as well as capital flows, this model provides a comprehensive and consistent representation of economic and trade relations between countries. Such a perspective is particularly relevant in the case of Indonesia, which is a major global food supplier where the economy is closely tied to international commodity markets. Additionally, the MIRAGRODEP model can account for environmental considerations and can be linked to individual surveys to assess the impact of various shocks and reforms on households. Specifically, the model can estimate the effects of such events on income, purchasing power, poverty, food security, and nutrition.

The MIRAGRODEP model is based on an input–output framework and its theoretical structure is derived from optimizing behavior of economic agents, particularly households and firms. The model assumes perfect competition in all sectors and constant returns to scale, enabling detailed geographic and sector decompositions. A complete documentation can be found in (Bouët et al., 2022).

The recursive dynamic version of the model was used for this analysis on food system transformation in Indonesia. The model incorporates a capital accumulation framework, where the capital for year t+1 is based on the capital of year t, increased by the previous year's investment, and adjusted for depreciation. The model is then solved sequentially, moving the equilibrium from one year to another.

The primary data source for MIRAGRODEP is GTAP11 database (fully documented in (Aguiar et al., 2019). The database includes world macroeconomic accounts and trade flows for five reference years (2004, 2007, 2011, 2014, and 2017). It describes the values of production, intermediate and final consumption of commodities and services for 141 countries or regions and 65 sectors. The database also provides information on global bilateral trade patterns, international transport margins, and protection matrices allowing for an accurate representation of linkages between individual countries and regions.

4.2 Supply side

Regarding the supply side, the production function is modeled for each sector as a Leontief function of intermediate inputs and value-added. Specifically, to produce one output unit, x percent of productive factors (labor, capital, land, and natural resources) are required, and (1-x) percent of intermediate inputs.

The intermediate inputs function is a Constant Elasticity of Substitution (CES) function of all goods, to account for the substitutability between two intermediate goods, depending on their relative prices. The level of substitutability is assumed to be constant for any pair of intermediate goods.

Similarly, value added is a CES function of unskilled labor, land, natural resources, and a bundle of skilled labor and capital. This nesting structure enables the model to capture the lower substitutability between capital and skilled labor compared to other factors.

4.3 Demand side

In each region the demand side is modeled with a representative agent who is assumed to own all factors of production, have a constant propensity to save and seek to maximize his utility by purchasing goods. The agent's utility function is a linear expenditure system-constant elasticity of substitution (LES-CES) function to capture his preferences between goods and determine the allocation of expenditure across those goods. The LES-CES function also allows for different income elasticities of demand for goods and can therefore account for the evolution of demand structure across regions as income levels change. This is particularly relevant for modeling agricultural and non-agriculture sectors since income elasticities for food tend to be lower than those for manufactured goods and services. Additionally, the elasticity of substitution among sectoral consumptions is constant only above a minimum level, which can vary by region, such as developing versus developed countries.

MIRAGRODEP is a bilateral trade model that is consistent with the Armington assumption, which posits that commodities are heterogeneous based on their origin and thus, imperfect substitutes for each other (Armington, 1969). The model uses nested CES functions to reflect preferences for varieties originating from different countries. This approach allows for countries to import and export the same product simultaneously, reflecting consumers' preferences for specific varieties.

Lastly, MIRAGRODEP explicitly models the government as separate from private agents. The government's income comprises taxes on production, factors of production, exports, imports, consumption, and households' income. The model assumes that the government aims to maximize a Cobb-Douglas utility function, where its expenditure on each commodity is a fixed share, in value, of the total public expenditure on goods and services.

4.4 Four main assumptions

The model rests on four major assumptions: the factor market closure, the private account closure, the external account closure, and the government account closure.

With respect to the factor market closure, total employment is assumed to remain constant as a proportion of the active population, which is defined as individuals aged between 15 and 60 years old. Labor markets are differentiated by gender, accounting for an imperfect substitution between male and female labor within each skill category. Skilled labor is perfectly mobile, while unskilled labor has imperfect mobility between agricultural and non-agricultural sectors, as determined by a Constant Elasticity of Transformation (CET) function. Natural resources are the only factor with a fixed supply over time. Land supply, on the contrary, is endogenous and depends on the real remuneration of land. Additionally, it is assumed that land has imperfect mobility between agricultural sectors. Finally, installed capital and natural resources are modeled as sector specific.

Regarding the private account closure, the model makes the neo-classical assumption that the marginal propensity to save remains constant. Consequently, variations in income result in variations in savings, which, in turn, bring variations in investment. Investments are therefore savings driven.

For the external account closure, it is assumed that the current account balance remains stable as a proportion of global GDP. Hence, the real exchange rate adjusts through different changes in domestic prices across various regions, referred to as competitive disinflation.

Finally, with respect to the public account closure, it is assumed that the government budget remains a fixed share of the national GDP, and that the real public expenses per capita are held constant to ensure a constant provision of public goods. There are therefore no changes in the size of the public sector and no crowding-out effect on private investment. To keep the government budget and the real public expenses per capita at a constant level, a consumption tax is adjusted. The magnitude of this tax thus measures the cost of maintaining a steady supply of public goods.

4.5 Poverty and environmental aspects

The poverty analyses were carried out using the POVANA household model, as documented in Laborde Debucquet et al., 2020. The POVANA model is based on the POVANA dataset which provides the full income distribution for approximately 300,000 households. The model captures the endogenous evolution of households' real income in response to changes in multiple factors, such as employment, prices of goods and services, wages, and productivity. Additionally, the comprehensive information on household consumption patterns within the POVANA dataset enables the estimation of the effects of economic shocks on household costs, including the costs of food.

Regarding land use, the models builds on the AEZ approach of (Hertel et al., 2008) and evaluates land use change across agroecological zones defined for each region in the model. Within each agroecological zone, the model reallocates land between forest areas and various types of agricultural land in response to changes in returns. Specifically, a constant CET specification is used to represent the competition for land between forestry and agricultural uses. Land is then redistributed between agricultural activities based on changes in relative prices.

Finally, the model includes a post-solution module to compute the impact on greenhouses gas (GHG) emissions. This module is based on a GHG database that maps GHG emissions to crop and livestock production, by region. The database was developed by (Laborde et al., 2021), and subsequently updated with research by (Tubiello et al., 2021). Additionally, the database is used to calculate GHG emissions resulting from land use change, such as the conversion of forestland to grazing or cropland.

4.6 Farm policies

The model accounts for farm policies through a comprehensive set of instruments, including ad-valorem output subsidies, ad-valorem input subsidies, and payments to production factors, such as subsidies to capital, labor, and land. The model draws on detailed data on agricultural support from the 2021 release of the Ag-Incentives database, which covers nearly 90 percent of global agricultural production for most years since 2005. A technical summary of the dataset is available in Annex 1 of the FAO et al., 2021. Non-product-specific expenditures are allocated among relevant products based on the agricultural value of production. Additionally, the model incorporates other relevant food system policies, such as general services payments and consumer subsidies.

4.7 Baseline

The economic and environmental outlook for the baseline scenario was established using the most reliable data projections available. Specifically, the latest population projections from the United Nations, Department of Economic and Social Affairs, Population Division (UNDESA, 2022) were used, as well as the latest GDP projections from the IMF - World Economic Outlook database (IMF, 2023). Various quality checks were carried out, including comparisons with other sources, to ensure the accuracy and validity of the projections.

5 Scenarios design

The Indonesian government has placed a strong emphasis on food system transformation as a national priority. To achieve this, specific scenarios have been identified to enhance the nutritional quality of Indonesian diets, increase sustainable food availability, and reinforce environmental sustainability.

Table 1 - Policy Interventions Modelled in MIRAGRODEP

Policy Goal	Policy Intervention
Healthy Diet	Social Safety Nets with Food Stamps
Socioeconomic sustainability of agri-food supply	Farm subsidy repurposing
Environmental sustainability, including climate action	Land Use Regulation
	Innovation, Technology and Knowledge for Farmers
	Reducing Food Waste and Loss

5.1 Improving the quality of Indonesian diets

The Government of Indonesia has prioritized poverty reduction as a key policy objective, with the aim of decreasing the percentage of people living below the national poverty line to 4.33% by 2030, as stated in the Indonesia National Voluntary Review (VNR) 2021 (Republic of Indonesia, 2021b). In 2015, the poverty rate stood at 11.2% according to the World Bank.

Improving the quality of Indonesian diets has long been a significant objective. It was first mentioned in Presidential Regulation no. 22 of 2009 on Acceleration of Local Resource-Based Food Consumption Diversifications (Republic of Indonesia, 2009), reaffirmed in the Law no. 18 of 2012 on Food (Republic of Indonesia, 2012), and most recently in Presidential Regulation No. 18/2020 on the 2020-2024 National Medium-Term Development Plan (Republic of Indonesia, 2020a). The latter sets specific targets, including reducing the prevalence of undernourishment from 6.7% in 2019 to 5% in 2024 and increasing the Indonesian desirable dietary pattern score from 86.4 in 2019 to 95.2 in 2024[2]. Furthermore, the Government of Indonesia has committed to the objective of ending hunger and ensuring access to nutritious and sufficient food for all people, as outlined in the Strategic National Pathway for Food Systems Transformation (Republic of Indonesia, 2021a). One of the milestones mentioned in the Strategic National Pathway is the integration of a healthy and nutritious food aid program into the social safety net system.

To address the objective of improving the quality of Indonesian diets, a specific policy intervention has been developed: the implementation of a social safety net program associated with food stamps. This intervention involves providing food stamps in order to bridge the "poverty gap" between each household's per capita income and the affordability of a healthy diet. The food stamps are modeled as income transfers intended to be spent on food products and their cost is initially calibrated based on The State of Food Security and Nutrition in the World Report (SOFI) 2019 (FAO et al., 2019).

[2] A desirable dietary pattern score of 100 corresponding to a diet composed of grains (50%), tubers (6%), animal food (12%), oils and fats (10%), oily fruits/seeds (3%), beans/legumes (5%), sugar (5%), vegetables and fruits (6%), others (3%) (Composition being expressed as share of total caloric intake) (Arif et al., 2020)

5.2 Increasing food availability sustainably

Improving the socio-economic sustainability of the agri-food supply is a major objective of the Indonesian government, as outlined in Presidential Regulation No. 18/2020 on the 2020-2024 National Medium-Term Development Plan (Republic of Indonesia, 2020a). This regulation sets specific targets to achieve this objective. These targets include increasing the value added per labor in agriculture to Rp 59.9 million/agricultural labor by 2024 (compared to 46.9 million/agricultural labor in 2019), increasing farmer's terms of trade to 105 by 2024 (up from 100 in 2019), increasing rice availability to 46.8 million tons by 2024 (compared to 38.4 million tons in 2019), and increasing animal-based protein availability to 2.9 million tons by 2024 (up from 2.4 million tons in 2019).

Aligned with the objective of increasing food self-sufficiency, as stated in Government Regulation No. 1/2011 on the Determination and Conversion of Sustainable Agricultural Staple Food Land, Presidential Regulation No. 18/2020 emphasizes the need to improve strategic food production and sets production targets. These targets include reaching a biofortified rice production of 200,000 hectares by 2024 (compared to 195,000 hectares in 2019), maize production of 35.3 million tons by 2024 (compared to 24.8 million tons in 2019), meat production of 4.9 million tons by 2024 (compared to 3.8 million tons in 2019), and tubers production of 25.5 million tons by 2024 (compared to 23.3 million tons in 2019).

To increase the socio-economic sustainability of the agri-food supply, a specific policy intervention has been designed: farm subsidy repurposing. In this intervention, all farm subsidies, including those for outputs, inputs, and others, are redistributed in the form of a subsidy to the farmers' revenue. The support rate is determined endogenously by the model to maintain the farm subsidy budget constant, but a sectoral bias is introduced to incentivize the production of healthier and more sustainable agricultural products. Specifically, nutritious and low-emissions products[3] are subsidized at twice the average rate, while products with low nutritional value and high emissions[4] are subsidized at half the average rate.

5.3 Strengthening the environment, improving climate resilience, and promoting low carbon development

a) Forest Preservation

The preservation of forests is a paramount objective for the Indonesian government. In 2011, the government took a significant step by implementing the Presidential Instruction no. 10 of 2011, which aimed to halt the issuance of new permits and improve the governance of primary natural forests and peatlands (Republic of Indonesia, 2011). This directive was crucial in safeguarding the integrity of these vital ecosystems. Furthermore, the Regulation of the Minister of Environment and Forestry no. 16 of 2020, which outlines the Strategic Plan 2020-2024, reinforced the importance of preserving primary forest cover (Republic of Indonesia, 2020b). It set a specific target of reducing the deforestation rate to 0.31 million hectares by 2024, representing a notable decrease from the 0.44 million hectares recorded in 2019.

Additionally, the Operational Plan Indonesia's Forests and Land Use (FOLU) net sink 2030, developed by the Ministry of Environment and Forestry of Indonesia, highlights the necessity of establishing a deforestation quota. This quota is aimed at achieving the FOLU net sink target by 2030 and involves an average annual deforestation rate of 57,000 hectares from 2021 to 2050 (Ministry of Environment and Forestry of Indonesia, 2022).

[3] The nutritious and low-emission products are identified by the following GTAP codes: v_f (vegetables, fruits, nuts, roots, tubers, and pulses), rmk (raw milk), and oap (poultry and eggs).

[4] The low nutritional value and high emissions products are identified by the following GTAP codes: pdr (paddy rice), woht (wheat), and gro (maize)

To align with these objectives related to forest cover, a policy intervention has been implemented, with a primary focus on land use regulation. This intervention seeks to limit land use change by implementing an annual deforestation quota of 57,000 ha from 2024 to 2035.

b) Climate Action

The Republic of Indonesia, in its Enhanced Nationally Determined Contribution (Republic of Indonesia, 2022), has made a firm commitment to reducing GHG emissions by 32% (unconditionally) or 43% (conditional on global support) by 2030, compared to the business-as-usual scenario. To achieve this, the Forests and Land Use (FOLU) sector plays a vital role in the country's climate mitigation strategy. The Regulation of the Minister of Environment and Forestry no. 16 of 2020, which outlines the Strategic Plan 2020-2024 (Republic of Indonesia, 2020b), sets a specific target of reducing emissions from forestry and waste to 17.54% by 2024, an increase from the 16.28% recorded in 2019. Moreover, the Presidential Regulation No. 18/2020 on the 2020-2024 National Medium-Term Development Plan (Republic of Indonesia, 2020a) underscores the significance of improving productivity.

To effectively address these climate action goals, a comprehensive package of policy interventions has been developed and modeled in MIRAGRODEP. This package focuses on fostering innovation, technology, and knowledge among farmers to enhance farm productivity while simultaneously reducing the environmental impact.

It consists of investments in irrigation (1), livestock production (2), crop productivity and soil practices (3). For the increased irrigation system component (1), the modeling assumes that 30% of cultivated land will benefit from new investments by 2028, with an initial cost of $500 per hectare. This upgrade results both in improved water efficiency and an increase in yield of 100%. Regarding the livestock production component (2), the modeling considers a 50% increase in livestock productivity and reduced emissions per unit of production through improved livestock genetics and best practices. It assumes that 30% of the livestock population will be improved by 2028, with an average initial cost of $200 per standard livestock unit. As for crop productivity and soil practices (3), the modeling assumes it will lead to a 25% increase in total factor productivity. It is considered that 30% of farmers will benefit from the training, along with an increase in soil carbon sequestration and the presence of one extension agent per 100 farmers on average. By implementing these three interventions, Indonesia aims to achieve its emissions reduction targets, promote sustainable agricultural practices, and contribute to global climate change mitigation efforts.

c) Food Waste

Reducing food waste is a key objective of the Indonesian government, as emphasized in the Indonesia Strategic National Pathway for Food Systems Transformation (Republic of Indonesia, 2021a). In line with this objective, the strategy outlined in "Food Loss and Waste in Indonesia - Supporting the Implementation of Circular Economy and Low Carbon Development" (Bappenas, 2021) aims to achieve a significant reduction of 55.88% in food loss and waste compared to the business-as-usual scenario by 2045 (with a decrease by 36.9% by 2030). The analysis conducted assumes a 35% decrease in waste generation consumption between 2022 and 2030.

To tackle this objective, a policy intervention has been designed and modeled in MIRAGRODEP to specifically target the reduction of food waste and losses. The intervention's primary aim is to achieve a 37% decrease in food waste and losses, including losses that occur in the field. The model integrates a recurrent cost per unit of restored food to implement this policy intervention effectively.

6 Results

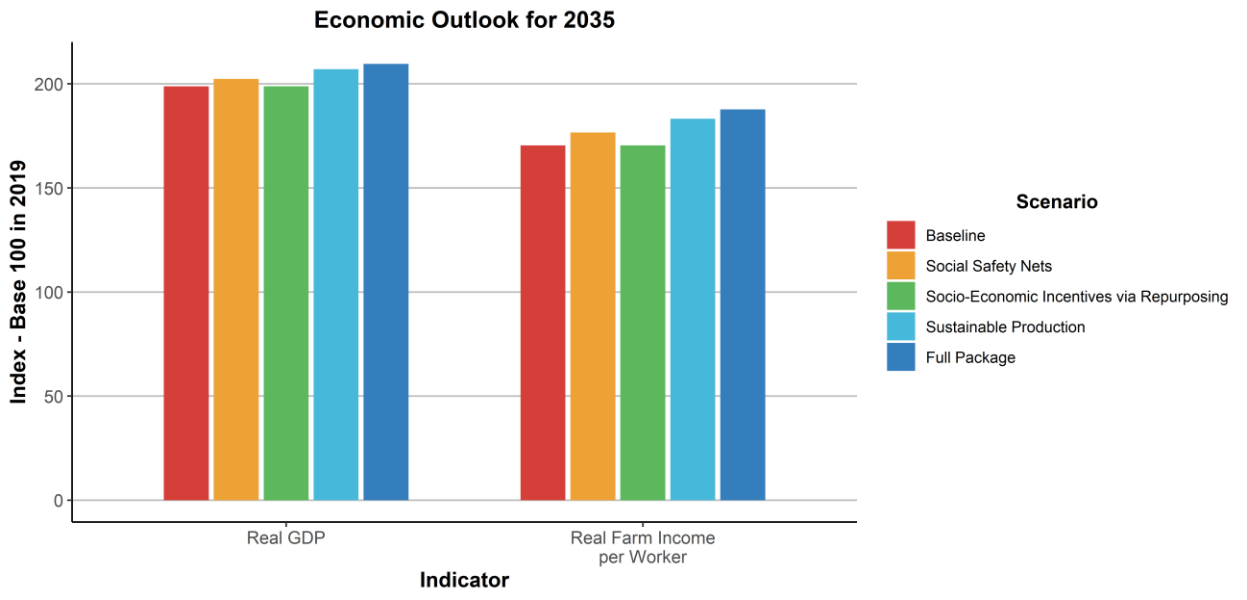
In this section, the four different policy interventions identified in the previous section are analyzed and compared to the business-as-usual scenario or baseline scenario by 2035, considering their impact on the economy, poverty, diets, and the environmental sustainability.

6.1 Economic impact

All interventions modelled would lead to an augmentation of both real GDP and real farm income per worker compared to the business-as-usual scenario. Among the different policy scenarios modelled, the sustainable production and the full policy package scenarios, which incorporates all interventions from the other three scenarios, would yield the highest increase in the real GDP in 2035 compared to 2019-levels (respectively by 4.1% and 5.4% compared to the business-as-usual scenario) and in the real farm income per worker (respectively by 7.5% and 10.1%) as these scenarios are improving the production side with the investments in irrigation, livestock production, crop productivity and soil practices.

The social safety nets would also increase the real GDP (by 1.8%) and the real farm income per worker (by 3.6%) by boosting demand through food stamps, indirectly supporting production. Finally, the socio-economic incentives intervention would yield the smallest increase in GDP (by 0.01%) and in real farm income per worker (by 0.01%). Indeed, in this scenario total support remains unchanged, but it is redirected towards nutritious and low-emission agricultural products, resulting in only a minor upswing in GDP and real farm income per worker.

Figure 1 - Economic indicators



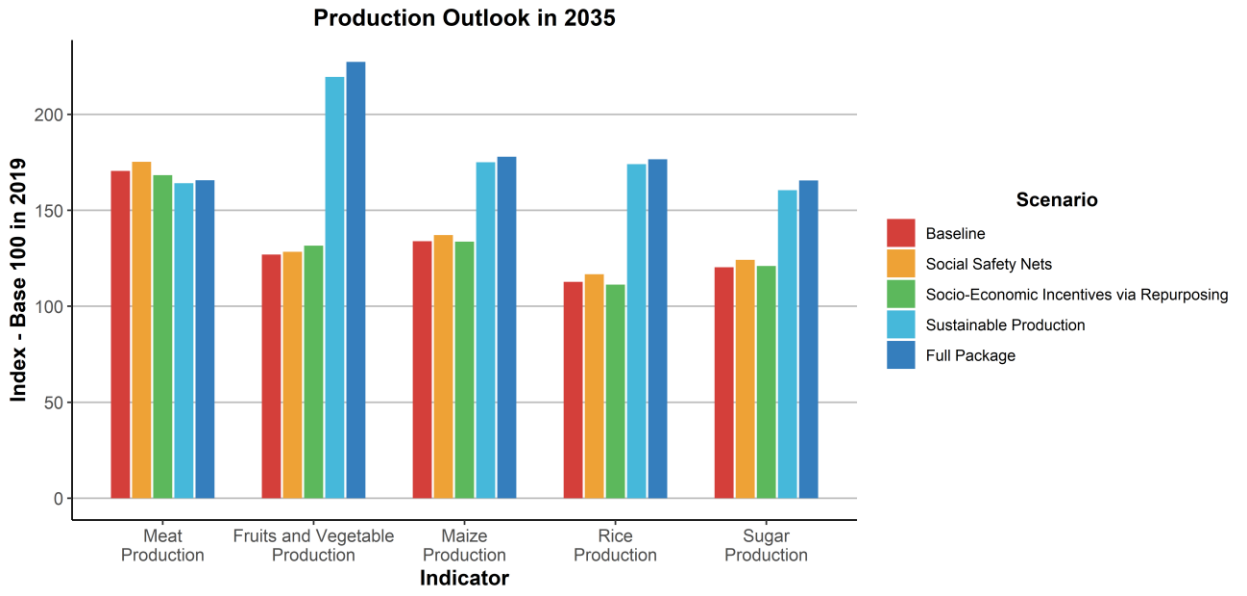
Source: Author's based on MIRAGRODEP

In terms of agricultural production, all scenarios project an increase in the output volumes of meat, fruits and vegetables, maize, rice and sugar in 2035 compared to 2019-levels. However different policy interventions yield distinct production patterns.

Under the socio-economic incentives, the production volumes of fruits and vegetables rise more than under the business-as-usual (with a 31.6% increase compared to 2019-level, against an increase of 27.0% under the business-as-usual scenario), and, on the contrary, the production volumes of meat increases less (68.3% increase, against an increase of 70.5% under the business-as-usual scenario) as this interventions consists in redirecting support towards nutritious and low-emissions agricultural products (including fruits and vegetables), away from high-emission commodities with lower nutritional value (including meat).

The sustainable production and the full package interventions would lead to the most substantial shifts in relative growth compared to the business-as-usual scenario. Fruits and vegetable production would increase significantly more than under the business-as-usual scenario (by respectively 119.4% and 127.4%, against 27% increase under the business-as-usual scenario), as would maize (by respectively 75.0% and 78.0% against 34.0% under the business-as-usual scenario), rice (by respectively 74.1% and 76.6% against 12.7% under the business-as-usual scenario) and sugar (by respectively 60.5% and 65.5% against 20.3% under the business-as-usual scenario). Meat production, on the contrary, would increase less with the sustainable production and the full package interventions (respectively 64.1% and 65.7% against 70.5% under the business-as-usual scenario).

Figure 2 - Production Indicators



Source: Author's based on MIRAGRODEP

6.2 Impact on poverty and diets

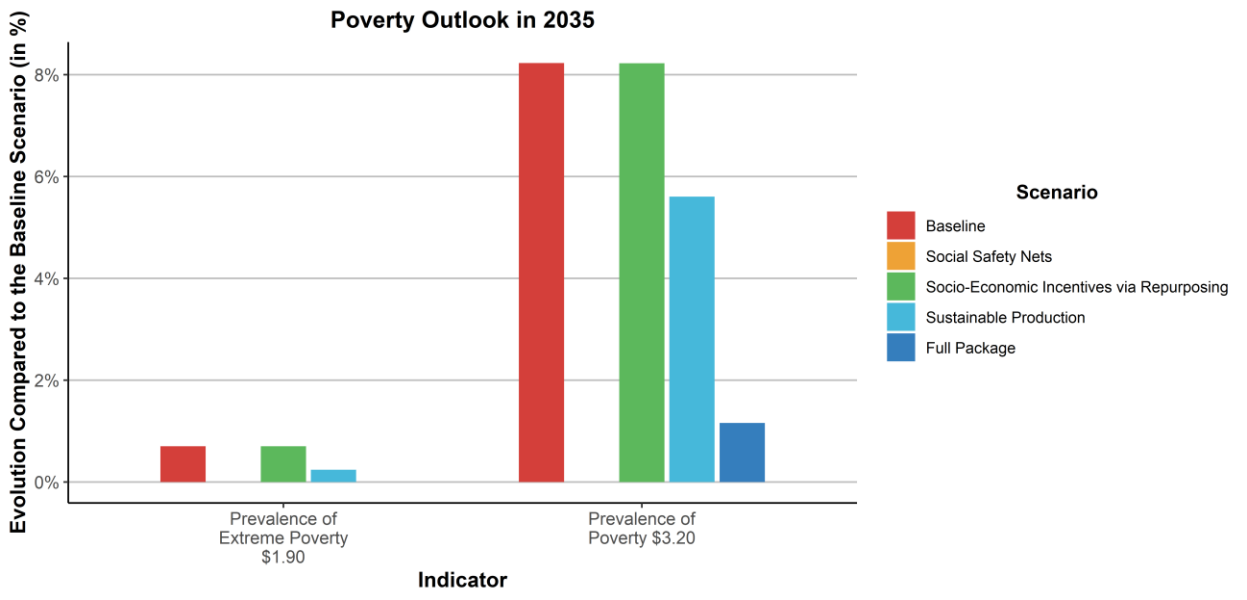
Under the business-as-usual scenario or baseline, 8.2% of the Indonesian population is projected to live with less than PPA$3.2 (with 0.7% of the population living with less than PPA$1.9), and 1.6% of the population is expected to experience undernourishment in 2035. Farm subsidy repurposing would not lead to improvements on those regards: the prevalence of undernourishment and the proportion of the population living in poverty would be the same as the ones in the baseline scenario.

The sustainable production scenario would eradicate hunger by 2035 and yield a decrease in the percentage of the population living in extreme poverty (the portion of the population living on less than PPA$1.9 would decline to 0.2%) and poverty (population living with less than PPA $3.2 would fall to 5.6%).Such improvements would support the countries goal of eliminating extreme poverty while providing further poverty reduction benefits beyond these targets. (Pape Ali 2023). (These improvements are due to two main factors: firstly, poor farmers' income would increase due to their enhanced productivity in this scenario.

Secondly, there would be a decrease in food prices as a result of increased food production and a reduction in food waste and loss.

The implementation of social safety nets and the full policy package appears to be the most effective policy interventions to reduce poverty and undernourishment. Under these scenarios hunger is eradicated and there is a significant reduction in poverty. In 2035, the entire population would exceed the PPA$3.2 threshold, effectively ending poverty in Indonesia under the social safety nets scenario and only 1% of the Indonesian population would be living below the PPA$3.2 poverty line under the full package scenario.

Figure 3 - Poverty Indicators

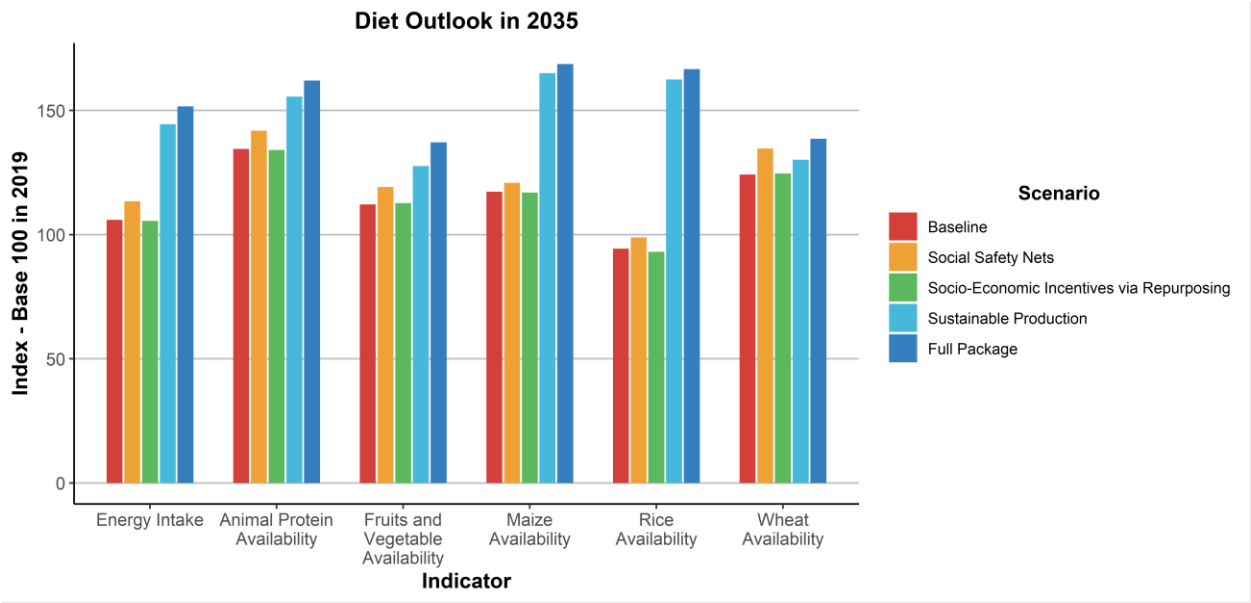


Source: Author's based on MIRAGRODEP

As highlighted in Figure 2, in all scenarios, there is an overall increase in the total amount of calories produced by 2035, resulting in a rise in energy intake. However, the Presidential Regulation No. 18/2020 on the 2020-2024 National Medium-Term Development Plan (Republic of Indonesia, 2020a), specifies that the energy intake needs to decrease in order to reach the recommended level of 2100 kcal/ca/day (compared to the 2019 level of 2121 kcal/ca/day). This objective of stabilizing energy intake is not fully compatible with the simultaneous increase in food production, reduction in food waste and losses, and the economic growth target for the agricultural sector. The surplus food generated must either be exported or consumed domestically. However, exporting all the surplus food is not feasible due Indonesia's export capabilities, leading to higher domestic consumption and consequently increased energy intake.

Additionally, the increase in the energy intake is notably more substantial under the sustainable production and full policy package scenarios, exceeding 40%. This notable increase can be attributed to a significant rise in rice and maize availability by more than 60%, whereas the other scenarios show a slight decrease in rice availability compared to the 2019 levels. Moreover, all policy interventions lead to an increase in the availability of animal protein, with a slightly more prominent rise observed in the sustainable production and full policy package scenarios.

Figure 4 – Diet-related indicators



Source: Author's based on MIRAGRODEP

Healthy diets affordability would improve in all policy scenarios modelled. Through the incentivization of nutritious commodities, the socio-economic incentives would steer production towards healthier agricultural products (as depicted in Figure 2), resulting in a reduction in the prevalence of healthy diets unaffordability. However, due to the limited scale of this intervention (constrained by initial support levels), the reduction in the prevalence of unaffordability for healthy diets is comparatively modest when compared to other policy interventions.

In the sustainable production scenario, a notably substantial reduction in the prevalence of unaffordable healthy diets is achieved (decreasing to 40.9% against 50.8% under the business-as-usual scenario). This outcome can be attributed to investments in irrigation, livestock production, crop productivity, and soil enhancement practices, which lead to an increase in the production of agricultural goods, including nutritious commodities (as highlighted in Figure 2), and consequently lead to an increase in the availability of healthy products (as depicted in Figure 4).

Under the social safety nets scenario, the whole population would have the means to access a healthy diet as this intervention is designed to bridge the affordability gap between households' per capita income and the cost of a healthy diet.

Lastly, the prevalence of unaffordable healthy diets would also be eliminated under the full package policy scenario since this policy scenario encompasses interventions that target both the demand side (via food stamps) and the production side (via subsidy repurposing and investments to promote sustainable production) in a complementary manner.

6.3 Environmental impact

Forest cover remains relatively stable across all interventions. The sustainable production scenarios and full policy package scenarios exhibit a slightly higher efficiency in limiting deforestation (reduction in the forest cover by 0.8% compared to 2019 levels against 1.3% in the business-as-usual scenario).

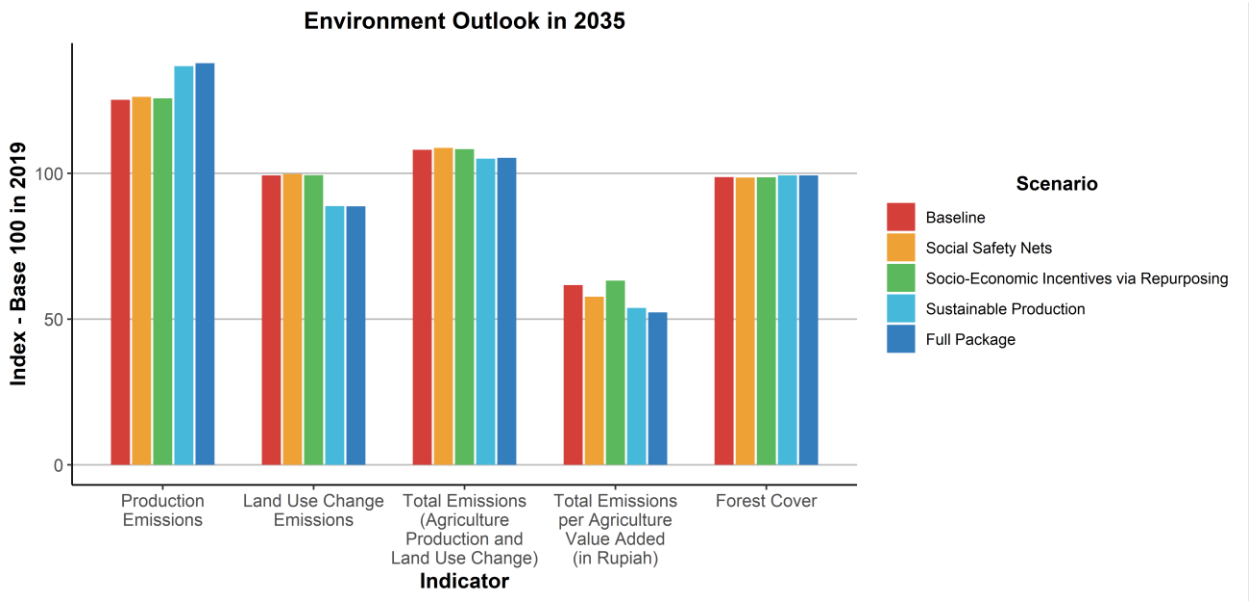
Emissions from agriculture and land use change are projected to increase by 2035 across all scenarios considered compared to 2019 level. In the baseline, social safety net, and repurposing scenarios, emissions stemming from land use change remain relatively stable, while agricultural emissions rise due to the

increase in agricultural output and the absence of measures to reduce the emission intensity per unit produced. Consequently, total emissions increase under those scenarios. Under the sustainable production scenario and the full policy package scenario, while measures to reduce food waste and adopt greener technologies do lead to a decrease in emissions per unit produced, they also increase the cost-efficiency of the agricultural sector. This enhanced efficiency improves the international competitiveness of Indonesian agricultural products and subsequently boosts demand abroad, prompting an increase in agricultural production (as seen in the subsection on diet indicators). However, this increase in production leads to a rise in production emissions due to the "scale effect." The growth in agricultural production outweighs the gains achieved by reducing emissions per unit produced through sustainable practices (the "intensity effect"). This phenomenon is known as the rebound effect, often referred to as Jevon's paradox, where the overall decrease in emissions per unit is offset by the overall increase in production, resulting in a net increase in production emissions (Bellemare, 2023). While land use change emissions do decline in the sustainable production scenario and the full policy package due to curtailed deforestation, the reduction is insufficient to counterbalance the substantial increase in production emissions, resulting in an overall increase in total emissions.

Moreover, there is a notable decline in emission intensity (per unit of value added) by 2035, with the most substantial reductions occurring under the safety net scenario, the sustainable production scenario, and the full policy package scenario (a respective decrease of 42.3%, 46.2%, and 47.7% compared to 2019 levels). The large decrease in emission intensity under the safety net scenario stems from the increased value added in the agricultural sector, driven by higher food prices resulting from safety nets. However, emissions level under this scenario remains similar to that under the business-as-usual scenario. For the sustainable production scenario and the full policy package scenario this large decrease in emission intensity is due to both the decrease in total emissions and the increase in the value added in the agricultural sector.

Finally, the increase in emissions in all policy scenarios, even the full policy package scenario, highlights that emissions reduction will not be achieved through traditional policy interventions or productivity gains due to the land use inertia and emission production. Land use inertia comes from existing peatland under cultivation. While bending deforestation does help, the existing peatlands that have been drained will continue to emit carbon unless ‘re-wetted’. In terms of food production emissions, due to the substantial increase in food production, new technologies or efficiency improvements alone cannot achieve the Enhanced Nationally Determined Contribution (Republic of Indonesia, 2022). Instead, it will be necessary to implement policies specifically targeting emission reduction.

Figure 5 - Environmental indicators



Source: Author's based on MIRAGRODEP

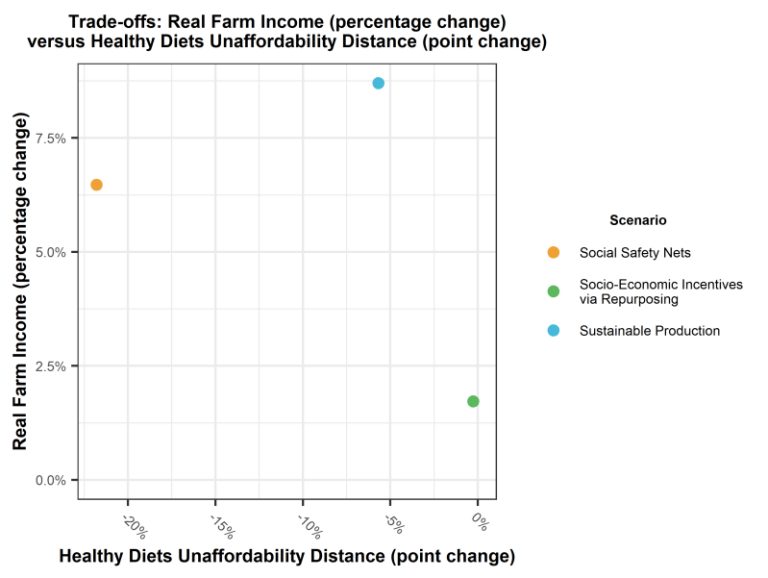
6.4 Analysis of the trade-offs

The scenarios described in the previous sections highlight the existence of tradeoffs with respect to the three pillars of sustainability -economic, social and environment- depending on the scenario.

The full policy package is the most effective policy intervention for achieving substantial progress across the three pillars of sustainability. Under this policy scenario, the GDP increases the most, poverty is substantially alleviated, the affordability of healthy diets significantly improves, and total emissions per agriculture value added are notably reduced. However, due to potential feasibility constraints in implementing this extensive package of policy interventions, this subsection delves into the trade-offs inherent in the other three policy approaches.

Among the policy interventions considered, the social safety net approach emerges as the most efficient in mitigating the unaffordability of healthy diets. Nonetheless, this policy intervention results in a comparatively smaller increase in real farm income compared to the sustainable production scenario. The repurposing scenario does contribute to a reduction in the unaffordability of healthy diets and a simultaneous increase in real farm income, however, the extent of these improvements remains limited due to the constraints of the initial support.

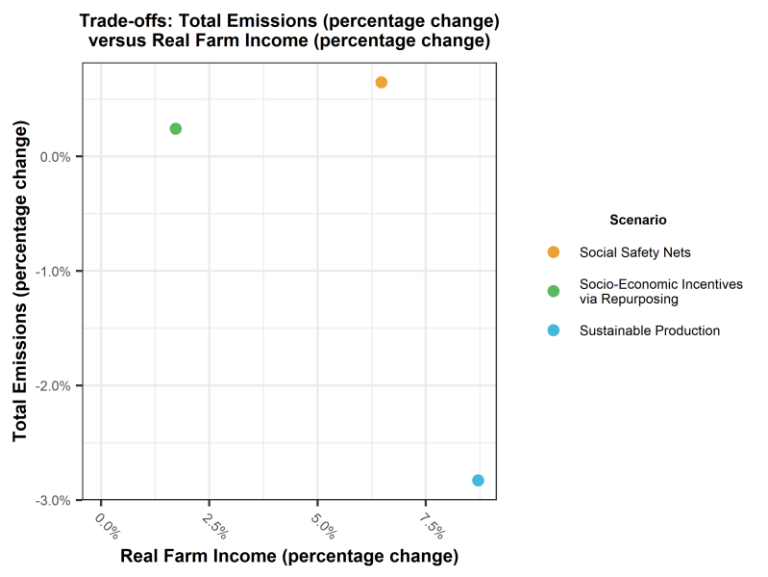
Figure 6 – Economic Pillar versus Poverty Pillar



Source: Author's based on MIRAGRODEP

Among the different policy scenarios, the social safety net scenario leads the most substantial rise in total emissions. This intervention increases the demand for agricultural products without concurrently reducing emissions per unit produced, resulting in an increase in agricultural emissions. On the other hand, the repurposing scenario does result in increased total emissions, albeit to a lesser degree as this intervention incentivizes the production of low emission products. However, emissions per unit produced remain unaltered, preventing the required reduction in production-related emissions. In contrast, the sustainable production scenario emerges as the most effective option for both reducing total emissions and increasing real farm income.

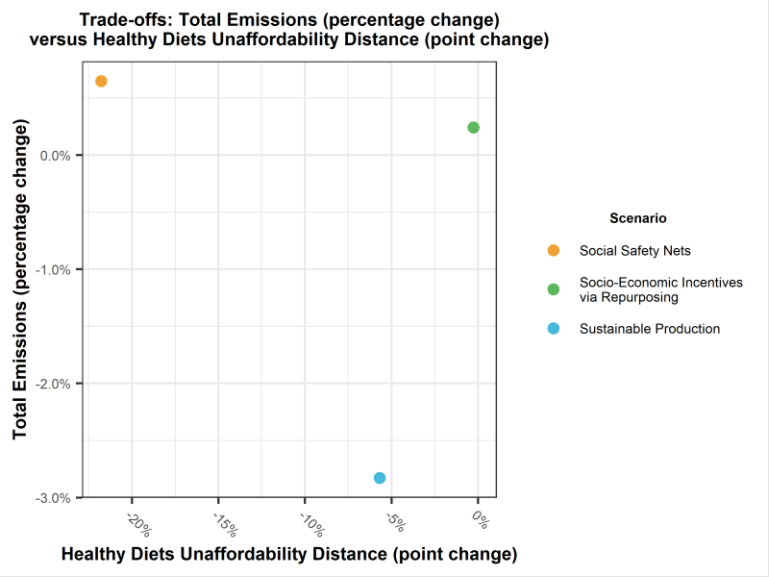
Figure 7 – Environnemental Pillar versus Economic Pillar



Source: Author's based on MIRAGRODEP

Finally, when considering both environmental and poverty aspects, no scenario emerges as perfectly relevant: the social safety nets scenario reduces the most substantially the healthy diets unaffordability but at the expense of an increase in total emissions. Sustainable production does reduce total emissions, but it falls short in achieving a significant reduction in the unaffordability of healthy diets.

Figure 8 – Environmental Pillar versus Poverty Pillar



Source: Author's based on MIRAGRODEP

7 Policy recommendations

The study's findings highlight the significant impact that various interventions can have on crucial aspects like undernourishment, poverty, economic outcomes, dietary choices, and environmental considerations. Among the interventions analyzed, the full policy package emerges as the most effective in generating positive outcomes across all dimensions. This comprehensive approach not only reduces poverty but also enhances value added per worker, improves dietary quality, lowers emission intensity, and safeguards forest cover.

While the other three policy packages also show positive impacts, their effects are not as prominent as those observed with the full policy package. For instance, package using safety nets to promote healthy diets reduces poverty and improves dietary quality, but its influence on economic and environmental outcomes is not substantial. On the other hand, the socio-economic incentives via repurposing package positively affect economic outcomes, but it lacks significant impacts on social or environmental aspects. Similarly, the sustainable production via investment and food waste and loss reduction package yields positive environmental outcomes but has limited effects on social or economic aspects.

In conclusion, the full policy package emerges as the most effective way to achieve positive outcomes across all four areas. However, the other three policy packages also demonstrate some positive impacts and may prove more feasible to implement in specific cases.

To achieve a sustainable food system in Indonesia, a comprehensive package of interventions is indispensable. Relying on individual interventions alone will not be sufficient to meet the ambitious goals. Moreover, the interventions analyzed have a direct impact on production levels, and it is essential to acknowledge that increased production can lead to higher greenhouse gas emissions. Relying solely on stopping deforestation will not be enough to offset these emissions. Therefore, innovative approaches are imperative to make the Indonesian production system more emission efficient.

8 Conclusion

In conclusion, Indonesia, as the largest economy in Southeast Asia, faces formidable challenges in ensuring food security, promoting sustainable food systems, and combatting deforestation. With a population of 272 million, the country's efforts to transform its food system, enhance nutrition, and protect its vast tropical forests are of utmost importance. This report delves into the key initiatives promoted by the Indonesian government, their impact on food security, and the challenges posed by deforestation.

The government's prioritization of food system transformation as a national policy objective aims to improve food quality and access, promote sustainable production, and align with the Sustainable Development Goals (SDGs). Specific programs under the 2020-2024 RPJMN address global, national, and local challenges in increasing food availability, access, and quality, enhancing human resource development, and ensuring the sustainability of agricultural resources.

However, Indonesia faces significant hurdles in achieving food security for its large population. Despite economic growth and social development investments, the country still grapples with high rates of undernourishment, stunting, wasting, overweight, obesity, and micronutrient deficiencies. Efforts to address these issues include nutrition education, food labeling regulations, promotion of local and traditional foods, and collaboration with the food industry. Initiatives supporting smallholder farmers, strengthening supply chains, and implementing market incentives and policies are also crucial for sustainable increases in food availability.

Addressing deforestation is equally vital for Indonesia's food production and ecosystem services. The country's vast tropical forests play a critical role in biodiversity conservation and climate regulation. Deforestation poses a significant threat, with commodity production being the primary driver. The Indonesian government recognizes the urgency and has taken measures to protect forests, promote sustainable land use, combat illegal activities, empower local communities, and address the underlying causes of deforestation.

The findings from this analysis highlight the substantial impact of policy interventions on key aspects such as undernourishment, poverty, economic outcomes, dietary choices, and environmental sustainability. The full policy package stands out as the most effective across all dimensions, emphasizing the need for a comprehensive approach. While other policy packages show positive impacts, they are not as pronounced as the full policy package. Collaborative efforts among government agencies, private sector entities, civil society organizations, and local communities are essential to achieve a sustainable food system in Indonesia.

To successfully navigate the path towards food system transformation, food security, and deforestation mitigation, innovative and multifaceted approaches are imperative. The policy options analyzed in this article lay the foundation for improved nutrition, increased food availability, and strengthened environmental sustainability. By addressing challenges and implementing effective policies and interventions, Indonesia can move closer to realizing a sustainable, secure, and resilient food system while preserving its invaluable forests and natural resources.

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Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org

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