POLICIES TO SUPPORT INVESTMENT REQUIREMENTS OF INDONESIA'S FOOD AND AGRICULTURE DEVELOPMENT DURING 2020–2045

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
IFPRI

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In this publication, "$" refers to United States dollars.

On the cover: A vegetable farmer pulling out fresh produce in a high elevation farm (photo by Al Benavente/ADB).

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Foreword

Indonesia is the fourth most populous country in the world. Food security is one of the national development priorities. The country has improved its food security, and agricultural production has substantially improved over the past four decades. With greater access to better technologies-high-yielding rice varieties, fertilizers, and agricultural extension program coupled with investments in rural infrastrucutre and irrigation-paddy production has increased by three folds over the past four decades. However, the rising population, which has nearly doubled reaching 262 million during the same period, other demographic dynamics, and climate change pose challenges to future food security. In 2018, Indonesia ranked 65th out of 113 countries in the Global Food Security Index. In terms of natural resources and resilience, the country ranked 111th, indicating that sustainability has to be one of the prioritized agendas in food and agriculture planning of the country. Indonesia needs to continuously increase its food production while conserving its natural resources, especially soil and water. It is, therefore, important to determine the amount and nature of investments and policies required to achieve these twin goals.

The *Policies to Support Investment Requirements in Indonesia's Food and Agriculture Development during 2020–2045* report, prepared in partnership with the International Food Policy Research Institute (IFPRI), provides recommendations for making informed investment decisions to meet the food security targets. The Government of Indonesia is preparing its next 5-year development plan 2020-2024 and the Vision 2045 with the aim of becoming one of the top world economies by 2045. The country is committed to attain the Sustainable Development Goals (SDGs) by 2030. A Presidential Decree was issued and the Ministry of National Development Planning (BAPPENAS) is preparing a detailed roadmap to meet SDG targets. This report provides timely inputs to the government's development planning exercise.

The report analyses different policy and investment scenarios for three subsectors, namely, agricultural research and development, irrigation and water resource management, and infrastructure development to reduce postharvest losses. Simulations were run under different climate change scenarios using a combination of parameters from agriculture and non-agriculture sectors, gross domestic product, skilled and unskilled employment, and household consumption. The analysis shows that while it is important to increase investments in all subsectors of food and agriculture, more focus should be given to research and development. Especially, investments in crop and livestock breeding should be prioritized to withstand the climate change stress, end hunger and malnutrition, and enhance agricultural productivity by 2030 (SDG 2) while conserving natural resources.

The report brings together ADB's knowledge and experience in agriculture and natural resources sectors; IFPRI's expertise in modelling and analyzing information on agricultureal policies and investment; and BAPPENAS' knowledge and expertise on food and agricultural development planning in Indonesia. This report is aligned with ADB's Strategy 2030 which envisions a region that is food-secure, free of poverty and malnutrition, prosperous, inclusive, resilient, and sustainable. In addition to meeting the knowledge needs of Indonesia to prepare its development plans, this report also responds to ADB's operational priority of promoting rural development and food security.

We are confident this report will become a key resource for policymakers of Indonesia to undertake pragmatic and evidence-based decisions. This report will also help the development practitioners and researchers of other developing member countries.

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Other members of the implementation team were Leah P. Arboleda, Natural Resources and Agriculture Officer, SDCC and Maria Angela Pilar M. Banaria, Senior Operations Assistant, SDCC.

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The report is an outcome of the collaboration between ADB and International Food Policy Research Institute (IFPRI). The IFPRI research team, led by Mark W. Rosegrant (then Director of IFPRI Environment and Production Technology Division (EPTD) and currently Research Fellow Emeritus, includes Bustanul Arifin, Professor, University of Lampung, Senior Economist, Institute for Development of Economics and Finance, and Professorial Fellow, School of Business, Bogor Agricultural University, Indonesia; Nicostrato Perez, Senior Scientist, EPTD, IFPRI; Angga Pradesha, Senior Research Analyst, Development Strategy and Governance Division, IFPRI; Rowena A. Valmonte-Santos, Senior Research Analyst, EPTD, IFPRI; and editorial assistance from Lorena Danessi, Administrative and Project Monitoring Coordinator, EPTD, IFPRI.

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Abbreviations

ABGC	academe, business, government, and civil society
ADB	Asian Development Bank
Bal-Crop-Lives	balanced, less investment-intensive program promoting the development of crop and livestock enterprises, not necessarily on the same farm but within the same province or district
BAPPENAS	Badan Perencanaan Pembangunan Nasional (National Development Planning Agency)
BPS	Badan Pusat Statistik (Central Bureau of Statistics)
Bulog	Badan Urusan Logistik (National Logistics Agency)
BUMR	Badan Usaha Milik Rakyat (community-owned enterprise)
Crop-Farm	concerted investment scenario promoting crop-based farm enterprise development
DAK	Dana Alokasi Khusus (special allocation transfers)
Def-R&D	defensive research and development (scenario)
DEWI	Dynamic Economy-Wide Model for Indonesia
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FDI	foreign direct investment
GDP	gross domestic product
ha	hectare
HadGEM	Hadley Centre Global Environmental Model (scenario)
Hi-NARS	intensified NARS research
HYV	high-yielding variety
IARC	international agricultural research center
ICT	information and communication technology
IFPRI	International Food Policy Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
Inpari	inbrida padi irigasi (irrigated inbred rice)
Int-Crop-Lives	intensive investment program with a simultaneous and balanced development focus on crops and livestock, promoting the development of semicommercial and commercial crop and livestock enterprises, not necessarily on the same farm but within the same province or district
IRREXP_WUE	irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements
IRREXP+_WUE	irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements
IWSF	irrigation water service fee
kcal	kilocalorie

kg	kilogram
km	kilometer
KUR	Kredit Usaha Rakyat (credit for the poor)
LandEXP	rural enterprise development program involving opening new land for agriculture
Lives-Farm	concerted investment scenario promoting livestock-based farm enterprise development
LiveStock	rural enterprise development program involving promoting small and medium enterprises in the livestock sector
MOA	Ministry of Agriculture
MPWH	Ministry of Public Works and Housing
MRD	Ministry of Rural Development
MT	metric ton
NARS	national agricultural research system
NGO	nongovernment organization
No CC	no climate change (scenario)
No Fert-Sub	efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D
O&M	operation and maintenance
OECD	Organisation for Economic Co-operation and Development
PHL	postharvest losses
PHL/Mktg	postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs
R&D	research and development
Re-Hi-NARS+	efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development
Re-NARS	efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system
RPJMN	Rencana Pembangunan Jangka Menengah Nasional (national medium-term development plan)
SMEs	small and medium-sized enterprises
SOE	state-owned enterprise
UGM	Gadjah Mada University
WUA	water users association
WUE	water-use efficiency

Currency Equivalents

As of 23 September 2019

Currency Unit – rupiah (Rp)

Rp1.00 = $ 0.0000710484

$1.00 = Rp 14,074.94

Executive Summary

The Indonesian agricultural sector and economy have made significant strides over the past several decades. Strong growth has promoted a structural transformation and refashioned the agrarian economy, with dominant roles now being played by industry and services. However, a significant number of people are still engaged in traditional agriculture, trapped in low-paid and less productive activities. Many of them do not get enough food and their children are prone to stunting, keeping them in a vicious cycle for generations. In 2016-2018, about 22.0 million people in Indonesia still endured hunger.

Agriculture retains an important role in the Indonesian economy, even though its share of the country's gross domestic product (GDP) has declined with economic growth, as is typical in the process of economic growth and structural transformation. The share of the agriculture sector declined from 30% in 1975 to around 23% in 1985 and continued to decline to 15.3% in 2010 and to 13.1% in 2017. The structural transformation is also seen in employment dynamics, with the share of agricultural labor in the country's total labor force decreasing from 62% in 1975, to 42.5% in 1995, 39% in 2010, and 29.7% in 2017 (BPS 2018). The slower decline in the share of agricultural labor compared with agricultural GDP indicates the relatively slow absorption of labor outside agriculture. As the service sector is less labor-intensive than the agriculture and manufacturing sectors, and the GDP share of the manufacturing sector has declined, excess agricultural labor has remained in the agriculture and rural sectors, often becoming disguised unemployment.

The agricultural sector serves a variety of functions. Agricultural development can deliver numerous economic, social, and environmental co-benefits. However, perhaps the most fundamental purpose of this sector is to ensure food security. The eradication of hunger should also be a primary aim of climate action in the sector, and thus a primary target of countries and the international community. Despite increasing trends in food production and availability, and in household incomes, access to food remains unequal in Indonesia and food insecurity remains a problem. Indonesia ranks 65th among 113 countries in the Global Food Security Index (GFSI) published regularly by the Economist Intelligence Unit (The Economist 2018). It ranked below the Association of Southeast Asian Nations (ASEAN) peers such as Singapore (1st), Malaysia (40th), Thailand (54th), and Viet Nam (62nd), mostly because access to food in Indonesia is quite low.

The poverty level in Indonesia is still high by ASEAN standards, with nearly 26 million people (9.8%) below the poverty line in March of 2018 (Arifin et al. 2018; WB 2019). There were 4.6 million malnourished children and 20.7 million people (8.3% of the population) at risk of hunger in Indonesia in 2015. The number of people at risk of hunger represented a significant improvement over the 42 million people (20% of the total population) in 2000, but additional effort is needed to further reduce hunger.

Increased investment in agriculture to modernize food systems and markets and make them more efficient is key to breaking this vicious cycle. Such investment will not only help improve the country's food production but will also enable households to engage in more productive sectors and earn a better income. Given the significant influence of the country's food policy on the domestic market, this effort needs innovative government support. Synergies between investment and policy goals must be attained to create more opportunities and efficiencies in achieving food security for the society as a whole. This country report examines the potential for agricultural investments to generate faster agricultural and economic growth and to improve food security. The results show that Indonesia can virtually end hunger by 2030 and fully eradicate hunger by 2045 with a combination of higher investments in agricultural research and development (R&D), irrigation expansion and water use efficiency (WUE), and rural infrastructure including roads, electricity, and railways.

The impact of agricultural investments and policies on food security and income is undertaken using a scenario modeling approach that links IFPRI's International Model for Analysis of Agricultural Commodities and Trade (IMPACT) agricultural sector model with a computable general equilibrium dynamic Economy-Wide Model for Indonesia (DEWI). Linking the two models also allow the assessment of the macroeconomic income and welfare effects associated with alternative pathways for agricultural growth under different scenarios. The linked models analyze socioeconomic and climate pathways under different assumptions about policy, agricultural R&D, and investments – to understand the possible impacts on food security and other agricultural outcomes and agricultural, non-agricultural, and economy-wide GDP.

In order to assess the impact of increased investments, the first step is to simulate projected agricultural, food security, and economy-wide outcomes under reference scenarios with and without climate change. This procedure allows the assessment of the impacts of climate change on agriculture and food security.

Following establishment of the reference scenarios, a series of investment scenarios are simulated for agriculture and the rural sector, including increased investments in agricultural R&D, irrigation expansion, WUE, and rural infrastructure in Indonesia. Rural infrastructure includes rural roads, railways, and rural electrification. Increased agricultural R&D boosts crop and livestock yields, reduces food prices, and increases farm income and economy-wide GDP through multiplier effects on the non-agricultural sectors. Irrigation and WUE investments increase crop area harvested and crop yields, reduce food prices, and thereby generate higher incomes. Enhanced rural infrastructure reduces post-harvest losses (PHL) and marketing margins, improving the profitability of farm production, and boosting supply to consumers for any given level of production. These effects also increase farm and broader income. These investment scenarios are simulated individually and in various combinations. In addition to the investment scenario, fertilizer subsidy policies and trade policy are simulated in the DEWI model.

The analysis shows that there are investment opportunities that can significantly improve the performance of the agriculture sector and increase food security. Investment in agricultural R&D is particularly effective in boosting productivity and improving food security while cutting hunger in half. Investment in rural infrastructure to reduce PHL and marketing costs also markedly improve food security. Investments in irrigation expansion also reduce hunger, although not by as much as the other types of investments, and reduce water use by 7%. Removal of the fertilizer subsidy and reinvestment of the funds saved due to removal of the subsidy into agricultural R&D also increases agricultural productivity and economy-wide GDP and reduces hunger. To further enhance the productivity of the food system, these investments can be combined into a more comprehensive portfolio together with targeted investments in crop and livestock enterprises. The most intensive comprehensive investment scenarios are projected to end hunger in Indonesia by 2034.

In addition to ending hunger, the comprehensive investment scenarios have big economy-wide economic benefits. The economic benefit or cost of an investment scenario in the economy-wide analysis is measured by the change in total real absorption (the total value of final demand, comprising aggregate consumption, investment, and government spending) compared with the baseline values. The impact of comprehensive agricultural investment on national welfare can be derived from changes in absorption value. Total absorption under the most intensive comprehensive investment scenario is projected to increase annual total economic benefits (as measured by absorption) by Rp1,834 trillion in 2045.

Several policy recommendations are derived from the scenario modeling.

- **Expenditure on agricultural research and development, especially crop and livestock breeding, should be increased significantly.** Investment in agricultural research and development has the strongest impact in reducing hunger and childhood malnutrition and should be substantially increased. It is important to increase the investment in broad-based yield-enhancing research, but more focus should also be given to stresses that are likely to increase with climate change, including heat, drought, pests, and diseases. Research should target increased yield with respect to both land and water.

- **Infrastructure investments, including rural roads, electricity cell phone towers, markets, cold chains, and processing facilities, should be expanded in partnership with the private sector.** By reducing marketing margins and post-harvest losses of food, and thus generate substantial production and income gains, and reduce hunger. Private sector investments will be critical to meeting higher investment targets, and the provision of government guarantees, or risk sharing could incentivize the private sector to fund infrastructure investments.

- **Increased investment in irrigation expansion and in improvement of existing irrigation systems is warranted, but careful attention should be paid to cost-effectiveness.** More investment in irrigation expansion and improvement will increase crop yields and area and promote the adoption of advanced technologies. Increased investments will lead to higher agricultural and total income and reduced hunger, but the impacts are not as high as for agricultural research and development and rural infrastructure, so care must be taken to invest in cost-effective irrigation.

- **Extension services need to be upgraded to expand the adoption of both conventional and advanced agricultural technology such as precision farming.** Extension systems should seek to improve knowledge and increase capacity, and there should be wider use of innovative forms of extension, including radio and mobile phones. The government, in partnership with the private sector, should also promote more rapid adoption of precision agriculture.

- **In conjunction with investments in improved extension and rural infrastructure, there should be increased funding for agricultural education to develop the ability to use advanced agricultural technology and information and communication technologies.** This combination of policies will promote the participation of youth and entrepreneurial farmers and foster innovative start-ups.

- **Legal and re gulatory reforms should be implemented to reduce barriers to the adoption of new seed varieties and other agricultural technologies.** Constraints on new technology transfer, including barriers to foreign direct investment, excessive testing and certification requirements, and ad hoc biosafety decision making, should be reduced.

- **Fertilizer subsidies have distorted farmer production decisions and encouraged excess use of fertilizer that is not economically justified and that results in higher runoff pollution and more greenhouse gas emissions and should be phased out.** Fiscal savings from the phase-out of subsidies should be invested in increased agricultural research and development and non-distorting income support for small farmers. Both the agriculture sector modeling and the economy-wide modeling show the large benefits from implementing this policy.

Chapter 1: Introduction

Poor geographic location, rapid population growth, soaring food prices, unequal income distribution, weak institutions, and inadequate or mediocre policies, compounded by changes in climate conditions, are some major threats to food security affecting developing countries. In Asia and the Pacific alone, an estimated 491.3 million people endure chronic hunger; these regions account for almost 66% of undernourished people globally (FAO 2017a). The high rates of malnourished children below 5 years and micronutrient deficiencies among different age groups, on the one hand, and overweight or obesity, on the other, especially in middle-income countries, exemplify the nutrient imbalance or improper diet in these regions. Food availability and accessibility is heavily affected by climate change. Increasing temperature, frequent and intense rainfall, and rising sea levels are some environmental changes that cause problems for the agriculture sector.

The sector serves a variety of functions. Agricultural development can deliver numerous economic, social, and environmental co-benefits. However, perhaps the most fundamental purpose of this sector is to ensure food security. The eradication of hunger should also be a primary aim of climate action in the sector, and thus the main target of countries and the international community. The goal of ending hunger in Asia and the Pacific by 2030 should inform calculations of the costs of helping agriculture in Asia and the Pacific to adapt to climate change.

The International Food Policy Research Institute (IFPRI) is currently doing a research study, Investment Requirements to Achieve Food Security in the Asia-Pacific Region by 2030, with country case studies for the People's Republic of China and Indonesia. This research study is part of the technical assistance umbrella project Investment Assessment and Application of High-Level Technology for Food Security in Asia and Pacific (TA 9218-REG) of the Asian Development Bank (ADB). The objectives of this research study are (i) to assess the impact of climate change on the agriculture sector in Asia and the Pacific; (ii) to estimate the climate change adaptation investment, including agricultural research and development, rural roads and railways, electricity, irrigation expansion and efficiency, and clean water and sanitation, required in the agriculture sector; and (iii) to undertake a rigorous calculation of the investments needed to achieve food security targets and end hunger in Asia and the Pacific by 2030.

The Indonesia case study, done to assess the country's agricultural investments and policies, included a modeling approach linking IFPRI's IMPACT agriculture sector model with a computable general equilibrium DEWI. The use of the IMPACT model allowed the analysis of socioeconomic and climate pathways, with different assumptions about policy, agricultural research and development, and investments, to understand their possible impact on food security and other agricultural outcomes and to assess the investment costs required to adapt to climate change and to end hunger.

IFPRI developed DEWI for this project to evaluate the economy-wide impact of the alternative agricultural scenarios. Linking the two models enabled IFPRI to assess the macroeconomic income and welfare effects associated with alternative pathways for agricultural growth under different scenarios. Outcomes simulated by DEWI under any policy or investment scenario were agricultural, nonagricultural, and economy-wide gross domestic product (GDP); skilled and unskilled employment; and household consumption, by quintile.

The study also looked into the policy environment for agriculture in Indonesia, including trends in policies and investments and current developments in the food security situation in the country. In addition, to assist the Indonesian government in planning, IFPRI projected key indicators under different scenarios, encompassing the number and percentage of hungry people, and the number and percentage of malnourished children.

This draft report on the Indonesia case study starts with the evolution and current state of the country's agricultural policy. This is followed by an examination of recent analyses of future scenarios for the agriculture sector. Prospects for Indonesian agriculture and food security up to 2030 and 2045 are discussed with the help of the formal approach to scenario analysis and the IMPACT model. Next, the report goes into the economy-wide impact of alternative agricultural scenarios with the application of DEWI. Finally, conclusions and recommendations, including investment priorities based on a synthesis of policy review and impact analysis from the scenario assessment, are presented.

Chapter 2: Assessment of Indonesia's Agricultural Policies

2.1 Introduction

This chapter assesses the current status of Indonesian agriculture and its policy challenges and responses. Major agricultural policies have not changed much under the current government. The focus is on food sovereignty, self-sufficiency in the staple foods of rice and maize, and increased production of other strategic crops. The national medium-term development plan (RPJMN) for 2014–2019 set production targets of 82 million tons of rice, 24 million tons of maize, and 2 million tons of soybeans by 2019. In nearly 4 years, this administration has been implementing a major intensification program known as Upsus Pajale, a special effort to improve rice, maize, and soybean production by increasing the amount of fertilizer and seed subsidies, providing pre- and post-harvest machineries, improving irrigation infrastructure, building new dams, and maintaining existing dams and irrigation canals. The government has also been carrying out a major extension program to utilize/optimize abandoned/less-utilized agricultural land for rice, maize, and soybean cultivation and to connect the new rice fields with irrigation infrastructure.

The Ministry of Agriculture (MOA) is implementing the Upsus Pajale program to increase the production of rice and maize, and the productivity of farmers, with the help of provincial and local governments, and is monitoring the additional planted areas of rice and maize monthly and weekly. The government has also assigned the state-owned enterprise (SOE) Bulog, the National Logistics Agency, to improve rice procurement systems at the field. To expand the planted areas and boost rice procurement, the government is obtaining special assistance from district, subdistrict, and field military personnel. MOA is likewise implementing the Upsus Siwab program, an intensive program of livestock production involving insemination, animal fattening, and community-based livestock breeding. The RPJMN has set the ambitious target of increasing beef production by 755,000 tons by 2019, or by 37.7% yearly. In the livestock sector, Bulog is assigned to maintain the stability of beef prices, which generally calls for lowering the retail price of beef from the current Rp115,000 ($8.60) per kilogram (kg) to below Rp80,000 ($6), another ambitious target. Bulog is also tasked with stabilizing the prices of 10 food commodities—rice, maize, soybeans, sugar, cooking oil, onion, chilies, beef, chicken, and eggs.

In 2017, the Indonesian government disbursed about Rp60 trillion ($4.5 billion) directly to 115,000 villages throughout the country for rural investment and rural development in general. The Ministry of Villages, Development of Disadvantaged Regions, and Transmigration is responsible for administering the funds, along with the country's 74,000 village heads. Each village receives about Rp800 million ($60,000) for rural investment in physical, social, or economic development, including agricultural development and food-related concerns. The villages spend their allocations at their discretion to establish and develop village-owned enterprises, rural-based enterprises, and market networks that could improve the rural economy, create rural employment, and improve social welfare, thus contributing to economic growth and income equality. Other government funds from MRD and other related government organizations are meant to be used to provide a decent living to rural villagers, including farmers, fisherfolk, and small-scale enterprises in the rural areas. The government plans to transform 47,000 disadvantaged villages (40% of the country's total villages) into progressive and self-sufficient villages.

Besides the policies in the food crop sectors and rural development, agricultural policies under the current administration are accelerating the production of horticultural products, cash crops, and agricultural commodities such as palm oil, coffee, and cocoa, as well as improving the postharvest handling of strategic products. The first 2 years of the current administration saw an increase in the production of rice and maize (but not of soybean and livestock).

Extreme weather events—drought brought by El Niño in 2015 and the subsequent La Niña–induced wet season in 2016—have, however, affected the production performance of major agricultural crops, although government officials have been reluctant to acknowledge this weather impact. Indonesia therefore continues to import rice: 0.86 million tons in 2015 and 1.28 million tons in 2016, mostly because of the drought in 2015. As of June 2018, according to data from the Central Bureau of Statistics (BPS), rice imports for the year had reached 896,000 tons, a significant increase from the 305,000 tons in 2017. By October 2018, with the drought starting to hit some rice production centers, rice imports had gone up to 1.8 million tons. The government had decided to import 500 tons of rice at the start of the year for Bulog stock, and possibly 500,000 tons more for market operations and other emergency response.

Indonesian agriculture has not adjusted well to extreme weather, as most farmers have not fully adopted drought- and flood-tolerant crop varieties. Since 2017, MRD has accelerated the development of water catchment receptacles (locally known as *embung*) to harvest water during the rainy season and manage the water collected during the dry season. Indonesian agriculture lags behind some of its developing-country counterparts in terms of modern technology in food production, the development of precision agriculture, and the use of information and communication technology (ICT) in general.

This chapter explores rural investments, trends in the adoption of advanced technologies such as precision agriculture and other related ICT, and policy obstacles to investment in agriculture. Policy recommendations to promote agricultural investment in Indonesia will be provided. This report draws heavily on desk studies, available literature, and relevant documents, and a full-day project inception workshop in Jakarta in 2017 that gathered input from senior government officials, academics, and private agriculture and agribusiness sector participants. Interviews, consultations, and interactions with individuals in the government, academe, and the private sector were conducted to verify some policy responses and general initiatives related to investment in food and agriculture and agricultural development in Indonesia. The report also presents lessons learned from ongoing action research into consolidated land management in the context of "agricultural corporatization," to examine the viability of such initiatives in tackling the issues of economies of scale in agricultural development and the future of rural investment and adoption of advanced technologies in Indonesian agriculture.

2.2 Agricultural Development and the Food Economy

2.2.1 Structural Transformation of the Indonesian Economy[1]

Agriculture retains an important role in the Indonesian economy, even though its share of the country's GDP has declined with economic growth, as is typical in the process of economic growth and structural transformation. The share of the agriculture sector declined from 30% in 1975 to around 23% in 1985 and continued to decline to 15.3% in 2010 and to 13.1% in 2017 (BPS 2018). The share of the industrial sector, on the other hand, increased from 33.5% in 1975 to 35% in 1985, and continued to rise to 41.8% in 1995. Following the 1998 economic crisis, which hit the manufacturing and the financial and other service sectors the hardest, the industrial sector's share declined to 38.5% in 2005. The economic crisis also put an end to much of the import-substituting manufacturing capacity and employment (JICA 2013).

Indonesia has been experiencing early deindustrialization since the economic crisis, with the share of the manufacturing and mining industries continuing to decline from 36% in 2010, down to 28.7% in 2015 and 27.7% in 2017 (BPS 2018). The share of the services sector, on the other hand, increased significantly, from 36.3% in 1975, to 41% in 1995, and to 48% in 2005, and by 59.2% of the total GDP of the economy (Table 2.1). The structural transformation is also seen in employment dynamics, with the share of agricultural labor in the country's total labor force decreasing from 62% in 1975, to 42.5% in 1995, 39% in 2010, and only 29.7% in 2017 (BPS 2018). The slower decline in the share of agricultural labor compared with agricultural GDP indicates the relatively slow absorption of labor outside agriculture. As the service sector is less labor-intensive than the agriculture and manufacturing sectors, and the GDP share of the manufacturing sector has declined, excess agricultural labor has remained in the agriculture and rural sectors, often becoming disguised unemployment.

[1] This section draws on Arifin (2014) and the data are updated.

Table 2.1: Agriculture and Structural Transformation in the Indonesian Economy, 1975–2017

Item	1975	1985	1995	2005	2010	2015	2017
Share of GDP (%)							
Agriculture	30.2	22.9	17.1	13.4	15.3	13.5	13.1
Industry (manufacturing, etc.)	33.5	35.3	41.8	38.5	36.0	28.6	27.7
Services	36.3	42.8	41.1	48.1	48.7	57.9	59.2
Share of Employment (%)							
Agriculture	62.0	56.0	46.0	42.5	39.0	32.9	29.7
Industry (manufacturing, etc.)	6.0	9.0	12.8	13.0	14.5	13.3	14.5
Services	32.0	35.0	43.2	44.5	47.5	53.8	55.8

Note: The GDP share is calculated from BPS data.

GDP = gross domestic product.

In the 1970s and 1980s, when export revenues from oil and natural gas (oil and gas) were quite large, the government was relatively free to boost agriculture sector spending. However, since revenues from oil and gas exports have declined and export revenues from plantation commodities, especially those managed by state companies, are not large enough, budget flexibility is diminishing. Therefore, the capacity of the state budget to boost industrialization to absorb the increase in labor and create new jobs is reduced. The strategy for developing manufacturing industries based on agriculture, as well as non-agriculture, has become difficult to realize. Efforts to encourage domestic and foreign companies in the manufacturing sector to play a greater role in industrial development are hampered by the weakening in the investment climate, capital capacity, and financial sector support, among other factors.

Despite strong growth in GDP per capita during the past decade, growth in agricultural labor productivity has been slow because of limited value addition in agriculture, slow diversification in the agricultural export base, and inadequate employment creation in nonagricultural sectors. Poor infrastructure has also affected farmer access to markets and input. While the poverty rate dropped from 11.2% in March 2015 to 9.8% in March 2018, the number of poor people in rural areas is still large—about 15.81 million people (13.2% of the population in rural areas), higher than the number of urban poor (10.14 million people, or 7.0% of the urban poor). Income inequality increased between 1998 and 2018, making social protection policies a higher priority. More importantly, ineffective government policies have contributed to Indonesia's income inequality, as will be discussed below.

Currently, after nearly 4 decades of change, the challenges of the food economy in Indonesia, and the agriculture sector in general, have become increasingly complex. The current and future challenges come not only from the growing population pressures (a global population of 7.4 billion, with nearly 260 million in Indonesia alone) but also from ecological risks, climate change, extreme weather like droughts and floods, and declining food production capacity due to excessive use of chemicals, in a move away from the principles of sustainable agriculture. In the future, the food economy and agricultural development need to be bolder in searching for strategic breakthroughs, business models, policy options, and farmer assistance and civil society empowerment in the development forms of modern biotechnology, precision agriculture, eco-friendly agriculture, resource conservation, and more efficient postharvest handling. Agricultural development must be farsighted, and not merely pursue politically motivated self-sufficiency goals for staple food crops but also contribute to the structural transformation of the economy that gives priority as well to food consumption and diversification. Future agricultural development must reduce the transaction costs of small rural farmers serving urban consumers, which often arise throughout the food value chain, and use modern science and information technology to improve nutritional content and food quality, as well as people's consumption behavior, to achieve balanced nutrition and high-quality consumption.

2.2.2 Investment in Agriculture: Research and Development and Extension

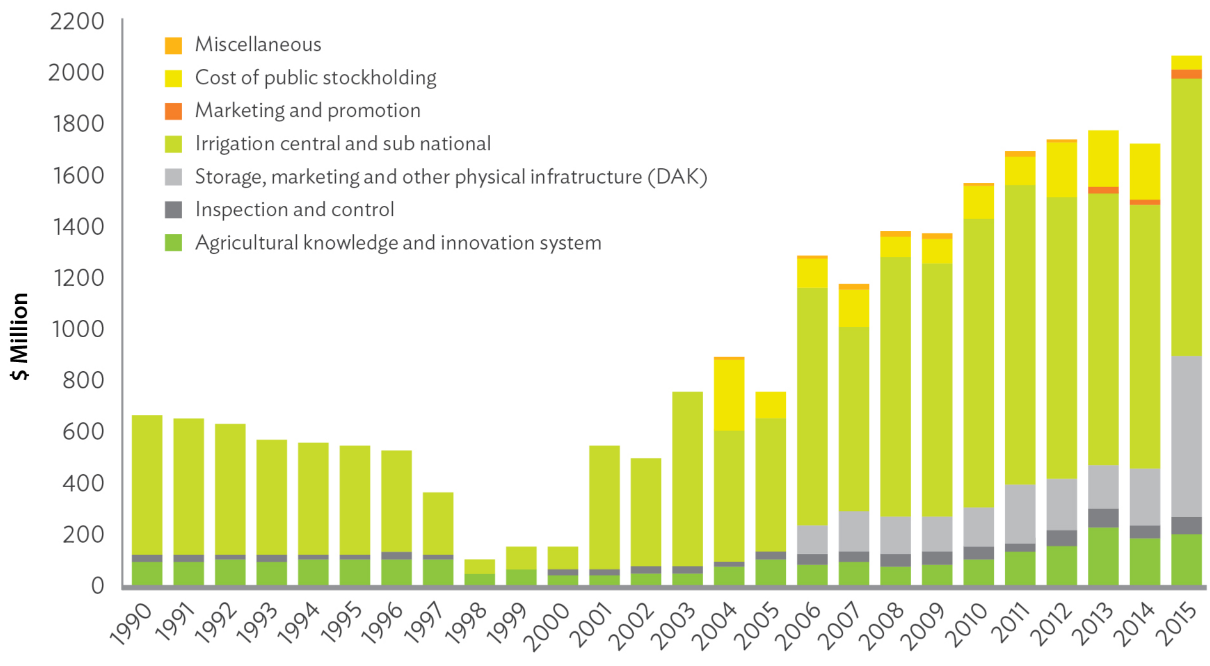
Investment in Indonesian agriculture comes from farmers, the private sector, and the government. Total investment in agriculture in 2016 was about Rp400 trillion ($30 billion), mostly from farmers' initiatives in the form of land development, small infrastructure, and supporting facilities. Government investment in the form of the state budget (APBN) and provincial and local budgets (APBD) is only about 4% of total investment in agriculture. Investment from the private sector is very small, although it has showed an increasing trend in recent years. The total value of domestic investment in 2016 was Rp9.43 trillion ($709 million) and foreign investment was $1.35 billion. For private investment in agriculture to increase, economic growth potential must improve, and the investment environment must be more favorable (DGWR 2016).

From 2010 to 2014, domestic investment approvals in agriculture fluctuated yearly, although growth was about 4.2%. Foreign direct investment (FDI) in agriculture increased by about 18.6% per year (BPS 2018). Investment in agriculture was mostly in the food crop and plantation sectors; a small portion went to horticulture and livestock. This allocation was most likely related to the desire of the current and previous government administrations to achieve self-sufficiency in staple food crops. In addition, investment in palm oil plantations, both domestic and FDI, continued to increase until Government Regulation Number 71/2014 on the Protection and Management of Peatland Ecosystems was passed. MOA Regulation 98/2013 on Plantation Business Licensing Guidelines limited the ownership of plantations by an individual company or group of companies to a maximum of 100,000 hectares (ha). Similarly, investment in horticulture increased rapidly until the passage of Law Number 13/2010 on Horticulture, which limited FDI to a maximum of 30% of total investment in the sector.

Private investment in the upstream sector of food crops such as rice and maize has been limited, primarily because of the complexity of the landholding issues for food crops. Most investment in the upstream sector and food crop production processes comes from individual farmers and the government. Individual farmers, farmers' associations, and the community generally invest in land development and preparation, small-scale infrastructure such as tertiary and artery canals and water catchments, and the purchase of agricultural machinery and equipment for the production process. Unfortunately, no credible data on the value of agricultural investment from individual farmers, farmers' associations, and the community are available. The government invests in large-scale agricultural infrastructure such as dams, irrigation, and drainage canals; research and development (R&D); and education and extension. Historically, the biggest expenditures by far have been o n irrigation, followed by agricultural knowledge (mainly R&D) (Figure 2.1). Over the past decade, storage, marketing, and other infrastructure have grown rapidly.

Among the subsectors shown in Figure 2.1, irrigation was allocated the highest average annual investment, at $1.08 billion, followed by storage, marketing, and other physical infrastructure, at $0.28 billion, and agricultural knowledge and innovation systems, at $0.18 billion, including $0.11 billion for agriculture research in 2011–2015 (OECD database). Additionally, average agricultural GDP during the same period was computed at $120 billion (WDI database). Of this figure, 0.09% was earmarked by the Indonesian government for agriculture research. However, agriculture and development expenditures relative to agricultural GDP remained well below those of neighboring countries. A commonly accepted target indicator is that countries should spend the equivalent of at least 1% of agricultural GDP on agriculture research and development. Although other Asian countries also have not made the 1% target in recent years, the PRC's intensity ratio was 0.62 in 2013, India's was 0.30 in 2014,

Figure 2.1: Investment Trends in the Indonesian Agriculture Sector, 1990–2015



Source: OECD database.

Table 2.2: Slow Adoption of New Paddy Varieties (%)

Province	IR-42	IR-64	Ciherang	Inpari 13
Year of release	1980	1986	2000	2009
Length of release (years)	35	29	15	6
East Java	na	15.34	41.02	3.29
West Java	na	3.29	46.51	0.88
South Sulawesi	na	na	26.30	3.85
West Sumatra	18.25	3.43	7.93	na

na = not available.
Source: Suryana (2015).

and Malaysia's was 0.84 in 2014 (Stads 2016). Indonesia has been slow to adopt new rice varieties in recent decades (Table 2.2). According to recent studies by Suryana (2015), the adoption of new rice varieties is a generally slow process, dependent on production cycles and location specifics such as agroecology and the socioeconomic condition of the rice farmers. Table 2.2 shows that many rice farmers are still growing Ciherang rice, a high-yielding local variety that was released for wider use 15 years ago (around 2000). In the provinces of East Java and West Java, the two largest rice production centers in Indonesia, more than 41% and 46.5% of rice farmers, respectively, are growing this rice variety. Inpari 13, a new variety of irrigated inbred rice released in 2009, has been adopted by only 3.3% of farmers in East Java and by less than 1% in West Java. In South Sulawesi province, the Ciherang variety has been adopted by 26.3% of rice farmers, but the Inpari 13 variety has been adopted by only 3.9%.

The research and breeding process for each new high-yielding variety (HYV) usually takes about 7–10 years, after which the HYV is released for public use. Wide adoption of a new HYV usually takes about 10–15 years, depending on the performance of the extension system, farmers' enthusiasm for the HYV, and consumers' likely demand for such rice varieties. More than 15.3% of rice farmers in East Java, 3.3% in West Java, and 3.4% in West Sumatra still grow IR-64 rice, an HYV that was released more than 30 years ago. About 18.3% of rice farmers in West Sumatra still grow the IR-42 variety, the first-generation HYV of the 1980s. IR-42 rice is generally long-grain, a bit hard, and not sticky, and has become a typical rice specialty in West Sumatra.

The slow rate of adoption of new varieties indicates that the government should pay more attention to developing and adopting new crop varieties to improve productivity and efficiency in the national and local agriculture sectors. The importance of R&D in facilitating agricultural modernization cannot be overemphasized, especially in developing sustainable farming systems, along with support systems to promote them. Increased investment in agricultural R&D and extension will be essential to ensure the development and adoption of improved crop varieties that will boost farmer adoption. Increased effort requires both increased investment in R&D and improved integration of the research and extension system. With most functions for agriculture and rural development shared among the various levels of government, integration has often been poor, with relatively weak links between national agricultural research centers, the 32 Assessment Institutes for Agricultural Technology (AIATs), and agricultural extension teams in the districts (JICA 2013). New investment in ICT to improve R&D, as well as in the education and extension system for farmers and human resources associated with the agriculture sector, is needed. Such investments could be the basis for the further development of precision agriculture and the preparation of breeds for future rural investment that could contribute to agricultural and economic development in general.

The World Bank (2007) noted that "the experience of the Indonesian decentralization of its extension system has been mixed, with adverse impacts on extension through sharp reductions in funding and removal of central-level guidance." The implementation of decentralization has created disparate understanding of extension service delivery and uncertainty about institutional affiliation and staff management. Overall, there are still no effective means of dealing with the constraints faced by small farmers in the adoption of new technologies. The assessment by JICA (2013) concluded that, "While some improvements have been made, research and extension agencies continue to suffer from weak (and sometimes confusing) budgetary support, an incomplete reform agenda and the confusion caused by decentralization."

However, experimentation with "a shift [from] top-down to participatory approaches [and from] input and technology dissemination to dissemination of market and upstream information and technology, and some movement toward privatization of extension" (World Bank 2007) has also had positive results. Field extension personnel need to equip themselves with better capabilities, including being able to identify appropriate farming businesses for farmers, considering farmer-specific conditions; motivate farmers to enhance their farming activities, and not limit themselves to production; facilitate the procurement of credits from the banks, to enable partnerships with agricultural enterprises; and partner with farmers to market their end products.

On balance, greater guidance from the central government will be important in the future. The Indonesian consumer market demands enhanced product standards, and (nontariff) barriers to international markets are of increasing concern to more diversified farmers and farming systems. The rapid dissemination of technologies and their proper adoption and use is another critical area that goes hand in hand with R&D. Extension and seed industry reforms must address bottlenecks in the adoption of improved technologies. Only strong organizational, information, and extension strategies will give smallholders access to both domestic and international trade. Moreover, extension services should work with AIATs to make sure that productivity increases (and not area expansion) are at the forefront of efforts to stimulate agricultural growth. Reliance on extension agents is also likely to decline over time. Since many of the technologies are knowledge-intensive, extension systems need to be upgraded, with better use of information and communication technology. To further support the adoption of new technologies, improved legal and regulatory systems that do not hinder the development and uptake of new technologies will be important, as will investments in rural infrastructure. The reach of public extension should be expanded through better coordination with nongovernment organizations (NGOs) and private companies engaged in delivering extension advice to farmers.

2.2.3 Public Investment in Irrigation Systems

The current administration allocated a state budget of Rp33.26 trillion ($2.5 billion) for water resources development and management in 2017—a significant increase from the Rp28.61 trillion ($2.15 billion) allocated in 2016. The government plans to improve water resource infrastructure to support water and food security. The plan includes the development of new dams, water catchment systems, irrigation infrastructure, and groundwater irrigation. The government has set priorities including (i) building five new dams under central government jurisdiction, (ii) improving surface or gravity irrigation infrastructure under central government jurisdiction up to 472.4 kilometers (km), (iii) constructing nine other dams, and (iv) constructing groundwater irrigation infrastructure up to 147 km. More specific targets include 384,000 hectares (ha) of irrigated land, swamp irrigation of 165,000 ha, and brackish-water irrigation of 29,000 ha; 970 km of irrigation canals and rivers normalized; and 1,560 units of new water catchment built across the country.

Moreover, the government has allocated significant amounts—a budget of Rp4 trillion ($300 million) for irrigation infrastructure in special allocation funds (Dana Alokasi Khusus, or DAK)—in direct transfers to local governments to support the national irrigation targets set out in the RPJMN for 2015–2019. These targets are: rehabilitating 3 million ha of irrigated land through the Irrigation Improvement Program (IIP), developing new irrigation, and rehabilitating irrigation infrastructure. The government is also continuing to support World Bank grants for the Water Resources and Irrigation Sector Management Project–Phase II (WISMP-2) with Rp253 billion ($19 million) to improve capacity building and human resources for water resources management along the watersheds and irrigated areas, and to increase production and productivity in some regional rice production centers.

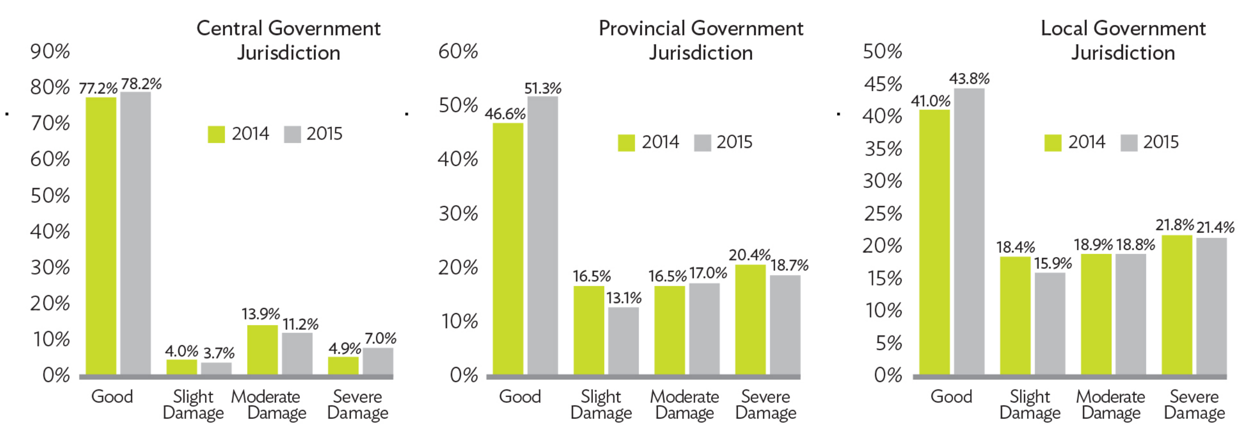
In addition to the water resources management program under the Ministry of Public Works and Housing (MPWH), the government has set key performance indicators for irrigation systems in the MOA portfolio. In 2017, the MOA's irrigation targets were (i) building tertiary irrigation to cover 100,000 ha of rice fields (ii) expanding rice fields by 80,000 ha and (iii) providing direct subsidy for 63,693 units of agricultural machinery and equipment. These targets were set to support specific programs for optimizing agricultural land and increasing the planted and harvested area for rice. The MOA is also allocating Rp1.3 trillion ($100 million) in DAK funds for water resources infrastructure and has transferred the amount directly to the local governments.

Official MPWH data, based on Ministerial Decree No. 293/2014, show that Indonesia has a total irrigated area of 9.1 million ha—7.3 million ha of irrigation and 1.8 million ha of swamps and wetlands. Surface irrigation with gravity and canal systems covers more than 7.1 million ha. Irrigation systems that use more advanced technology, such as groundwater irrigation, cover only 113,600 ha; pump irrigation covers only 44,200 ha. The central government is responsible for planning and for the operation and maintenance (O&M) of about 2.4 million ha of the total area served by irrigation (33.26%); provincial governments, for about 1.1 million ha (15.47%); and the district governments, for about 3.7 million ha (51.27%).

Nevertheless, a 2015 government internal audit showed the following extent of damage to irrigation infrastructure, according to the Regulation of the Minister of Public Works and Housing No. 12/PRT/M/2015: over 56% under district government authority (from 52% damage in 2010), 49% under provincial government authority (from 61%), and 22% under central government authority (from 54%). The current administration has set the ambitious target of reducing the damaged irrigation infrastructure to only 10% by 2019, to support self-sufficiency programs for strategic crops, primarily rice, maize, and soybeans. Figure 2.2 shows the irrigation system performance in 2014 and 2015, at a time when infrastructure damage received serious attention from all levels of government, which hoped to increase rice production, and productivity and agricultural development in general (DG of Water Resources, Ministry of Public Works and Housing 2017).

ADB estimates point out that the long-term development plan for 2015–2025 will require around $9.9 billion (Table 2.3) (Quincieu and Tabor 2016). The Irrigation Improvement Program calls for participatory irrigation management, asset management, needs-based budgeting, and the strengthening of water users associations (WUAs) and water resources agencies to improve management, O&M, and service delivery. The program will rehabilitate 3.2 million ha of irrigation systems. The majority (71%) of its budget is for rehabilitating irrigation infrastructure under national and provincial and/or local government jurisdiction.

Figure 2.2: Performance of Irrigation Systems under Central, Provincial, and Local Government Jurisdiction, 2014 and 2015 (%)



Note: "Damage" is defined according to Ministerial Decree No. 12/PRT/M/2015, which classifies irrigation infrastructure as (i) being in good condition, if the damage is less than 10%; (ii) slightly damaged, if the damage is 10%–20%; (iii) moderately damaged, if the damage is 21%–40%; and (4) severely damaged, if the damage is over 40%.

Source: DG of Water Resources, Ministry of Public Works and Housing (2016).

Table 2.3: Summary of Program Expenditure Framework, 2015–2025 (2016 prices)

Item	Amount ($ million)	Share of Total (%)
Capital Expenditure		
Infrastructure rehabilitation and upgrading	6,395.00	64.37
O&M and management services	328.00	3.30
Planning and detailed engineering design	513.64	5.17
Recurrent Costs		
O&M expenditure	2,469.00	24.85
Staffing and operations	230.00	2.32
Total	9,935.64	100.00

O&M = operation and maintenance.

Source: ADB estimates, based on government planning documents, including the national medium-term development plan, the Irrigation White Book, the Irrigation Blue Book, the Irrigation Green Book, and other supporting documents.

In addition, Indonesia's central government has been providing resources to local governments to enable them to rehabilitate and improve the irrigation infrastructure under their jurisdiction. However, even the large sums transferred to local governments through the DAK allocation funds have not been able to prevent deterioration and damage to the infrastructure. In 2017, about Rp4 trillion ($300 million) was allocated for irrigation rehabilitation and improvement by local governments. This amount represented a substantial reduction from the DAK irrigation allocation in 2016 of Rp13.9 trillion ($1 billion). The MPWH generally provides technical recommendations and ensures the technical soundness of proposals submitted for DAK funding. Unfortunately, only 30% of local government agencies report yearly on the progress of their nationally funded irrigation rehabilitation and improvement projects. Funding adequacy is therefore difficult to assess, since actual expenditure on irrigation at the local level depends on local government priorities, which often differ from budget provisions (Quincieu and Tabor 2016).

The current administration plans to increase irrigation system capacity to support the medium-term target of increased food production to meet the political mandate of food sovereignty. The government intends to build and improve irrigation networks for up to 9.9 million ha of surface water, groundwater, and swamp area by 2019—an increase of 2% per year from the 2014 baseline of 8.9 million ha. The RPJMN for 2014–2019 suggests that these irrigation network projects will rehabilitate up to 3 million ha in 2019—a 2.1% increase per year.

Furthermore, the government plans to develop swamp irrigation covering more than 304,000 ha in 2019, to support fish production by improving aquaculture management. The government has aggressive plans to build new dams to reach 49 units by 2019—a rate of increase of 18.5% per year from the 21 new dams built in 2014. The government plans to expand dam irrigation from 761,000 ha (10.7% of the 7.1 million ha of gravity and canal systems) in 2014 to 1.3 million ha (18.6%) by 2019. Cropping intensity will increase from 1.43 to 1.49, for both dam and non-dam irrigation. If the ambitious dam-building and improvement targets are met, irrigation capacity would increase from 12.5 billion cubic meters (m^3) to 19.4 billion m^3—equivalent to an increase from 50 m^3 per capita to 71 billion m^3 per capita (RPJMN 2014–2019).

Development planning to upgrade and transform irrigation systems during the RPJMN (2014–2019) period covers at least five irrigation-related concerns: (i) water reliability, resilience, and vulnerability; (ii) infrastructure condition and functioning rate; (iii) supply-based management of water in terms of efficiency, effectiveness, and equity; (iv) institutional aspects of government and farmers' organizations; and (v) human resource dimensions of government officials and farmers, such as human capital, competence, knowledge, and intellect. These components of irrigation system development planning do not explain the links between irrigation and crop production systems. However, their message is clear: upgrading and transforming the irrigation systems is an important component of achieving food sovereignty, as mandated under Law 18/2012.

2.2.4 Improved Irrigation Performance

New irrigation investments should consider modernizing irrigation systems to make farmers better able to improve crop production and productivity and increase water-use efficiency, and even to allow farmers to move to higher-value crops such as horticulture crops, vegetables and fruits, and exotic crops. Depending on the reason for the reduction in irrigation capacity in each region, according to Molle (2003), the steps in the process of upgrading the irrigation systems can be classified into three categories: (i) supply augmentation, (ii) water conservation, and (iii) water reallocation. Table 2.4 shows the different policy and management initiatives that can be considered for each of these categories. While some elements may not be relevant to the current situation of the irrigation systems in Indonesia, they could be considered as possible alternatives in the future.

Reallocation initiatives with the highest potential for improving water-use efficiency—sectoral allocation policy, water pricing, water quotas, water markets, and basin-level institutions—could be adopted by the central government. However, despite the urgent need for better water management, few such initiatives have been implemented. At the local level, farmers and local government or extension agencies could plan better for a change in crops or varieties, depending on the water flow; arrange for better equity of water allocation; and more effectively release the use of water to suit local conditions. For example, Rodgers and Hellegers (2005) suggest reducing water use in irrigated rice production to meet the increasing urban demand for water. Both the central and local governments can manage the supply augmentation of water, although the funding comes mostly from special allocation transfers (DAK) by the central government. As explained earlier, the central government has implemented or is planning to build reservoirs, tap groundwater by

Table 2.4: Irrigation Management in Response to Water Scarcity

Irrigation Upgrade Category	Central Initiatives	Local Initiatives
Supply augmentation	Reservoir building	Groundwater tapping
	Groundwater tapping	Small drainage gate construction
	Drainage gate construction	Conjunctive use
	Trans-basin diversion	
	Wastewater treatment	
Conservation	Canal lining	Micro-irrigation
	Improvement of dam management	Management improvement (location)
	Conduct of awareness campaign	Changing of crop calendars
	Water pricing	Embung, or on-farm storage
		Reduction of return flow
Reallocation	Water pricing	Introduction of new crops or varieties
	Implementation of sectoral reallocation policy	Allocation for better equity
	Use of water quotas	Cessation or release of use
	Use of water markets	
	Participation of basin-level institutions	

Source: Adapted from Molle (2003).

pumping groundwater and surface water (known as pompanisasi), introduce trans-basin diversion, and promote water treatment. An innovative plan involves the trans-basin diversion of the Greater Way Sekampung watershed in Lampung, where the main canal that connects to the main Sekampung River flowing to East Lampung is diverted to the northern part of Central Lampung. The main consideration is reducing the water flow of the main Sekampung River to East Lampung, as the district is usually flooded during the rainy season. Worsening floods during high tide at the Lampung Sea in the eastern coastal area are causing crop failures in the district of East Lampung. Meanwhile, the Central Lampung district, a potential production center for secondary food crops (*palawija*) such as maize, soybean, and cassava, often suffers from serious drought. The planned trans-basin diversion will attempt to address these disparities. At the time of writing, irrigation infrastructure in the subdistricts of Bekri and Punggur, Central Lampung district, was working well (Budiyuwono 2018). Local groundwater tapping initiatives could also be considered, although the local governments might not formally allow individual farmers to tap groundwater for use in agriculture. As noted above, the total area served by groundwater irrigation is currently 113,600 ha, although there are no available data on the amount of groundwater being pumped for agricultural uses.

Water conservation has become an important logical option, especially given the current pressures of water scarcity due to climate change, extreme weather, and other ecological risks. Indonesia's central government normally engages in canal lining, dam management improvement, awareness, and water pricing campaigns. However, implementing efficiency-based water pricing or water markets is difficult,

if not impossible, in the current environment in Indonesia. Water markets or efficiency pricing requires improved irrigation infrastructure, measurement capability, and institutional capacity. The development of water trading beyond the local level is therefore likely to be a long-term process in Indonesia. An important first step would be the realistic allocation of water on a seasonal basis, together with the registration of rights based on shares (Rosegrant 2016). Pilot-testing incentive-based water allocation schemes could also have important benefits, but in the short term, water conservation and water reallocation policies could emphasize empowering economic actors and policy makers under the current decentralized system. Meanwhile, other policy reforms in related areas such as changing cropping patterns and introducing water-efficient crops, or providing on-farm storage facilities, can improve efficiency in water allocation mechanisms in general.

Since the 1990s, the Government of Indonesia has been trying to implement water pricing for irrigation with little success. Irrigation water service fees (IWSFs) are managed by the MPWH through the state-owned enterprises (SOEs) that serve the Perum Jasa Tirta I and Perum Jasa Tirta II provinces in Java. These companies manage the distribution of basin water to multiple users, both agricultural and nonagricultural.

The IWSF is intended to generate operating funds for O&M and for the rehabilitation of irrigation systems. Farmers pay the IWSF to their WUAs (locally known as "P3As"). In the 1990s, IWSFs of about Rp12,000–Rp14,000 (about $1.00) per ha were collected. These area-based fees were calibrated to reflect desired levels of O&M, land productivity, and farmers' ability to pay. The program was successful until the mid-1990s, but fee collection was suspended after the 1997-1998 Asian financial crisis (Rodgers and Hellegers 2005). After the crisis, the government tried to reactivate water pricing, allowing local authorities to determine the amount of the IWSF depending on the specific location. A recent study on IWSFs in West and East Java done by Syaukat, Arifah, and Minha (2014) suggests that most farmers do not pay the IWSF, although the economic value of irrigation water in rice farming far exceeds the current irrigation fees. The IWSF per hectare per cropping season is Rp50,000 ($3.75) in West Java, and Rp25,000 ($1.88) in Central Java. Unfortunately, only 34% of farmers in two study locations in Bogor and Kudus pay the water charges. As a result, the problems of canal sedimentation, inadequate water outreach, and water leakage persist. Local WUAs cannot perform O&M on tertiary irrigation, while local governments are unable to allocate the local budget (APBD) for irrigation O&M.

Improvements in IWSF collection and irrigation systems performance require more empowered WUAs. Irrigating farmers could be better organized into empowered WUA federations that can invest in and manage tertiary irrigation infrastructure, to ensure adequate water supply and access for all farmers under the tertiary irrigation scheme. Institutional support for the WUAs is also necessary; this could mean improving their legal status, developing by-laws for WUAs and their federations,

Table 2.5: Stages toward Modern Irrigation

Service Indicator	Existing or Conventional Irrigation	Stages toward Modern Irrigation		
		Minimum	Medium	Advanced
Cropping intensity	120% rice 20% *palawija*	140%–160% rice 50% *palawija*	140%–160% rice 50% *palawija*	180%–250% rice 50% *palawija*
Water loss	40%–60%	40%–50%	30%–40%	10%–30%
Water allocation	10–15 days	3–7 days	1–3 days	1–3 days
Water productivity	0.5 kg GKG/m3	0.6 kg GKG/m3	0.8 kg GKG/m3	1.0 kg GKG/m3
Water provision	Fair	Adequate	Good	Excellent
Irrigation water	K factor	Demand-driven and semi-supply	Demand-driven	Demand-driven
Water control	Upstream	Upstream	Downstream	Downstream
Water utilization	Surface irrigation	Surface, but drip irrigation	Surface, but drip irrigation	Surface, but full drip system
Water use	Continuous	Mostly continuous, some intermittent	Some intermittent	Fully intermittent
Water rights	Nonexistent	Some existing	Fully existing	Fully existing
Drainage	Crop failures unknown	Crop failures 20%–30%	Crop failures 10%–20%	Crop failures <10%

GKG = gabah kering giling (dry-milled paddy), kg = kilogram, m^3 = cubic meter.

Source: Modified from DG Water Uses, Ministry of Public Works and Housing (2016).

assigning roles and responsibilities that are acceptable to all the farmers involved, and complying with government policies and procedures.

The improvement of irrigation systems is a major priority of the government. Table 2.5 presents the stages in the development of modern irrigation systems by the government, in the course of which at least 11 service indicators will be upgraded. The time frame for achieving this improvement differs between provinces and between districts. In line with decentralization, acceptable roles for both the government and local communities in the whole process of irrigation systems improvement and in the agriculture–water management nexus must be defined.

The first service indicator of improved irrigation is cropping intensity. The current cropping intensity is 120% for rice and 20% for secondary food crops (*palawija*). Improved irrigation systems could increase cropping intensity significantly—by up to 250% for rice, and 50% for *palawija*. Under existing irrigation systems, water loss is very high (40%–60%) but water provision is fairly good. Indonesia should be prepared to reduce water loss down to 10%–30% of water provision. Modern irrigation systems require downstream water control, depending on the demand for irrigation water. The use of water in the modern irrigation system would be fully intermittent, with the efficiency level brought under control and the watering process to the root systems of crops integrated with other types of crop management. Modern irrigation systems are also concerned with drainage systems, especially for monitoring crop failures due to flooding during the rainy season. Ideally, in a modern irrigation system, crop failures could be reduced to less than 10%, minimizing the economic risks to farmers.

Large investments and substantial improvements in governance, management, and technology for irrigation systems and river basin authorities would be required to make progress toward these goals. Moreover, policies for developing modern irrigation systems and effective farming systems are hindered by the continuing decline in farm size, especially in Java. Small farm sizes make it difficult to adopt advanced water and farm management and technologies that work better on larger farms. Agrarian reform with land consolidation, either in terms of ownership or in operational units, would increase the potential for the adoption of advanced irritation and farming system management (Vermillion, Lengkong, and Atmanto 2005).

Other challenges for staple food and crop production systems in Indonesia include the conversion of as much as 30,000 ha of irrigated land per year to urban and other nonagricultural uses in Java. The younger generation is losing interest in becoming farmers and most are seeking off-farm opportunities. (This development could serve as another impetus for the consolidation of the operational size of farms.) Also, when in competition with other sectors for government funds, irrigation loses out to immediately visible areas like roads, housing, municipal water supply, and power. Degradation of irrigation systems due to lack of O&M can result in the need for high-cost rehabilitation, which could surpass Indonesia's fiscal capacity (Quincieu and Tabor 2016; Vermillion, Lengkong, and Atmanto 2005).

2.3 Dynamic Issues of Food Security

Food security issues in Indonesia, which are challenging at the individual, household, national, and global levels, include food availability and accessibility, and price stability issues. Indonesia ranks 65th in 2018 among 113 countries in the Global Food Security Index (GFSI) published regularly by the Economist Intelligence Unit. In September 2018, the country ranked below Association of Southeast Asian Nations (ASEAN) peers such as Malaysia (ranked 40th), Thailand (54th), and Viet Nam (62nd), mostly because access in Indonesia is quite low. As noted in Arifin et al. (2018), the poverty level in Indonesia is still high by ASEAN standards, with nearly 26 million people (9.8%) below the poverty line in March of 2018. Indonesia is also highly vulnerable to food price changes and deteriorating agricultural production resulting from climate change and extreme weather, such as droughts, floods, and natural disasters.

2.3.1 Food Availability

In recent years, Indonesia had to import the key crops, such as rice, maize, soybean, and sugar, to meet the growing demand for consumption, as shown in Table 2.6. In addition to the downward trend in production, extreme weather events, such as droughts, floods, and landslides, in food production centers in Indonesia have seriously affected farming practices and crop production, and hence the country's food security. Environmental changes are believed to have been an important cause of the major drop in food supply in 2014, when rice production decreased by 0.6%. The decrease occurred mostly in Java, where food production depends heavily on farm management, the quality of irrigation infrastructure, downstream water management, the stewardship performance of catchment areas, and general natural resource management. Other crops also face significant constraints and variability in production and resulting policy challenges. For example, increases in sugar production have not been enough to meet rising demand for sugar from the food industry and direct household consumption. Indonesia relies on imports of refined sugar from the international market, complicating the incentive system for domestic sugar production (Table 2.6).

An extreme dry weather cycle, during the 2015 El Niño, reduced production and incomes in several regions of Indonesia. Studies have shown that the 2015 drought reduced the income of 60% of households, especially in poor regions (WFP 2016). For about 31% of 2,400 households surveyed, the impact of El Niño–related weather was severe. Poor regions in Eastern Indonesia suffered the most, with nearly 50% of households engaged in food production and those reliant on agricultural wage labor experiencing severely reduced incomes. As a response to income reduction, one in five households cut back their food expenditures to cope with diminished purchasing

Table 2.6: Production of Major Food Crops in Indonesia, 2011–2015

Food Crop	2011	2012	2013	2014	2015
Rice					
Harvested area (ha)	13,203,643	13,445,524	13,835,252	13,797,307	14,116,638
Productivity (ton/ha)	4,98	5,14	5,15	5,13	5,34
Production (ton)	65.756.904	69.056.126	71.279.709	70.846.465	75.397.841
Import (ton)	2.750.480	1.810.370	472.660	844.160	860.000
Maize					
Harvested area (ha)	3.864.692	3.957.595	3.821.504	3.837.019	3.787.367
Productivity (ton/ha)	4,56	4,90	4,84	4,95	5,18
Production (ton)	17.643.250	19.387.022	18.506.287	19.008.426	19.612.435
Import (ton)	1.724.000	1.600.000	3.190.000	3.250.000	3.270.000
Soybean					
Harvested area (ha)	622.254	567.624	550.793	615.685	614.095
Productivity (ton/ha)	1,37	1,48	1,42	1,51	1,57
Production (ton)	851.286	843.153	779.992	954.997	963.183
Import (ton)	1.890.000	1.910.000	1.787.000	2.00.000	2.300.000
Sugar					
Harvested area (ha)	450.298	451.191	460.496	472.676	461.732
Productivity (ton/ha)	4,95	5,74	5,19	5,40	5,68
Production (ton)	2.228.259	2.591.687	2.390.000	2.575.392	2.623.931
Import (ton)	2.200.000	2.890.000	3.300.000	3.000.000	3.400.000

ha = hectare.

Note: Since 2015, the Government, coordinated by BPS and the Agency for Technology Assessment and Application (BPPT), has taken serious efforts to improve food crop production data. The improvement includes the application of the area sampling framework (KSA-kerangka sampling area) and the integration of spatial data and information. With those new methodologies, starting from 2018, Badan Pusat Statistik (BPS) has published new data of paddy production, in which 2018 paddy and rice production is corrected to be 57,38 million ton GKG of paddy (dry-milled paddy) or 32,90 million ton of rice.

Source: BPS (various issues).

power. Other primary responses were reliance on a second income source (27%) and reductions in non-food expenditure (24%) (WFP 2016).

Without the most recent production estimates from BPS—these have not been available since 2016—the national impact of the severe El Niño weather in 2015, particularly the extent attributable to environmental factors such as flood and drought, cannot be estimated. However, actual data from the field confirm that production decreased as harvested area for rice, maize, and soybean shrank. The change was most significant in Java (the provinces of East Java, Central Java, Yogyakarta, West Java, and Banten) and Sumatra (the provinces of Lampung, South Sumatra, West Sumatra, North Sumatra, and Aceh), the country's main food production centers, which were most affected by drought. These provinces also experienced serious problems with agricultural infrastructure, from physical infrastructure to software and human resources, but were especially affected by damage to irrigation networks. Over the past decade or so, WUAs that used to contribute significantly to improved food production and productivity have had no hand in maintaining the quality of agricultural practices and water or other resource use in the fields. The implications for food security are serious. Without significant progress in technological change and land expansion for food production outside Java, Indonesia will face grave challenges in meeting its growing demand for food.

2.3.2 Food Accessibility

Food accessibility is usually measured in terms of food consumption, especially by the poor, who are highly vulnerable to price changes and a drop in production. Rice consumption in Indonesia declined from nearly 140 kilograms (kg) per capita per year in 2006 to 114 kg per capita in 2015, mainly because of urbanization and changes in dietary preferences that go with rising incomes. But the level of rice consumption is still high and could cause problems for the Indonesian economy unless the food diversification drive begun in the last decade starts to have real impact. This move toward more diversified production and consumption is compatible with the development of modern yet simple food technology that complements Indonesia's food production system (Arifin et al. 2018).

Slow growth in food production could have severe consequences for Indonesian food security, especially among the poor and those with limited access to health-care facilities. Table 2.7 presents the latest poverty data published by BPS, showing that about 25.9 million people (9.8% of the population)—10.1 million (7.0%) living in the urban areas and 15.8 million (13.2%) in the rural areas—fall below the current poverty line of Rp415,614 ($29.0) per month. Poverty incidence has declined consistently over the past decade as the Indonesian economy grew significantly, after being hit hard by the Asian economic crisis. However, fluctuations still occur. In 2006, for example, poverty increased by 5% after the government removed the fuel subsidy, and purchasing power suffered following a surge in food prices and in the costs of housing, transportation, and education.

Table 2.7: Poverty Line, Percentage of Poverty, and Total Poverty in Indonesia, 2000–2017

Year	Poverty Line (Rp per capita per month)			Percentage of Poverty (%)			Total Poverty (million)		
	Urban	Rural	National	Urban	Rural	National	Urban	Rural	National
2000	91,632	73,648	82,640	14.58	22.38	19.14	12.30	26.40	38.70
2001	100,011	80,382	90,197	9.76	24.95	18.40	8.60	29.30	37.90
2002	130,499	96,512	113,506	14.46	21.10	18.20	13.30	25.10	38.40
2003	138,803	105,888	122,346	13.57	20.23	17.42	12.20	25.10	37.30
2004	143,455	108,725	126,090	12.13	20.11	16.66	11.40	24.80	36.10
2005	150,799	117,259	134,029	11.37	19.51	15.97	12.40	22.70	35.10
2006	175,324	131,256	153,290	13.36	21.90	17.75	14.29	24.76	39.05
2007	187,942	146,837	167,390	12.52	20.37	16.58	13.56	23.61	37.17
2008	204,896	161,831	183,364	11.65	18.93	15.42	12.77	22.19	34.96
2009	222,123	179,835	200,979	10.72	17.35	14.15	11.91	20.62	32.53
2010	232,989	192,354	212,672	9.87	16.56	13.33	11.10	19.93	31.02
2011	253,016	213,395	233,206	9.23	15.72	12.49	11.05	18.97	30.02
2012	267,408	229,226	248,707	8.78	15.12	11.96	10.65	18.48	29.13
2013	289,041	253,273	271,626	8.42	14.28	11.36	10.39	17.78	28.17
2014	289,041	286,097	302,735	8.34	14.17	11.25	10.51	17.77	28.28
2015	342,541	317,881	330,776	8.29	14.21	11.22	10.65	17.94	28.59
2016	364,527	343,646	354,386	7.79	14.11	10.86	10.34	17.67	28.01
2017	393,308	366,203	380,819	7.49	13.70	10.38	10.47	16.71	27.18
2018*	415,614	393,908	401,220	7.02	13.20	9.82	10.14	15.81	25.95

*2018 data are for March, accessed in August 2018.

Source: BPS.

The wide gap in poverty incidence between the rural and urban areas suggests that agricultural development without supporting rural development will have limited impact on welfare. Moreover, the national average broken down into provincial figures reveals large disparities in poverty incidence across the country. In March 2018, for example, only 3.6% of the population of the capital province of Jakarta, versus 27.7% and 23.0% in the provinces of Papua and West Papua, respectively, lived below the poverty line. Ironically, the poverty figures for the provinces on the island of Java, the food production centers of Indonesia, are quite high: 12.1% in Yogyakarta (not shown in the table), 11.3% in Central Java, 11.0% in East Java, and 7.5% in West Java. In the case of Lampung, the poverty figures are especially anomalous. This province, once declared an "agribusiness province," had a poverty level of 13.1% in March 2018, making it the third-poorest province in Sumatra, after Aceh and Bengkulu.

The vulnerability of poor people to food price increases is shown by the high proportion of food expenses (76.7%) in their household expenditures; housing, electricity, education, and transportation expenses account for the rest. The price of rice has contributed to 21.0% of the poverty line in the rural areas, and to 26.8% in the urban areas. Because of the inelastic demand for rice, poor households generally suffer the most when the price of rice goes up.

2.3.3 Food Price Stability

Food price stability has been a food security policy priority in Indonesia for the past 4 decades, but such policies have not been effective recently. Price stabilization polices have been implemented through a price-band approach, with Bulog seeking to maintain a floor price at the farm-gate price of rice above production costs. A ceiling price was set to make rice affordable to low-income households, especially in the urban areas (Arifin 2014). However, as Indonesian economic policy has shifted toward greater openness, including deregulation policies in international trade, banking, and finance, the price-band system has lost effectiveness.

In the case of rice, a widening gap between the global and the domestic price since 2010 has posed a serious challenge to food price stability and food security in Indonesia. Figure 2.3 shows that the average domestic price of rice (medium quality) in 2017 exceeded Rp10,000 ($0.75) per kg (the average world price was around Rp6,000 ($0.45) per kg) and remained high until mid-2018, creating significant food access problems, especially among the poor. In this context, food price stability is also related to inefficiencies in the food-value chains in Indonesia: rice and other strategic foods pass through the hands of traders, distributors, and retailers under asymmetric information and non-competitive market structures. The high domestic price of rice is driven by restrictions on imports, increasing production costs including labor costs and land rental, and the high costs of transportation and marketing.

Figure 2.3: Widening Gap between Global and Domestic Prices of Rice—A Serious Challenge

Source: OECD (2018)

mt = metric ton.

This rapidly increasing price difference indicates the high cost of the self-sufficiency policy. Domestic prices of beef and other food commodities are also well above international prices. Through these price premiums, Indonesian consumers are believed to have been "taxed" about $98 billion between 2013 and 2015 (Heufers and Patunru 2018). An estimate by the Organisation for Economic Co-operation and Development (OECD) for 2010 was of comparable magnitude. For 2010, OECD calculated the total support estimate for agriculture (the cost that support for the agriculture sector places on the overall economy) at $26.9 billion (OECD 2012). By comparison, development spending in agriculture (including infrastructure, R&D, agricultural schools, and inspection services, among others) totaled only $1.6 billion (OECD 2012). The high domestic food prices also do not benefit most farmers, since two-thirds of Indonesian farmers are net consumers of food and therefore face inflated food prices themselves. Rice importation procedures are cumbersome, with importers going through a complex licensing process that involves several government authorities. Delays caused by this process have resulted in losses of Rp303 billion ($22 million) for Indonesian taxpayers since 2010, besides providing opportunities for rent seeking (Heufers and Patunru 2018). Reform of price stabilization policies can significantly improve food security, as will be shown in the modeling analysis below. Price policies can be improved, and so can market effectiveness, through the removal of local regulations that hinder regional food distribution, the improvement of infrastructure, and control of food smuggling; the strengthening of local institutions, such as food security agencies; and the provision of support for policy instruments operating at the local level.

Reform of the rice-for-the-poor policies aimed at providing a price subsidy for those in need can make this policy a more effective tool for poverty reduction, and hence for meeting the country's food security objectives. The program is designed to reduce the impact of severe economic crisis by providing 15 kg of medium-grade rice every month to targeted poor households. In 2017, the program began a major transformation by introducing electronic voucher cards that can be used to collect the subsidized food assistance at designated modern retailers and traditional vendors. Arifin (2014) shows that the main challenge today is to make the program more cost-effective by providing more assistance in the urban areas, tightening eligibility criteria, increasing public awareness, improving beneficiary reporting, and ensuring the financial soundness of the program. A better public–private partnership in relief distribution could extend the outreach of the rice-for-the-poor program if standards of program accountability are maintained. Experience with the rice-for-the-poor program should lead to improved food security policies in the field with better-designed assistance measures for vulnerable households, possibly combining targeted food subsidies, ration shops, village granaries, food stamps, and subsidized food stalls (Arifin 2014).

2.3.4 Vulnerability and Malnutrition

Environmental risks such as flood, drought, landslides, and earthquakes can cause shocks that result in increased incidence of poverty and malnutrition. The poor and the near-poor are particularly vulnerable to food insecurity, vulnerability, and malnutrition in regions prone to environmental risks, such as the southern coastal area of East Java, Yogyakarta, West Nusa Tenggara, and East Nusa Tenggara. Moreover, the threat of malnutrition due to crop failures, especially among rural children, could increase with climate change, especially if policy responses by central and local government fail to address new knowledge about the relationship between environmental risks, crop production, and risk-reducing policies.

Like poverty incidence, food insecurity varies greatly across regions and across income groups in Indonesia. Among the low-income groups, energy intake is generally inadequate, and food is of very poor quality, as indicated by their low scores for desirable dietary patterns. For those living in poor regions and remote areas, energy intake is similarly inadequate and unbalanced, partly on account of the lack of diversity in production and diets. To estimate the prevalence of food insecurity in the country, based on Sustainable Development Goals (SDGs) Goal-2 targets and indicators, the Prevalence of Undernourishment (PoU) and Food Insecurity Experience Scale (FIES) are used. By this measure, based on SUSENAS data, PoU in 2018 is around 8.3% (or about 20.7 million people), while FIES in 2018 is around 6.9% (or around 17.2 million people). For malnutrition, the cutoff points are 10%, 5%, and 20% for underweight, wasted, and stunted children, respectively. The current prevalence of underweight children, at 19.6%, is quite high and obviously a public health problem. In addition, the incidence of stunting among children is also high for a country that achieves economic growth of over 5% per year.

2.4 Partnership Initiatives for Agricultural Investment

As mentioned above, private investment in the upstream sector of food crop production, such as rice and maize, is limited, primarily because of complex landholding issues. In the case of private investment in palm oil, on the other hand, land area expansion has continued until recently, reaching about 12 million ha. Local governments are generally active in promoting private investment in cash crop plantations and industrial forest plantations for pulp and paper. The government provides business permits and medium- or long-term rights for private investors to use state-owned lands, and the investments usually take the form of land development, nursery management and seedling production, and oil palm processing to produce crude palm oil. For food crops and horticulture, most investment in the upstream sector and production process is made by individual farmers, the government, and SOEs. Individual farmers, farmers' associations, and the community engage in land development, seed preparation, and small-scale infrastructure projects such as the construction of tertiary and quaternary canals and the purchase of agricultural machinery and equipment for production.

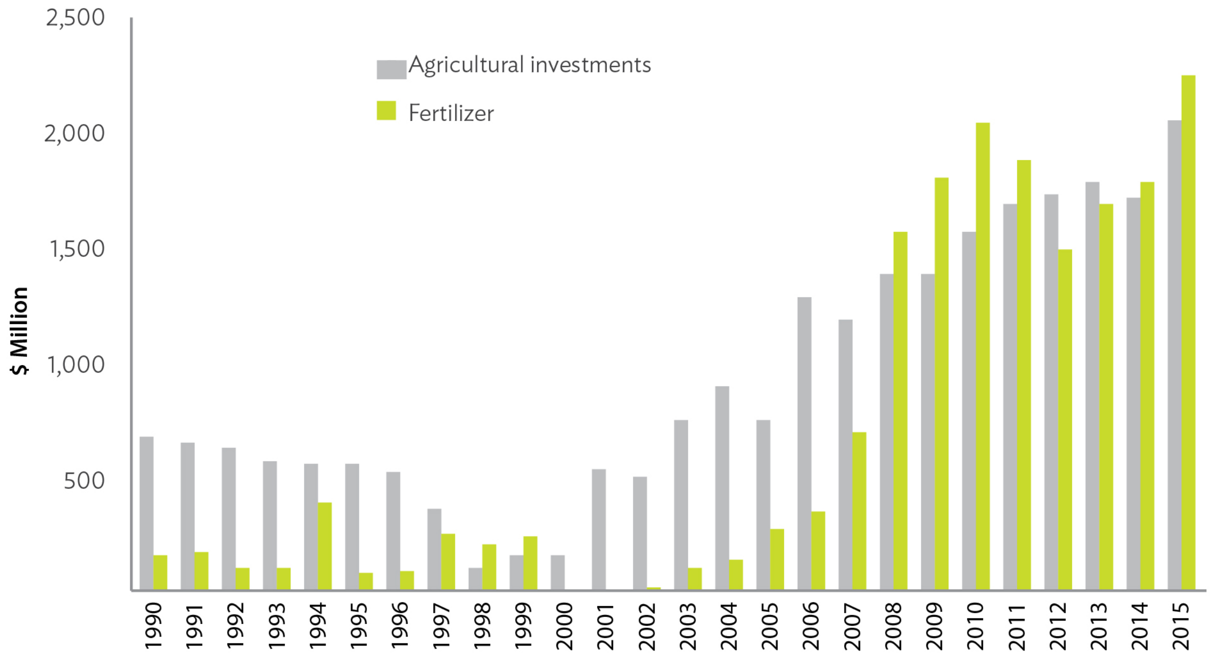
Key constraints on private investment in food crop sectors and horticulture include the lack of economies of scale due to the small size of landholdings (less than 2 ha per household) and the restrictions on foreign direct investment (FDI) noted above. The majority (over 56%) of food crop farmers are smallholders, about 49.5% of them living in Java and 18.7% living just outside Java. Of Indonesia's more than 27.7 million poor people, about 62.8% are farmers who live in the rural areas; more investment is therefore needed to boost agricultural growth and productivity. The current government has brought back the agrarian reform and spatial planning and development programs to increase farm-holding size and improve market access. In addition, as noted above, this administration has decided to proceed with major public investments in the agriculture sector, such as dam rehabilitation, irrigation and drainage systems construction and improvement, and other infrastructure projects like ports, bridges, railroads, and sea transport. Meanwhile, a new approach to corporate farming and partnership initiatives has emerged in recent years, promoted by the government and by individual and community initiatives. The primary goal of partnership initiatives for agricultural investment is to increase the economies of scale of food crop farming and encourage the adoption of advanced farming systems and technologies, including the use of agricultural machinery.

This section examines some examples of partnership initiatives for agricultural investment, mostly in the food crop-farming system, which have been implemented by stakeholders in agricultural development. The aim of such initiatives is to increase the commercial orientation of agricultural practices through a shift from subsistence-level and traditional approaches to a more commercial and modernized system using agricultural technologies and machinery.

2.4.1 Innovative Approaches to Modernizing Agriculture

The agricultural development strategies of the current government have largely been focused on special efforts to increase the production of rice, maize, and soybean (Upsus Pajale) to meet the political target of self-sufficiency in these staple food crops. After nearly 3 years, however, these policy efforts seem to have had no significant impact on agricultural development. What is more, strategies for increasing production and stabilizing rice prices have not improved the welfare of farmers or the general population. The government has taken the initiative to revisit overall development strategies through a Presidential Directive issued on 26 January 2017, which mandates the MOA to "formulate and implement broader agricultural development strategies, produce agricultural products that have higher economic value, and protect farmers and provide options (crops) to increase their income." The Ministry of Trade, on the other hand, has the strategic mandate to "produce a policy design that could provide the correct and normal price to the consumer," while the Coordinating Ministry for Economic Affairs has been asked to "produce a common vision of productivity, competitiveness and welfare improvement."

Figure 2.4: Agricultural Investments and Fertilizer Subsidies in Indonesia, 1990–2015



Note: No fertilizer data are available for 2000–2001.

Source: OECD database.

Fertilizer subsidies remain an important element of the government program to increase food production, but they come at a high fiscal cost. From the 1990s until 2007, the costs of agricultural investment were higher than those of fertilizer subsidies (Figure 2.4). But since 2008, the reverse has been true. In 2010–2015, fertilizer subsidies cost 6% higher than total agricultural investments. The lowest annual fertilizer subsidy, valued at $5 million, was noted in 2002 (OECD database). However, the subsidy started to increase rapidly thereafter, reaching $1.57 billion in 2008 and $2.24 billion in 2015. There is growing evidence that fertilizer subsidies are not a cost-effective policy for boosting rice production, given the excessive use of fertilizer in many regions (Arifin 2014).

Osorio et al. (2011) analyzed the impact of eliminating the fertilizer subsidy in 2008 and found that it would result in a 0.35% reduction in urea application. As a consequence, rice production would drop by 5.1%, leading to a 3.1-million-ton loss in rice production, equivalent to Rp6.75 trillion ($772 billion) in economic losses. But the fertilizer subsidy in 2008 cost Rp15.2 trillion ($1,567 billion), far outweighing the production benefits. The cost of these efforts to expand rice production is excessively high. (The analysis below updates this study and assesses the impact of shifting the value of the subsidy to productive investments.) The fertilizer subsidy is also regressive, because farmers gain from subsidized fertilizers regardless of farm size or the farmer's wealth, as the studies of Osorio et al. (2011) and Sudaryanto (2014) show. In fact, about 60% of the total subsidy goes to about 40% of the large farmers. In addition, as noted above, an examination of the historical sources of crop production growth has shown that fertilizer subsidies represent a misallocation of public resources (Rosegrant, Kasryno, and Perez 1998). Given that the output response to public investment in agricultural R&D and technology is substantially higher than the output response to fertilizer prices, eliminating fertilizer subsidies and transferring the resulting fiscal savings into investments in research, extension, and irrigation would be beneficial. Such a transfer of funds would be an important impetus for increased investment in agricultural research.

Fertilizer costs account for only 10.4% of total rice production costs in Indonesia, 12.0% of maize production costs, and 4.8% of soybean production costs (BPS 2016). Labor costs are the largest component of the country's rice production costs, making paddy production 2.5 times more costly in Indonesia than in Viet Nam (Bordey et al. 2016). The high price of rice has affected farmers and landless workers. Landless farmers have not benefited directly from some agricultural development programs, and do not receive fertilizer subsidies, seed subsidies, tractor assistance, or other agricultural machinery tools. Some 14.4 million small farmers (56% of farm households) own less than 0.5 ha of land, 4.5 million (17.4%) own 0.5–1.0 ha, and 3.7 million (14%) own 1.0–2.0 ha. Over 2 ha of land belongs to 3.1 million rich farmers (12.4% of the farm household total) (BPS 2014).

To overcome the constraint of small farm size, innovative strategies and partnership initiatives in agricultural development must complement the technical strategies for increasing food production in the rural areas. Such partnerships could, for example, serve as business integrators, working closely with small farmers to produce food crops and consolidate land management to increase economies of scale in production. A new business model under strategic partnership initiatives would involve the business integrators as important actors in integrating fragmented farmland management for modern agribusiness land management, and in applying good agricultural practices. Business integrators could serve as agents for improving farmers' welfare, farm management, sustainable cropping patterns, and postharvest activities. The role of a business integrator or entrepreneurial farmer lies in bringing together talent and potential from farmers, agricultural workers, agronomists, researchers, suppliers, extension agents, industrialists, agricultural and logistics equipment companies, fund owners, and retailers. Integrators facilitate technology adoption in the field, providing input and working capital to farmers while obtaining reasonable profits and necessary margins. In short, this partnership initiative model requires integrators that provide solutions, create value, and take risks.

Case 1: Partnership Initiative in the Special Region of Yogyakarta

A partnership initiative is being implemented in the Special Region of Yogyakarta by faculty members and students from the College of Agriculture of Gadjah Mada University (UGM), to improve consolidated land management for food crop production. The average landholding of rice farmers in Yogyakarta is less than 0.5 ha—too small to easily generate a decent farm income. In addition, these small farmers have difficulty gaining access to working capital and new technology, let alone increasing investment in agriculture. The first stage of the research is focused on strengthening the roles of farmers' associations in rural areas of Sleman district in

Yogyakarta, by improving group dynamics, reshaping the objectives of associations, and discussing current issues related to farming practices and other everyday matters. Each farmers' association consists of about 30–40 farmers who together control about 20 ha of farmland, generally planting rice twice a year, during the rainy season in October–March and the dry season in April–September. Farmers grow high-yield varieties (HYVs) of Ciherang rice, producing an average yield of 6 metric tons per ha. This high yield is believed to exceed 90% of production capacity.

Increasing land productivity in the study sites without introducing substantial technological changes is difficult, given the current production capacity. To increase this capacity, the researchers decided to bring in medium-scale tractors, transplanters, and combined harvesters to help with land preparation, crop care, and harvesting, as well as new varieties of irrigated inbred rice (Inpari). They were also able to persuade the farmers to allow the removal of boundaries between the small land parcels so that the agricultural machinery could operate freely in the paddy fields. Boundary removal did not mean a change in land ownership, the farmers were told. The farmers are not averse to replacing human labor with machinery, as rural areas in Sleman are experiencing agricultural labor shortages, but they remain skeptical about the future of this action research program to consolidate land management. Their primary concern is that they will lose their land when the program ends, considering the sensitivity of land ownership issues in recent years (Jamhari 2017).

At the time of writing, this action research program was to continue for 3 more years, so no conclusive findings could be reported as yet. The approach could turn out to be more effective than simply distributing or providing agricultural machinery to farmers' associations, in improving rice yield, and hence farmers' income. Clearly, partnership initiatives in the form of business integrators would increase the economies of scale in the rice economy by temporarily removing the constraints on farm size. But more rigorous methods of analysis—integrating the issues of property rights, incentive systems and responses to the incentives, institutional arrangements, and other relevant analytical frameworks—will still need to be applied to test the feasibility of implementing consolidated land management strategies for improved production among smallholder farmers in Indonesia.

Case 2: Business Integrator in Sukabumi, West Java

This innovative partnership involves a business integrator in Sukabumi, West Java, who has been working with small farmers in rice production and connecting them with rice millers and consumers (Susilo 2017). The integrator empowers farmers through the Sharia cooperative Ar-Rohmah and links individual farmers through the community-owned enterprise (BUMR) Pangan Terhubung (Food Connected). The BUMR buys the rice produced by small farmers and processes, packages, and markets the rice. Farmers receive additional revenue of about Rp2 million ($149,506) per month per ha, with the possibility of profit sharing at the end of the year according to the proportion of rice produced by each farmer during the year. Ar-Rohmah works with 850 small farmers on a total area of about 1,000 ha and, with the BUMR, employs 74 young farmers in jobs ranging from administration, marketing, and design to farmer assistance and empowerment. In addition, the business integrator manages 8 ha of paddy field, and harvests and mills at least 40–60 tons of unhusked rice to produce about 20–30 tons of milled rice using modern rice milling methods. The business integrator is also developing e-commerce for marketing the near-premium rice, collaborating with shipping and delivery companies to directly serve rice customers in nearby towns of Sukabumi and Bogor, and even in Jakarta.

In addition, the integrator has been working closely with 10 research institutes and universities to acquire HYV seeds, fertilizers, and natural pesticides, besides skills in applying new cropping patterns, marketing and management strategies, postharvest machinery, and product packaging. Given the current achievements of this business integrator model, there is high potential for its scale-up to extend to at least 65 similar business units of the BUMR, which could produce an additional 2.5 million tons of rice each year.

The role of the business integrator in this case is not only to consolidate land management or to connect farmers and markets, but also to facilitate technology adoption and establish links that will deliver the results of R&D to the farmers.

2.4.2 Partnership for Innovation and Technological Change

Innovation and technological change usually involves a systematic partnership of many stakeholders from the academe, business, government, and civil society (ABGC). The story of how Mallika, a new variety of black soybean resistant to pests and climate change, was developed may provide exemplary lessons in how investment in agriculture could lead to systematic business practices in new product development and branding.

Black soybean, less commonly known than the yellow soybean, is usually grown in Central and East Java, mostly for common local food products such as crackers (peyek) and as an ingredient of sweet soy sauce. However, black soybean farmers usually rely on local seeds with low productivity of less than 1 ton per ha. Supply and quality problems made it difficult for the company producing Kecap Bango, a local brand of soy sauce first sold in 1928, to stay in business. The company was in financial straits when it was taken over by Unilever.

A new partnership involving ABGC was developed. UGM in Yogyakarta did research into the breeding of black soybean varieties for high productivity and flood and drought tolerance. Unilever was interested in developing the product and positioning Kecap Bango as a market-leading brand of sweet soy sauce. The government, given its food security concerns, administered the release of new crop varieties proposed by individuals, private sector entities, and researchers. (The release of new varieties normally takes at least 3 years.) Finally, agricultural cooperatives facilitated crop production, postharvest processing, and farm product marketing, while farmers kept their eyes on market security and price guarantees for their products.

UGM researchers and company officers worked together to provide technical assistance and financial stimulus to black soybean farmers during the multilocation and multi-adaptation experiments. After several trials and careful long-term research, the new Mallika variety of black soybean was shown to increase yield. It was also robust enough to survive droughts, floods, and pests. Farmers in Central Java and East Java began to receive better farm-gate prices as the company bought all the black soybeans produced by these farmers. Price guarantees provided by the company through agricultural cooperatives reduced the risks to soybean farmers and helped improve their lives and livelihoods. The company thus ensured a reliable supply of black soybean, even in years when growing conditions were not particularly favorable. In the early 2000s, the MOA officially released the Mallika soybean, making it publicly available.

The ABGC partnership has agreed to provide Mallika seeds free of charge to farmers in Indonesia who are interested in growing black soybean. In fact, the partnership has implemented empowerment programs for farmers, including planting advice, support for increasing crop yield, and other activities related to quality improvement and efficiency. At least 9,000 farmers, including 2,000 women farmers, have participated in the empowerment programs, where they are able to share their experience and learn from one another.

2.4.3 Conclusion: Growth Accelerators

Agricultural development requires a growth accelerator, changes in human capital management, and expedited institutional and technological change. The following list of enabling factors or growth accelerators can help in scaling up innovative approaches to modernizing agriculture. The list is not exhaustive but should serve as a starting point for the development of more systematic strategies and agricultural development policies in the future. Many of these policies are emphasized at the end of this report.

- The government should promote the growth of farmer entrepreneurship and integrated agricultural business models by encouraging the participation of young and energetic farmers in the various provinces, regions, and districts in commodity development. This is to provide the agricultural technology assessment institute (BPTP) in each province across the country with appropriate directions for technology upgrading. The commodity being developed need not be rice but can be any food or cash crop that derives location-specific advantages from the agro-ecosystem and socioeconomic features of the province.

- The government should empower smallholders to adopt consolidated land management and community-based land management practices. Efforts being made by the College of Agriculture of UGM in Yogyakarta to develop community-based land management of rice fields could be scaled up to cover a wider area in the province or even extended to other provinces, with the help of local universities, especially those with a college of agriculture. The approach would, however, have to be adjusted to respond to local issues and answer the needs of local institutions.

- Precision agriculture—agriculture guided and managed by means of advanced digital technologies—is in its early stages in Indonesia and should be developed more rapidly. Precision agriculture and remote sensing technologies can improve farming systems and irrigation management by allowing the precisely targeted application of water, fertilizer, and other input. Satellite imaging can be particularly important, as it is often the only option available in remote agricultural areas. It also offers an ongoing source of global data for understanding changes over time and assessing the effectiveness of policies. If combined with information from airplanes, drones, and "ground truthing" through surveys and sensors, satellite imaging can be even more powerful. Greater benefit can be derived from precision agriculture if progress is made in consolidating farm operations, as recommended above.

- The government should also facilitate new investment in large- and medium-scale rice mills and at the same time encourage the consolidated management of small-scale rice mills, depending on the availability of raw materials and supporting infrastructure in the country's rice-producing regions. These policy actions could contribute significantly to quality improvements in rice production, primarily to meet the growing demand for high-quality rice, particularly in the urban areas.

- The government should support the rapid pace of "upward diversification" from low- to high-value local crops, such as horticultural products, by promoting high-quality rural development, building and maintaining rural and production roads, and implementing agrarian reforms, starting from very basic land administration involving legalizing and certifying land controlled by smallholder farmers. At a later stage, agrarian reforms could focus on redistributing state land previously controlled by corporations, to empower smallholder farmers by giving them access to markets, finance, and technology.

- To help reduce poverty, the government should continue carefully targeted subsidies for the active poor and improve their access to subsidized credit (KUR) for farmers and those involved in agriculture and in the running of cooperatives and small and medium-sized enterprises (SMEs), by simplifying credit access requirements at the field level.

- The government should implement concrete actions to combat child malnutrition and contribute to reducing the prevalence of stunting and prevent its future occurrence by promoting food diversification based on local endowments and food technology development available at the local level.

- The government should increase the budget for agricultural R&D to at least 1% of GDP. This increase could be implemented through effective research policies that close the gap between potential and actual yield levels. Local and regional universities across the country should be encouraged to submit research proposals (and relevant action research) for increasing the yield and labor productivity of both staple foods and other strategic commodities specific to the universities' location.

- In support of the first two recommendations above, the government should strengthen agricultural extension systems by connecting all extension agents and relevant extension institutions across the country with regional universities and other centers of excellence at the local level. At the central level, government officials at the MOA (home of the agricultural extension system) should work together with the Ministry of Research, Technology and Higher Education (home of knowledge and technology) and the Ministry of Home Affairs (home of the local government machinery) to shape the future of the agricultural extension system under Law 23/2014 on Local Government.

Chapter 3: Investment Potential for Sustainable Food Supply and Food Security up to 2020 and 2045

This chapter reviews recent trends in the agriculture sector of Indonesia and provides initial baseline scenarios showing some alternative agriculture and food security pathways up to 2020 and up to 2045. The main objectives of this chapter are to show past and potential future trends in the country's food supply and demand, and to identify investment opportunities that can enhance productivity and influence food security in the future.

3.1 Food Availability and Access in Indonesia, 2000–2015

3.1.1 Population, Income, and Demand for Food

Population and income growth are the main determinants of growth in food demand and changes in food preference. From 2000 to 2015, the Indonesian population grew by 1.34% yearly. Income, represented by GDP, grew faster, by 3.56%, and per capita GDP, by 2.22% (Table 3.1; Figure 3.1). These trends have resulted in increased total demand for food commodities, particularly per capita demand for poultry meat, wheat, and pig meat, all with annual growth rates higher than 3%. The high derived demand for maize as feed was the consequence of increased demand for poultry and pig meat. Demand for high-value crops such as fruits and vegetables has also grown substantially. In comparison, per capita demand for rice has grown slowly, at 1.1% per year (Tables 3.2a–3.2b; Figures 3.2a–3.2c).

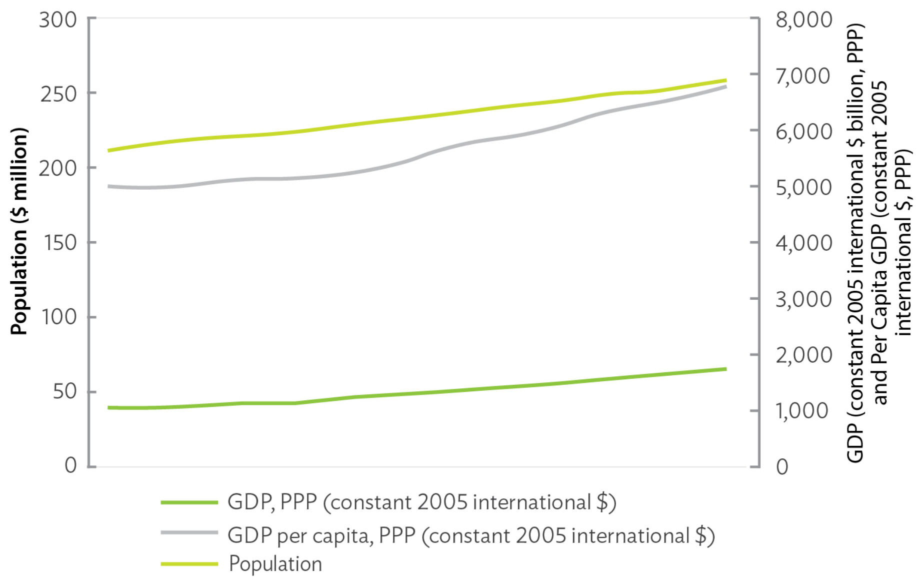
Table 3.1: Population, GDP, and GDP Per Capita Growth, Indonesia, 2000–2015

Item	Year				Change, 2000–2015 (%)	Annual Growth Rate (%)
	2000	2005	2010	2015		
Population (million) GDP	212	227	243	258	22	1.34
Total (constant 2005 international $ billion, PPP)	1,061	1,190	1,444	1,752	65	3.56
Per capita (constant 2005 international $, PPP)	5,017	5,250	5,954	6,785	35	2.22

GDP = gross domestic product, PPP = purchasing power parity.

Sources: FAOSTAT (online, for population data); World Bank, *World Development Indicators* (online, for GDP).

Figure 3.1: Population and GDP Trends, Indonesia, 2000–2015



GDP = gross domestic product, PPP = purchasing power parity.

Sources: FAOSTAT (online, for population data); World Bank, *World Development Indicators* (online, for GDP).

Table 3.2a: Growth in Demand for Food, Indonesia, 2000–2015

Food Commodity Group	Year ('000 MT)				Change, 2000–2015 (%)	Annual Growth Rate (%)
	2000	2005	2010	2015		
Meat Products	1,740	2,249	2,957	3,679	111.4	4.85
Beef and buffalo meat	422	425	585	686	62.6	3.83
Sheep and goat meat	79	118	114	120	51.6	0.70
Pig meat	414	553	696	783	89.2	4.59
Poultry meat	832	1,151	1,566	2,120	154.9	5.76
Cereals	50,731	53,901	68,206	78,897	55.5	3.47
Maize	10,935	12,690	18,532	23,043	110.7	5.85
Rice	36,076	36,274	43,908	49,436	37.0	2.51
Wheat	3,641	4,877	5,712	7,458	104.8	4.72
Fruits	8,419	14,566	15,270	18,342	117.9	4.32
Vegetables	7,185	8,613	10,338	11,592	61.3	3.75
Oil Crops	20,283	24,200	26,814	30,247	49.1	2.85
Soybean	2,294	1,893	2,647	2,672	16.5	2.58
Pulses	324	345	352	322	-0.5	0.08
Starchy Root Crops	19,652	21,754	28,282	30,403	54.7	3.38
Sugar	3,705	4,237	3,928	5,050	36.3	1.80

MT = metric ton.

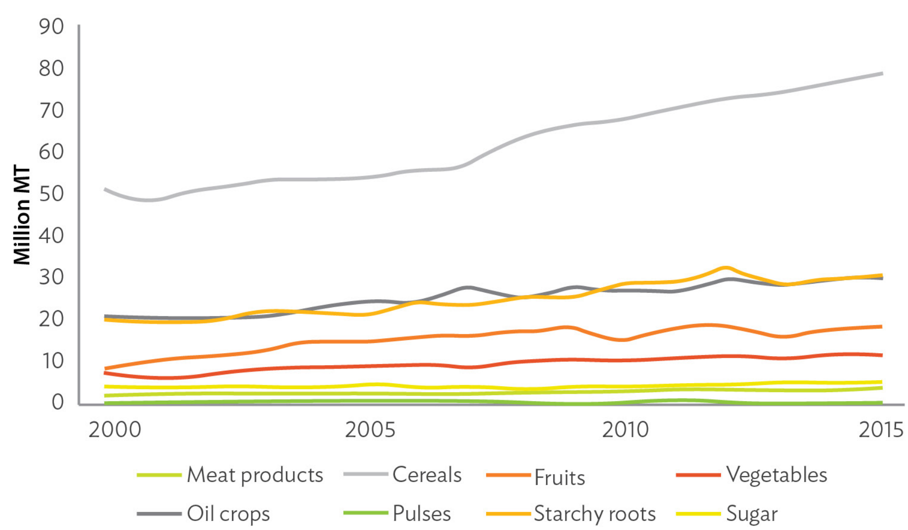
Source: FAOSTAT (online).

Table 3.2b: Growth in Per Capita Demand for Food, Indonesia, 2000–2015

Food Commodity Group	Year (kg per capita)				Change, 2000–2015 (%)	Annual Growth Rate (%)
	2000	2005	2010	2015		
Meat Products	8	10	12	14	73.2	3.46
Beef and buffalo meat	2	2	2	3	33.2	2.45
Sheep and goat meat	0	1	0	0	24.2	-0.64
Pig meat	2	2	3	3	55.0	3.20
Poultry meat	4	5	6	8	108.9	4.35
Cereals	240	238	281	306	27.4	2.10
Maize	52	56	76	89	72.7	4.44
Rice	171	160	181	188	10.4	1.10
Wheat	17	22	24	29	67.8	3.33
Fruits	40	64	63	71	78.5	2.93
Vegetables	34	38	43	45	32.2	2.37
Oil Crops	96	107	111	117	22.2	1.49
Soybean	11	8	11	10	-4.5	1.22
Pulses	2	2	1	1	-18.4	-1.25
Starchy Root Crops	93	96	117	118	26.8	2.01
Sugar	18	19	16	20	11.7	0.44

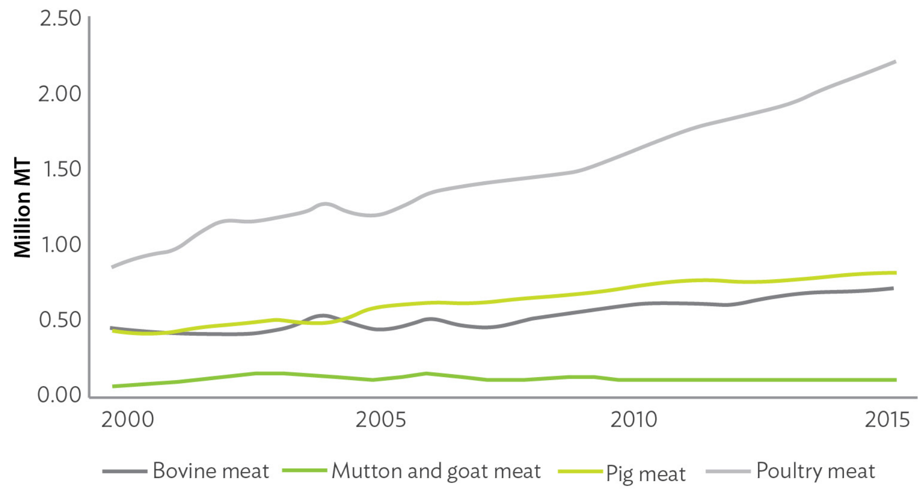
kg = kilogram.
Source: FAOSTAT (online).

Figure 3.2a: Trends in Demand for Major Food Commodity Groups, Indonesia, 2000–2015



MT = metric ton.
Source: FAOSTAT (online).

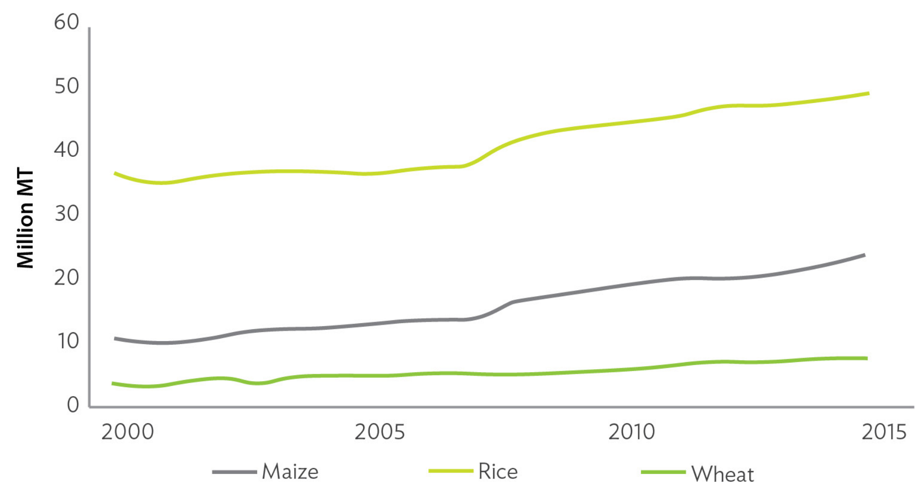
Figure 3.2b: Trends in Demand for Meat Products, Indonesia, 2000–2015



MT = metric ton.

Source: FAOSTAT (online).

Figure 3.2c: Trends in Demand for Cereals, Indonesia, 2000–2015



MT = metric ton.

Source: FAOSTAT (online).

3.1.2 Production of Food Commodities

Trends in food production in 2000–2015 show that although Indonesia has been an importer of many food commodities, the production growth rates for some commodities have matched or exceeded demand growth. The production of poultry, maize, and rice grew at almost the same rate as demand during the period but lagged in absolute levels because of lower starting values (Table 3.3; Figures 3.3a–3.3c).

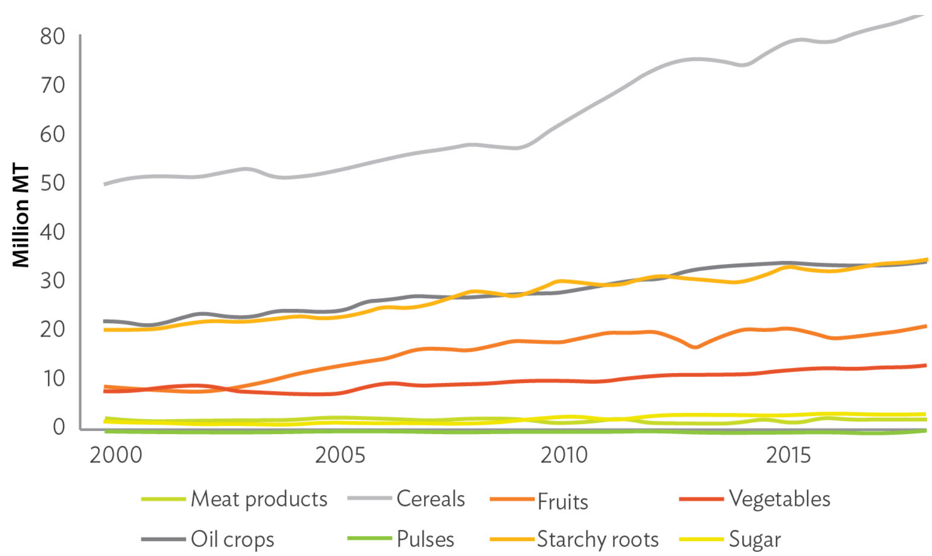
Table 3.3: Growth in Food Production, Indonesia, 2000–2015

Food Commodity Group	Year ('000 MT) 2000	2005	2010	2015	Change, 2000–2015 (%)	Annual Growth Rate (%)
Meat Products	1,695	2,213	2,849	3,606	112.7	4.76
Beef and buffalo meat	386	397	472	614	59.1	3.26
Sheep and goat meat	78	117	114	118	50.8	0.64
Pig meat	413	550	695	779	88.9	4.54
Poultry meat	818	1,147	1,566	2,119	159.2	5.79
Cereals	44,293	48,643	62,663	70,353	58.8	3.68
Maize	9,677	12,524	18,328	19,612	102.7	5.87
Rice	34,616	36,119	44,335	48,574	40.3	2.79
Wheat						
Fruits	8,413	14,529	14,881	17,999	113.9	4.10
Vegetables	6,985	8,264	9,780	11,347	62.4	3.72
Oil Crops	19,259	23,764	25,499	28,937	50.3	2.81
Soybean	1,018	808	907	963	-5.4	1.11
Pulses	291	322	293	245	-15.9	-1.51
Starchy Root Crops	19,269	22,565	27,395	28,402	47.4	2.77
Sugar	2,190	2,460	2,130	2,521	15.1	0.45

MT = metric ton.

Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

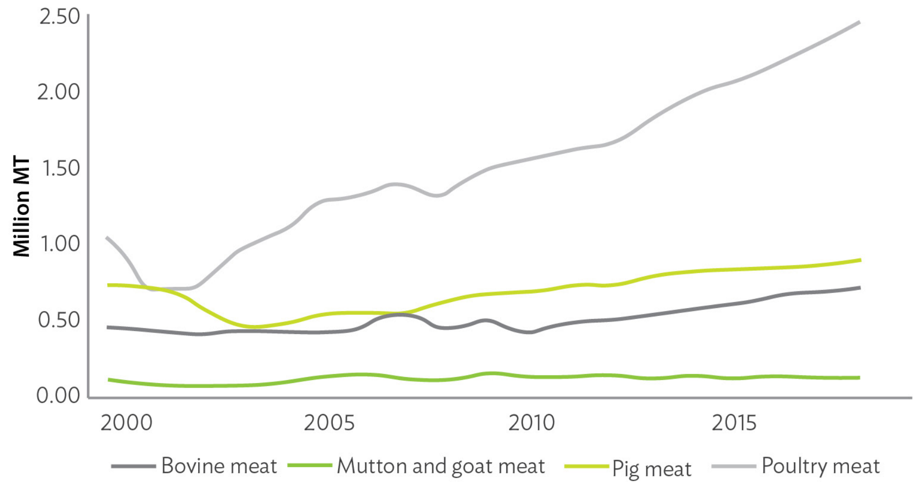
Figure 3.3a: Trends in the Production of Major Food Commodities, Indonesia, 2000–2015



Source: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

MT = metric ton.

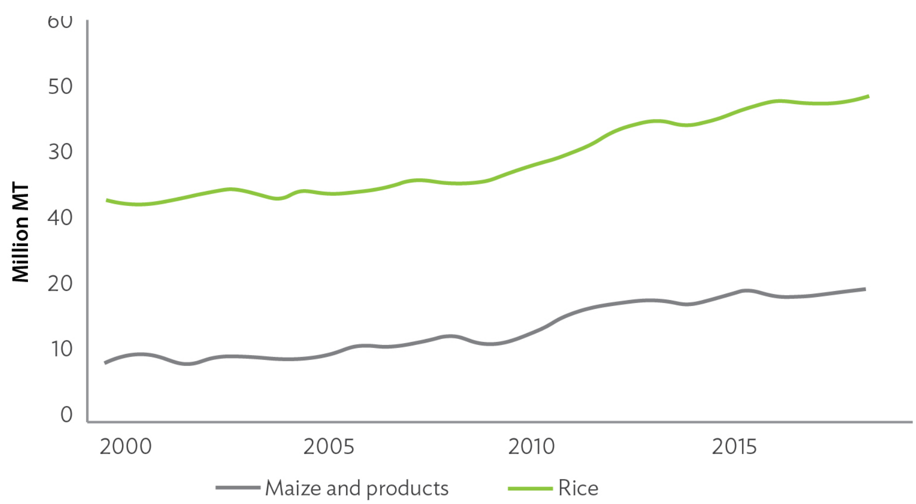
Figure 3.3b: Trends in the Production of Meat Products, Indonesia, 2000–2015



MT = metric ton.

Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Figure 3.3c: Trends in the Production of Cereals, Indonesia, 2000–2015



MT = metric ton.

Source: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Production growth rates were highest for maize (5.87%), poultry meat (5.79%), and pig meat (4.54%). They were also high for fruits (4.10%) and vegetables (3.72%).

3.1.3 Trends in Food Availability and Access

Historical trends in food demand and supply (production and trade) in 2000–2015 are presented in Table 3.4. Indonesia has been a traditional importer of food commodities, but the share of imports relative to production for rice, poultry meat, vegetables, and oil crops has been declining through the years, while the share of other meat products, and of maize, pulses, and starchy root crops, has been increasing. Indonesia imported 11% of its cereal demand during the period, mainly maize and wheat, and 2% of its meat demand.

Table 3.4: Food Commodity Demand, Production, and Trade, Indonesia, 2000–2015

Food Commodity Group	2000 ('000 MT)			2015 ('000 MT)			Demand		Production	
	Demand	Production	Trade	Demand	Production	Trade	Change, 2000–2015 (%)	Annual Growth Rate (%)	Change, 2000–2015 (%)	Annual Growth Rate (%)
Meat Products	1,740	1,695	(45)	3,679	3,606	(73)	111	4.85	113	4.76
Beef and buffalo meat	422	386	(36)	686	614	(72)	63	3.83	59	3.26
Sheep and goat meat	79	78	(1)	120	118	(1)	52	0.70	51	0.64
Pig meat	414	413	(1)	783	779	(4)	89	4.59	89	4.54
Poultry meat	832	818	(14)	2,120	2,119	(1)	155	5.76	159	5.79
Cereals	50,731	44,293	(6,438)	78,897	70,353	(8,545)	56	3.47	59	3.68
Maize	10,935	9,677	(1,258)	23,043	19,612	(3,432)	111	5.85	103	5.87
Rice	36,076	34,616	(1,460)	49,436	48,574	(862)	37	2.51	40	2.79
Wheat	3,641	--	(3,641)	7,458	--	(7,458)	105	4.72	--	--
Fruits	8,419	8,413	(6)	18,342	17,999	(343)	118	4.32	114	4.10
Vegetables	7,185	6,985	(199)	11,592	11,347	(245)	61	3.75	62	3.72
Oil Crops	20,283	19,259	(1,025)	30,247	28,937	(1,310)	49	2.85	50	2.81
Soybean	2,294	1,018	(1,276)	2,672	963	(1,709)	16	2.58	(5)	1.11
Pulses	324	291	(33)	322	245	(77)	0	0.08	(16)	(1.51)
Starchy Root Crops	19,652	19,269	(382)	30,403	28,402	(2,001)	55	3.38	47	2.77
Sugar	3,705	2,190	(1,515)	5,050	2,521	(2,529)	36	1.80	15	0.45

( ) = negative. "--" = not applicable or zero value. Negative trade = imports. Positive trade = exports. mt = metric ton.

Source: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

3.1.4 Food Security Indicators

Despite increasing trends in food production and availability, and in household incomes, access to food remains unequal in Indonesia and there is a certain level of food insecurity.

Indicators of food security include daily calorie consumption, number of malnourished children, and number of people at risk of hunger. Malnutrition can cause wasting or stunting in children 5 years old or younger. People at risk of hunger are the chronically undernourished (FAO 2017b). Estimated values for malnourished children and people at risk of hunger in Indonesia and the ADB regions in 2015 are presented in Table 3.5. On average, Indonesians consumed 2,639 kilocalories (kcal) per capita per day, less than the 2,750 kcal average daily consumption in all ADB regions. There were 4.6 million malnourished children and 27 million people (10.6% of the population) at risk of hunger in Indonesia. The number of people at risk of hunger represented a significant improvement over the 42 million people (20%) in 2000.

The investment scenarios proposed in this study are all aimed at eliminating malnutrition and hunger in Indonesia by 2030–2045, considering the effects of climate change, increasing population and income, limited land resources, changes in the rural employment landscape, and overall investment costs.

Table 3.5: Base Value of Food Security Indicators for Indonesia, 2015

Country	Calorie Consumption (kcal/capita/day)	Malnourished Children ($ million)	People at Risk of Hunger* ($ million)
Indonesia	2,639	4.6	27
ADB Regions**	2,750	88.4	519

kcal = kilocalorie.

* Also defined by FAO as chronically undernourished persons.

** Central and West Asia, East Asia, South Asia, Southeast Asia (excluding Indonesia), and the Pacific.

Source: IMPACT simulation results.

3.2 Determinants of Food Demand and Supply up to 2030 and 2045

3.2.1 Demand: Population and Income Projections

In 2000–2015, Indonesia's population grew by 22%, GDP by 65%, and per capita GDP by 35%. These increases in population and income spurred strong growth in demand for food over the period. Demand rose by 155% for poultry meat (111% for all meat products), 105% for wheat, and 61% for vegetables.

Table 3.6: Projected Changes in Population, GDP, and Per Capita GDP, Indonesia, by 2030 and by 2045

Item	2000	2005	Historical 2000–2015		Projections up to 2045 2015–2030		2030–2045	
			Change over the Period (%)	Annual Growth (%)	Change over the Period (%)	Annual Growth (%)	Change over the Period (%)	Annual Growth (%)
Population (million) GDP	212	258	22	1.34	10	0.66	4	0.25
Total GDP (constant 2005 international $ billion, PPP)	1,061	1,752	65	3.56	140	6.02	79	3.97
Per capita GDP (2005 international $, PPP)	5,017	6,785	35	2.22	79	5.36	73	3.72

GDP = gross domestic product, PPP = purchasing power parity.

Sources: FAOSTAT (online, for population data); IMPACT projections (GDP) based on OECD estimates.

In the 15 years leading up to 2030, the population of Indonesia is projected to increase by only 10%, but GDP and per capita GDP are expected to grow faster (Table 3.6). GDP is projected to increase by 140%, at an annual rate of 6.02%, and per capita GDP to increase by 79%, at an annual rate of 5.36%. Growth over the next 15 years up to 2045 would be slower than in the previous 15 years (up to 2030) but still higher than the 2000–2015 values. Therefore, the demand for food is expected to grow at even higher rates over the next 30 years.

3.2.2 Determinants of Food Supply up to 2030 and 2045

Meeting future growth in food demand in Indonesia will require investment decisions to enhance food security up to 2030 and 2045. The decisions should be made in the immediate future, given the lag in realizing the benefits of investments.

In Indonesia, growth in cereal and soybean production in the past was mainly due to improvements in maize and soybean productivity (yield), and to an increase in the area planted to rice and in rice yield (Table 3.7; Figures 3.4a–3.4c). In the livestock sector, growth in production was largely due to growth in the number of animals harvested (slaughtered) for beef/buffalo (bovine) meat; in the stock of animals bred for sheep/goat meat production; and in both the number of animals slaughtered and the stock of animals maintained for the production of poultry meat and pig meat (Table 3.7; Figures 3.5a–3.5d).

The investment strategies could build on the production growth rates of the past 15 years and work to continue or improve on the trend into the next 15 and 30 years.

Table 3.7: Sources of Production Growth in the Indonesian Food Sector, 2000–2015

Item	Annual Rate of Growth (%)						
	Rice	Maize	Soybean	Bovine Meat	Sheep/ Goat Meat	Pig Meat	Poultry Meat
Production	2.64	6.01	1.11				
Area	1.29	1.42	(0.44)				
Yield	1.33	4.53	1.56				
Meat production				2.82	1.49	5.74	5.74
Carcass/Meat yield				0.64	(0.05)	0.23	0.23
Stock of animals				1.66	4.30	2.76	4.38
No. of animals slaughtered				2.17	1.54	5.50	5.50

( ) = negative.

Source: Authors' estimates, using basic data from FAOSTAT (online) and BPS, *Statistical Yearbook of Indonesia* (various years).

Figure 3.4a: Historical Trends in Rice Area, Production, and Yield, Indonesia, 2000–2015

Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

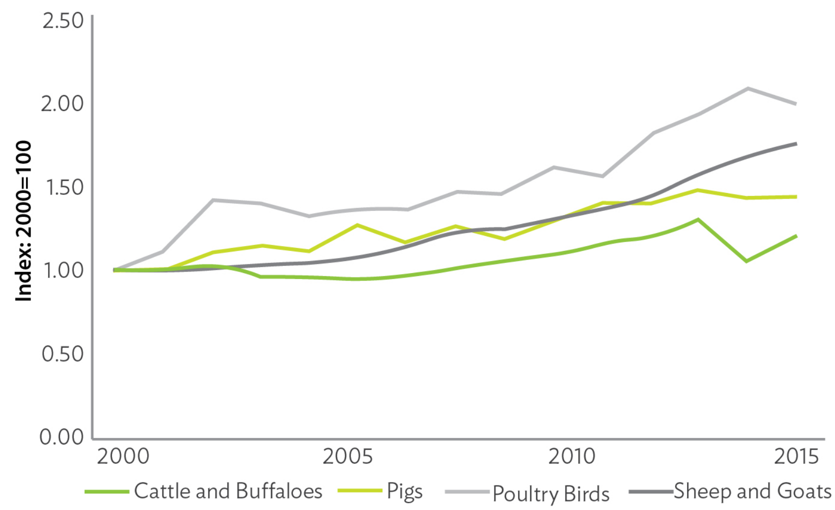
Figure 3.4b: Historical Trends in Maize Area, Production, and Yield, Indonesia, 2000–2015

Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Figure 3.4c: Historical Trends in Soybean Area, Production, and Yield, Indonesia, 2000–2015

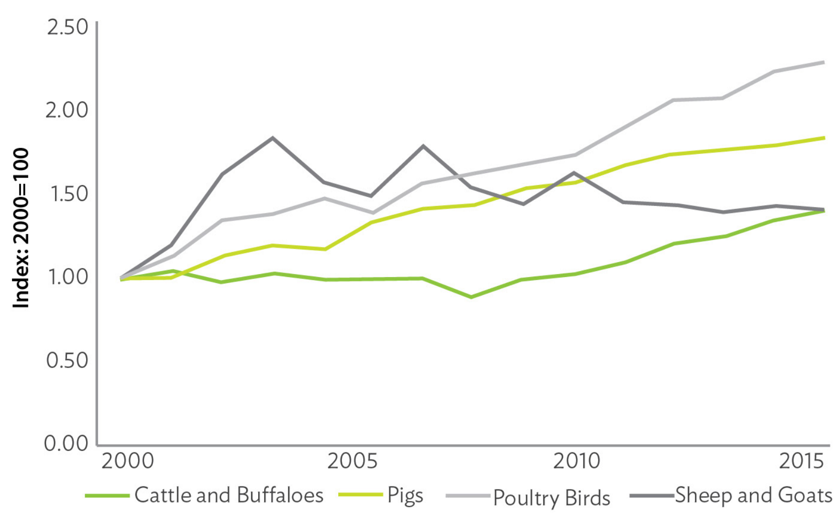
Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Figure 3.5a: Historical Trends in the Annual Stock of Animals, Indonesia, 2000–2015



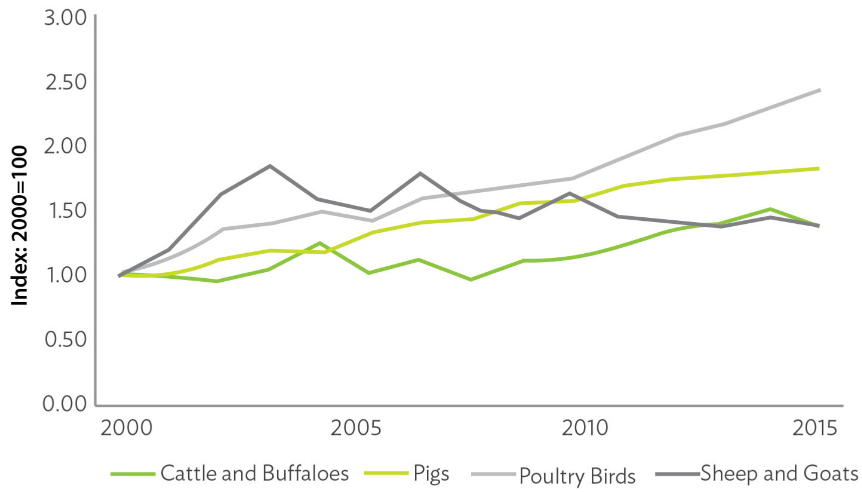
Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Figure 3.5b: Historical Trends in the Number of Slaughtered Animals, Indonesia, 2000–2015



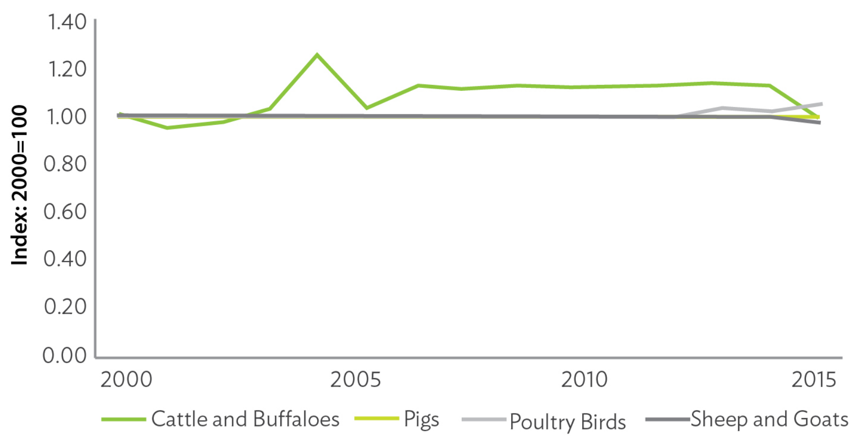
Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Figure 3.5c: Historical Trends in Meat Production, Indonesia, 2000–2015



Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Figure 3.5d: Historical Trends in Meat Yield, Indonesia, 2000–2015



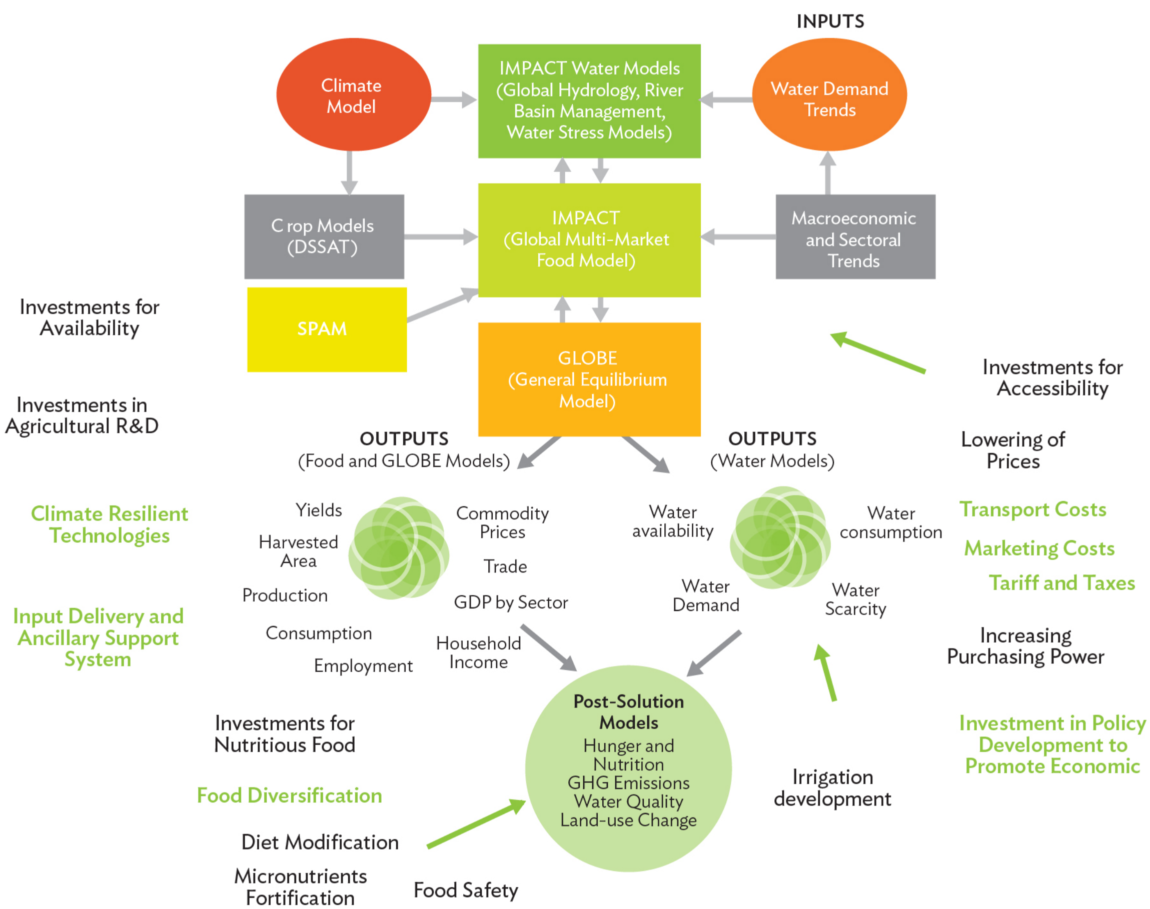
Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

3.3 IMPACT Model Simulations

IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model is the main analytical and simulation instrument used in this study. The IMPACT modeling system integrates information from climate models, crop simulation models, and river basin–level hydrologic and water supply and demand models into a core global, partial equilibrium, multimarket model focused on the agriculture sector. The model offers a high level of disaggregation, with 159 countries, 154 water basins, and 60 commodities (see Robinson et al. 2015 for a full description of IMPACT). IMPACT is linked to a computable general equilibrium Dynamic Economy-Wide Model for Indonesia (DEWI) to examine the effects of agricultural investments on the broader economy. The IMPACT modeling system simulates the impact of investments and policies on the agriculture sector and food security, and on the full economy, through the link with DEWI. The economy-wide results are presented in Chapter 4.

Figure 3.6a provides a schematic summary of the modeling system within an envelope of investment possibilities.

Figure 3.6a: IFPRI's IMPACT Model—Exploring Alternative Climate and Investment Possibilities



DSSAT = Decision Support System for Agrotechnology Transfer, GDP = gross domestic product, GHG = greenhouse gas, IFPRI = International Food Policy Research Institute, IMPACT = International Model for Policy Analysis of Agricultural Commodities and Trade, R&D = research and development, SPAM = Spatial Production Allocation Model, DEWI = Dynamic Economy-Wide Model for Indonesia.

Source: Modified from Robinson et al. (2015).

3.3.1 Productivity: R&D and Climate Change

Agricultural research and development (R&D) and climate change are two relevant determinants of agricultural productivity. Historical investment in R&D has increased rice yield by 21% and maize yield by 87% in the past 15 years (Figures 34a and 34b). Climate change, on the other hand, is projected to reduce crop productivity, on average, in the next 15–35 years (Table 3.8).

A baseline scenario serving as benchmark for evaluating the different sets of investments needs to be established next. As in the regional case study, at least three productivity scenarios can potentially serve as a baseline for Indonesian agriculture. The following scenarios project alternative food security pathways up to 2020 and 2045.

a. **R&D investment trend scenarios.** These assume an amount and type of investment that would sustain the historical crop and livestock productivity growth and area expansion up to 2030 and 2045. These scenarios are the same as the business-as-usual (BAU) scenario in other studies, especially with respect to growth of R&D investment. Two R&D investment trend scenarios were simulated for this study: one under a no-climate-change ("No CC") assumption, and the other under a climate-change assumption. The code for the latter, "HadGEM," stands for the Hadley Centre Global Environmental Model general circulation/climate model used to simulate climate change. These two scenarios highlight the differential effects of climate change on the projected productivity growth of Indonesian agriculture. (See the discussion below on the effects of climate change on crop yield.)
b. **Defensive R&D investment scenario (Def-R&D).** This assumes investment of an amount and type that would only maintain or protect the gains in productivity in the face of climate change, by maintaining annual investment in R&D at the 2015 level in real terms. Defensive or maintenance research is aimed at avoiding yield losses or declines, and not at improving yield. Only endogenous productivity responses due to price changes over time drive the yield levels under this scenario.

Unlike R&D, which in general increases productivity, climate change, on average, has significant negative effects on crop productivity worldwide. The negative impact of these changes in climate conditions is expected to be already significant in 2030, and to be even more pronounced by 2050.

In Indonesia, the crops more vulnerable to changes in climate are maize, sugarcane, potato, and oil crops (Table 3.8 and Figure 3.6b). In the case of livestock, the effects of climate change are manifested primarily through changes in the availability and prices of feed crops.

Table 3.8: Projected Impact of Climate Change on Crop Yield in Indonesia, 2030 and 2050 (% change in yield from No CC scenario)

Food Commodity Group	Irrigated		Rainfed	
	2030	2050	2030	2050
Cereals	(1.75)	(3.94)	(3.16)	(7.06)
Maize	(7.10)	(15.77)	(7.06)	(15.69)
Rice	(0.72)	(1.66)	(0.87)	(2.00)
Fruits and Vegetables	(1.11)	(2.57)	(1.11)	(2.56)
Banana	(1.03)	(2.39)	(1.03)	(2.39)
Tropical fruits	(1.06)	(2.46)	(1.07)	(2.47)
Vegetables	(1.07)	(2.49)	(1.08)	(2.49)
Oil Crops	(1.21)	(2.79)	(1.23)	(2.83)
Groundnut	(2.35)	(5.41)	(2.35)	(5.41)
Palm fruit	(1.19)	(2.73)	(1.20)	(2.77)
Soybean	(1.83)	(4.21)	(1.83)	(4.21)
Pulses	(1.06)	(2.47)	(1.07)	(2.47)
Roots and Tubers	(3.30)	(7.20)	0.61	1.42
Cassava	...	...	0.63	1.47
Potato	(8.77)	(18.94)	(8.77)	(18.94)
Sweet potato	(0.59)	(1.38)	(0.59)	(1.38)
Sugarcane	(3.62)	(8.24)	(3.62)	(8.24)

No CC = no climate change. ( ) = negative. "..." = not available

Source: IMPACT simulation results.

By 2030, the reduction in crop yield as a result of climate change is projected to be highest for potato (−9%), maize (−7%), and sugarcane (−4%). By 2050, even more significant effects are expected: −19% for potato, −16% for maize, and −8% for sugarcane.

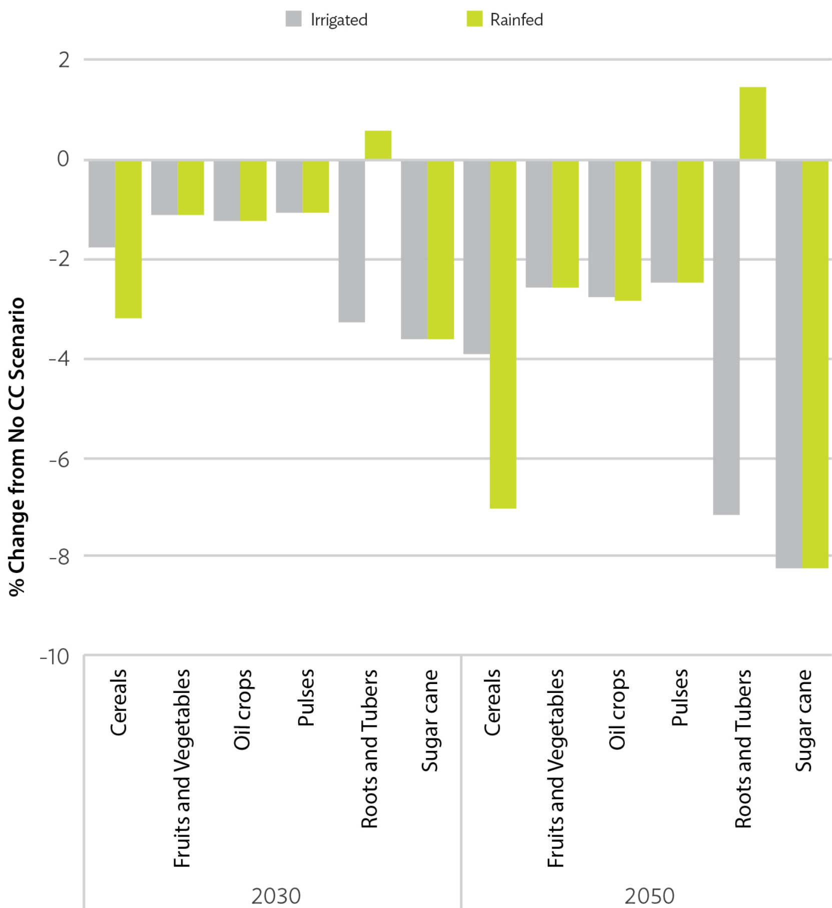
For rice, however, less severe biophysical impact is foreseen, with yield decreasing by only 1% by 2030, and by 2% by 2050, because of climate change. In the country's Asian neighbors, rice productivity is projected to be 4.3% lower, on average.

By land type, rainfed crops, especially cereals, are foreseen to be more vulnerable to climate change than their irrigated counterparts, except for rainfed root crops, which are likely to have small positive gains in yield with climate change.

3.3.2 Baseline Scenarios

Tables 3.9 and 3.10a present the results of the three baseline R&D investment scenarios for selected major commodity crops in Indonesia. They show not only how climate change adversely affects yield and production but also how these effects compare with those under the No CC scenario.

Figure 3.6b: Projected Impact of Climate Change on Crop Yield in Indonesia, 2030 and 2050



Sources: FAOSTAT (online); BPS, *Statistical Yearbook of Indonesia* (various years).

Table 3.9 shows the changes in yield and production under the various scenarios. Productivity is seen to improve under both the No CC and HadGEM scenarios because of positive growth in R&D investment; the lower values for HadGEM are due to the negative effects of climate change itself (Table 3.10a). With no increase in R&D investment, and climate change having adverse effects, the Def-R&D scenario shows declining productivity for most crops even as yield for oil crops and root crops is maintained, and slight increases in production for oil crops and sugarcane.

Table 3.10a clearly demonstrates the effects of climate change on crop productivity, especially for maize, sugarcane, and pulses. The yield for these crops is projected to decline by 14%, 4%, and 5%, respectively, by 2030, compared with the No CC scenario, and by as much as 21%, 8%, and 6% by 2045. The effects of climate change are heightened by the lack of increase in R&D investment under the Def-R&D scenario. Under this scenario, yield and production are projected to decline by as much as 34% and 44% by 2045.

The food security implications of not investing in climate change adaptation and mitigation, and not investing more public funds in productivity-enhancing R&D, are shown in Table 3.10b. The number of malnourished children and people at risk of hunger will remain high under HadGEM (2.33 and 19 million in 2045) and Def-R&D (2.35 and 20 million in 2045), despite the projected gains under the No CC scenario, where much lower values of 2.20 and 12 million are estimated for the number of malnourished children and hungry people in 2045.

These comparative simulations of climate and R&D investment scenarios show the differential impact of climate change and R&D investment on productivity and food security. Succeeding simulations in this study assume that climate change will continue to have a negative impact on productivity, as in the HadGEM scenario, and indicate the need to increase the level of investment in R&D to at least counter the effects of climate change. Therefore, the baseline HadGEM scenario is adopted as the baseline applies the projected effects of climate change and assumes an increase in R&D investment that supports historical trends in crop and livestock productivity. And as the baseline scenario, HadGEM also serves as benchmark for comparisons among the different investment and policy scenarios analyzed and presented in this study.

Table 3.9: Projected Impact of Baseline R&D Investment Scenarios on Yield and Production, Indonesia, 2030 and 2045 (2015 = 1)

Food Crop		No CC		HadGEM		Def-R&D	
	2015	2030	2045	2030	2045	2030	2045
Production							
All Cereals	70,353	1.1563	1.2721	1.1153	1.2178	0.8872	0.8320
Maize	19,612	1.1458	1.2544	0.8696	0.8682	0.7532	0.6990
Rice	48,574	1.1340	1.1913	1.1277	1.1700	0.9296	0.8742
Fruits and Vegetables	29,346	1.3260	1.6593	1.3094	1.6220	1.0030	1.0289
Oil Crops	136,307	1.6157	2.0153	1.6411	2.0688	1.5682	1.9309
Pulses	361	1.1405	1.2469	1.0890	1.1566	0.9445	0.9038
Roots and Tubers	26,588	1.1050	1.1311	1.1529	1.1786	0.9977	0.9558
Sugarcane	35,726	1.3209	1.5416	1.3032	1.4907	1.2204	1.3009
Yield							
All Cereals	3.80	1.1691	1.2818	1.1353	1.2302	0.9479	0.9096
Maize	5.18	1.1058	1.1530	0.9499	0.9060	0.8464	0.7597
Rice	5.34	1.1836	1.3072	1.1777	1.2980	0.9791	0.9573
Fruits and Vegetables	14.00	1.2234	1.3901	1.2052	1.3592	0.9792	0.9543
Oil Crops	13.70	1.2024	1.2667	1.1883	1.2448	1.0848	1.0895
Pulses	1.10	1.1143	1.1810	1.0707	1.1099	0.9511	0.9069
Roots and Tubers	17.80	1.1226	1.1663	1.1406	1.1870	1.0003	0.9819
Sugar	88.40	1.1054	1.1709	1.0532	1.0766	0.9395	0.8745

No CC = no climate change (scenario), HadGEM = Hadley Centre Global Environmental Model (scenario), defensive research and development (scenario).

Source: IMPACT simulation results.

Table 3.10a: Projected Impact of Baseline R&D Investment Scenarios on Yield and Production in Indonesia under Climate Change, Compared with the No CC Scenario, 2030 and 2045 (% difference)

Food Crop	HadGEM		Def-R&D	
	2030	2045	2030	2045
Production				
All Cereals	(3.54)	(4.27)	(23.27)	(34.60)
Maize	(24.10)	(30.79)	(34.26)	(44.28)
Rice	(0.55)	(1.78)	(19.83)	(31.58)
Fruits and Vegetables	(1.25)	(2.25)	(24.35)	(37.99)
Oil Crops	1.57	2.65	(2.93)	(4.19)
Pulses	(4.52)	(7.24)	(17.19)	(27.52)
Roots and Tubers	4.34	4.20	(9.71)	(15.49)
Sugarcane	(1.33)	(3.30)	(7.60)	(15.61)
Yield				
All Cereals	(2.88)	(4.02)	(18.92)	(29.04)
Maize	(14.11)	(21.42)	(23.46)	(34.11)
Rice	(0.50)	(0.71)	(17.65)	(27.74)
Fruits and Vegetables	(1.49)	(2.23)	(19.96)	(31.35)
Oil Crops	(1.18)	(1.73)	(9.78)	(13.99)
Pulses	(3.91)	(6.01)	(14.65)	(23.20)
Roots and Tubers	1.60	1.77	(10.89)	(15.81)
Sugar	(4.72)	(8.05)	(15.01)	(25.31)

Def-R&D = defensive research and development (scenario), HadGEM = Hadley Centre Global Environmental Model (scenario), No CC = no climate change (scenario), R&D = research and development, ( ) = negative.

Source: IMPACT simulation results.

Table 3.10b: Projected Impact of Baseline R&D Investment Scenarios on Food Security in Indonesia under No CC and Climate Change Scenarios, 2030 and 2045

Food Security Indicator		No CC		HadGEM		Def-R&D	
	2015	2030	2045	2030	2045	2030	2045
Consumption (kcal/capita/day)	2,639	2,987	3,214	2,940	3,105	2,925	3,082
Malnourished children (million)	4.64	3.15	2.20	3.22	2.33	3.24	2.35
Number of undernourishment (million)	27	23	12	24	19	25	20
Prevalence of undernourishment (%)	10.6	8.4	4.3	8.8	6.7	8.9	7.1

Def-R&D = defensive research and development (scenario), HadGEM = Hadley Centre Global Environmental Model (scenario), kcal = kilocalorie, No CC = no climate change (scenario), R&D = research and development.

Source: IMPACT simulation results.

3.3.3 Investment in Productivity Improvement and Growth

Investment in Agricultural R&D

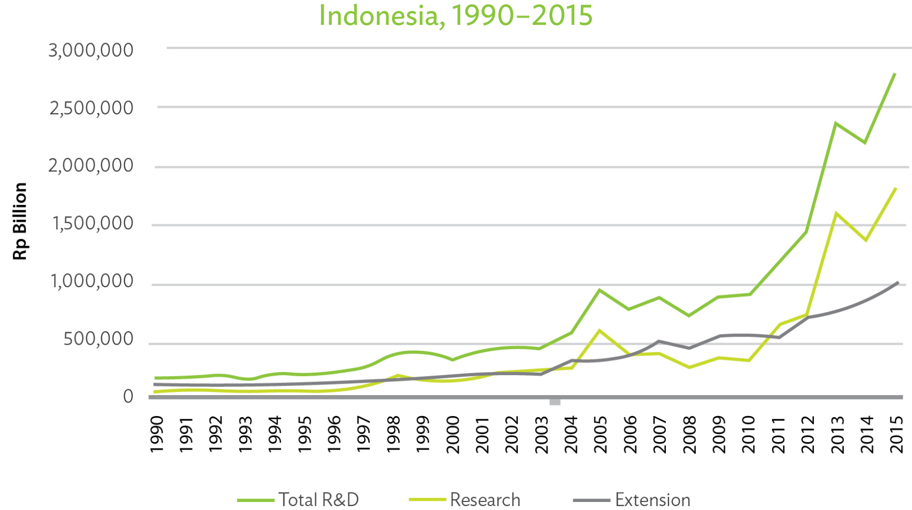
International agricultural research centers (IARCs) have been at the forefront of efforts to develop productivity-enhancing technologies and identify promising technologies. At the national level, Indonesia's national agricultural research system (NARS) is not only the IARCs' active partner but links farmers directly to scientific research and sources of knowledge and information.

Whether by maintaining existing technologies or by improving on them, both the IARCs and NARS spearhead achievements in productivity growth—through biotechnology, plant breeding, or gene-based technology. In food crop farming in Indonesia, productivity increases have been the major source of production growth. In livestock raising, on the other hand, production growth has come mainly from herd expansion, highlighting the rising demand for land resources and the wide yield gap that can be bridged by complementary international and national R&D networks.

Figures 3.7 and 3.8 present historical government expenditure on agricultural research and extension and the resulting gains in maize and rice productivity growth. Over the 25-year period from 1990 to 2015, public investment in agricultural R&D (total for research and extension) grew from Rp175 billion ($95.0 million) to Rp2.79 trillion ($209.5 million), or by 11.3% yearly. The annual growth rate was higher in the last 15 years (2000–2015)—13.2%, compared with 9.1% from 1990 to 2000.

Correspondingly, although with a lag in the effects of R&D on productivity, maize and rice yield also increased during the same 15-year period. Average maize yield grew by 87% (4.4% yearly), and rice yield, by 21% (1.3% per year).

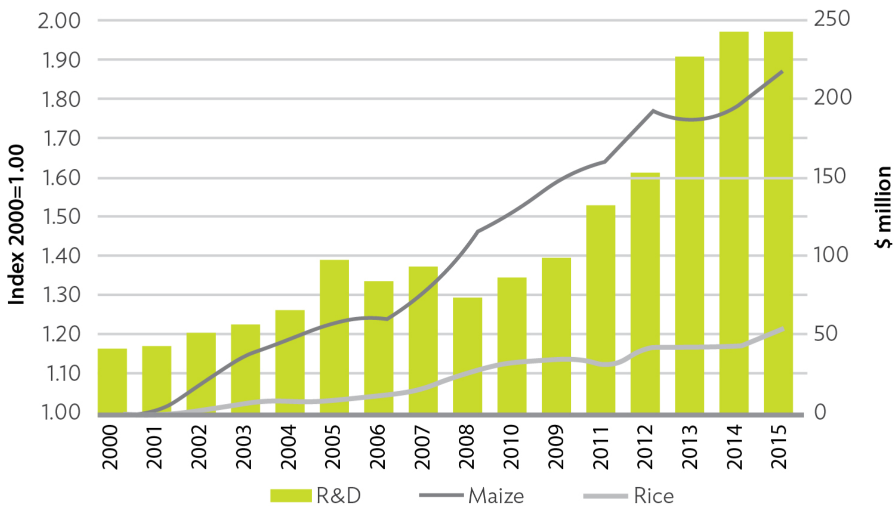
Figure 3.7: Historical Government Expenditure on Agricultural R&D, Indonesia, 1990–2015



R&D = research and development.

Source: OECD, Producer Support Estimate (PSE) Database for Indonesia (online).

Figure 3.8: Government Expenditure on Agricultural R&D and Maize and Rice Productivity Growth, Indonesia, 2000–2015



R&D = research and development.

Sources: FAOSTAT (online); OECD, Producer Support Estimate (PSE) Database for Indonesia (online).

R&D Investment Scenarios

Three alternative R&D investment scenarios, aimed at the development and adoption of productivity-enhancing technologies, are simulated in this section.

a. IARCs. Increased R&D investment through the IARCs. The IARCs mainly engage in public R&D in frontier and costly technologies. These centers develop public goods and receive contributions from both private and public donors. The technologies they develop also serve as input to Indonesia's NARS for country-specific adaptation and dissemination.
b. NARS. Increased R&D investment through the Indonesian agricultural research system. In this scenario, R&D by the IARCs complements NARS R&D work and boosts the extension of technologies to farmers and the rate of adoption by farmers.
c. Hi-NARS. Increased investment through the Indonesian agricultural system, together with improved efficiency in research in this system. In this scenario, investment growth accelerates across the research systems up to 2030 before tapering off over the 15 years that follow, but with increased research efficiency and speed in the development and delivery of productivity-enhancing technologies.

Technology development is a long process that starts in the laboratory, then moves on to testing on experimental farms and pilot-testing in farmers' fields, and finally to validation and certification. And because technology adoption by farmers also takes time, these three R&D scenarios are modeled to achieve peak adoption in 15 years.

For all three R&D scenarios, additional productivity improvements are projected to be achieved for the major crop and livestock groups in Indonesia.

Potential productivity gains from each scenario are based on the past performance of the IARCs and NARS and on the opinion of experts from the Consultative Group on International Agricultural Research (CGIAR) centers in the region, regarding such matters as the probability of success and the rate of adoption by farmers and stakeholders.

For the IARCs scenario, potential yield gains range from 12% to 20% for cereals; from 10% to 30% for fruits and vegetables; from 5% to 30% for roots and tubers; and from 10% to 12% for livestock. Fifty percent of the improvements in yield are to be achieved in 15 years; peak yields, in 30 years.

With larger investments in efficiency, yield gains in the Hi-NARS scenario can be 30% higher than those in the NARS scenario. Potential yield gains in both scenarios are similar, but in the High-NARS scenario they accelerate in the early (first 10–15) years, with peak yields achievable in 20–25 years. This acceleration in gains requires the highest investment rate and capital outlay in the first 5–10 years.

Simulation Results for R&D Investment Scenarios

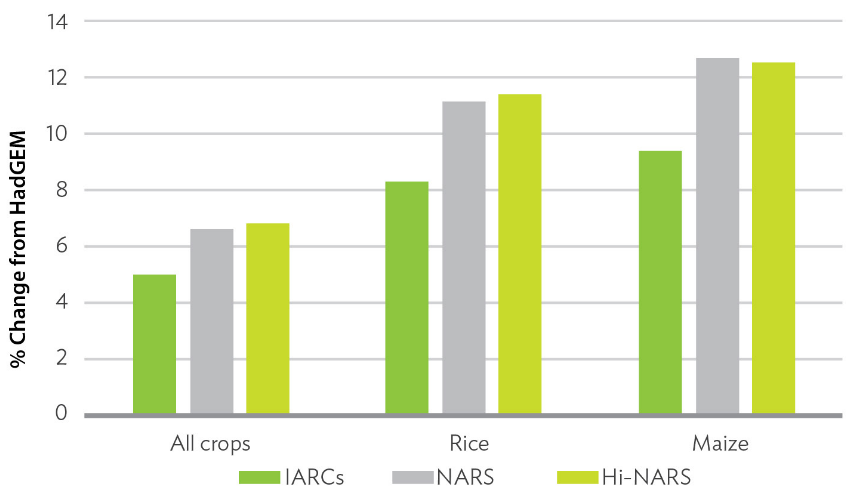
Productivity. Figures 3.9a–3.9c and Tables 3.11a–3.11d present the results of the simulations by cluster of food security indicators such as productivity (yield and production) and accessibility (net trade and consumption), and nutrition indicators such as energy food consumption, number of malnourished children, and number of people at risk of hunger.

The results show substantial productivity gains from increased IARC investment, compared with the HadGEM reference scenario (Figure 3.9a and Table 3.11a). Higher investment in NARS is projected to provide a bigger yield increment than the IARCs scenario—higher by 0.8 percentage point for all crops (ranging from 0.6 percentage point for fruits and vegetables to 2.8 percentage points for roots and tubers), and by 1.4 percentage points for all meat products.

However, the yield gains projected for the highly efficient Hi-NARS scenario are much higher than the NARS yield gains, and achievable in a shorter time. By 2030, Hi-NARS yield levels are projected to exceed yield levels in the NARS scenario by 1.8 percentage points for crops (ranging from 1.7 for fruits and vegetables to 8.2 percentage points for roots and tubers), and by 4.8 percentage points for livestock. In the long term though, with investment at a sustained rate under NARS but tapering off under Hi-NARS, the yield gains for NARS are projected to eventually catch up with those for Hi-NARS. Similarly, projected production is higher for NARS than for IARCs, and for Hi-NARS than for NARS.

Net trade. As shown in Figure 3.9b and Table 3.11b, Indonesia is projected to become a net exporter of rice by 2030 as changing dietary patterns begin to reduce per capita consumption of the cereal. Higher productivity growth by itself does not change rice net trade much: while rice production increases (Table 3.11a), so does rice consumption, because of the induced growth in income and drop in prices as productivity goes up (Table 3.11b). On the other hand, maize imports are projected to decline because of increased production, while wheat imports are projected to increase mainly because of higher consumption with higher income, and wheat substitution for rice in changing dietary patterns.

Figure 3.9a: Projected Yield Gains of Selected Food Crops under Different R&D Scenarios, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), Hi-NARS = intensified NARS research (scenario), IARC = international agricultural research center (scenario), NARS = national agricultural research system (scenario), R&D = research and development.

Source: IMPACT simulation results.

Table 3.11a: Projected Impact of Different R&D Investment Scenarios on Production and Yield in Indonesia, 2030 and 2045, Compared with HadGEM (% difference from HadGEM)

Food Commodity Group	R&D Investment Scenarios					
	IARCs		NARS		Hi-NARS	
	2030	2045	2030	2045	2030	2045
Production						
All Crops	1.31	2.62	1.73	3.34	3.04	3.48
All Cereals	3.35	6.97	4.38	9.27	8.66	9.49
Maize	6.05	13.05	6.78	18.90	16.80	17.31
Rice	2.73	5.72	3.83	7.27	6.78	7.87
Fruits and Vegetables	2.37	5.55	3.19	7.08	5.73	7.38
Oil Crops	(0.03)	(0.02)	(0.04)	(0.19)	(0.21)	(0.10)
Pulses	7.57	15.27	9.88	20.25	16.79	21.07
Roots and Tubers	8.83	18.75	11.64	25.00	19.88	25.62

Food Commodity Group	R&D Investment Scenarios					
	IARCs		NARS		Hi-NARS	
	2030	2045	2030	2045	2030	2045
Lamb/Goat	0.62	0.16	0.80	0.15	1.13	0.13
Poultry	0.65	0.36	0.97	0.20	0.91	0.33
Dairy Products	1.18	1.46	1.46	1.57	2.22	1.59
Yield						
All Crops	2.65	5.05	3.41	6.67	5.22	6.83
All Cereals	4.26	8.23	5.54	10.90	9.25	11.18
Maize	4.70	9.34	5.91	12.70	10.57	12.62
Rice	4.24	8.36	5.53	11.08	9.18	11.34
Fruits and Vegetables	2.10	4.14	2.70	5.56	4.41	5.74
Oil Crops	3.18	6.49	4.06	8.58	6.49	8.68
Pulses	8.40	16.81	10.93	22.53	18.42	23.07
Roots and Tubers	8.81	18.40	11.56	24.73	19.81	25.20
All Meat Products	4.83	10.04	6.24	13.36	10.89	13.10
Beef	5.35	11.00	7.01	14.52	11.88	14.31
Lamb/Goat	5.35	10.99	7.00	14.50	11.87	14.29
Poultry	5.30	10.89	6.94	14.38	11.76	14.16
Dairy Products	5.37	11.04	7.03	14.58	11.93	14.37

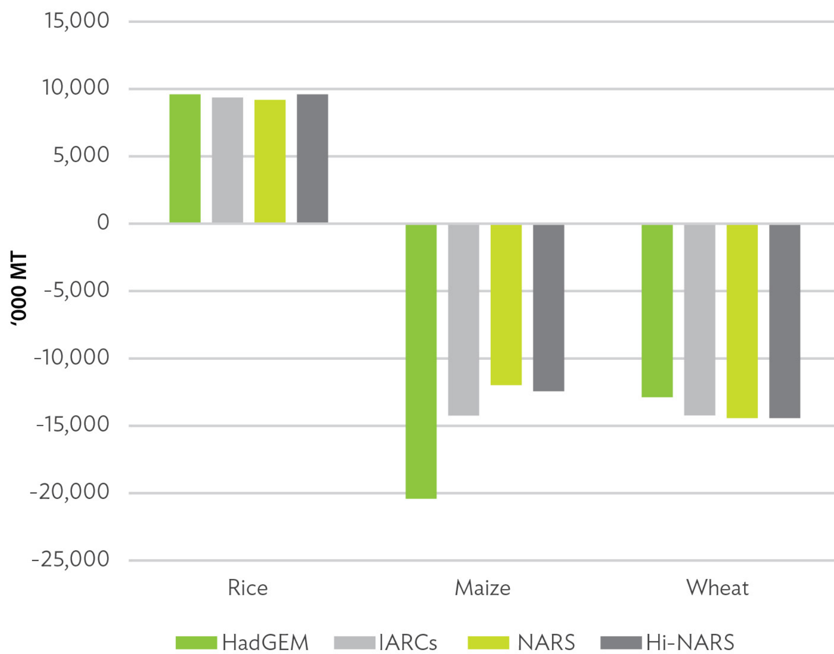
HadGEM = Hadley Centre Global Environmental Model (scenario), Hi-NARS = intensified NARS research (scenario), IARC = international agricultural research center (scenario), NARS = national agricultural research system (scenario), R&D = research and development.

Source: IMPACT simulation results.

Consumption and food security. Table 3.11c shows that higher consumption levels are projected for all R&D scenarios compared with the HadGEM baseline scenario assuming climate change. These projections signify better availability and accessibility of food, not only by commodity but also by inclusiveness of energy food intake. Per capita daily energy food consumption is projected to increase by 2.2%–5.1% by 2030, and by 4.9%–6.3% by 2045, under the different R&D scenarios, compared with HadGEM.

R&D investment can also improve food security, as shown by the projected reduction in the number of malnourished children and of people at risk of hunger compared with the baseline (Figure 3.11c). The expected reduction is highest for Hi-NARS, with the number of hungry people decreasing by 5.01 million by 2030, and by 14.23 million by 2045. Under this scenario, the total number of hungry people is projected to decline to 19.35 million (compared with HadGEM's 24.36 million) by 2030, and to 5.04 million (vs. HadGEM's 19.27 million) by 2045 (Table 3.11d).

Figure 3.9b: Projected Net Trade in Cereals under Different R&D Scenarios, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), Hi-NARS = intensified NARS research (scenario), IARC = international agricultural research center (scenario), MT = metric ton, NARS = national agricultural research system (scenario), R&D = research and development.

Source: IMPACT simulation results.

Box 1: R&D Scenarios

In summary, productivity gains are projected for all R&D scenarios—more moderate for IARCs and highest for Hi-NARS, with productivity increasing by 6.8% for all crops and by 13.1% for all meat products by 2045 under the latter scenario.

Indonesia is projected to become a net exporter of rice by 2030 as changing dietary patterns begin to reduce per capita consumption of rice. Maize imports are expected to decline, and wheat imports, to increase.

Higher consumption levels are projected for all R&D scenarios compared with the climate change baseline, signifying increased availability and accessibility of food, with consequent improvements in food security, as shown by the projected reduction in the number of malnourished children and people at risk of hunger. Under the Hi-NARS scenario, the number of hungry people is projected to decline to 19.35 million (compared with HadGEM's 24.36 million) by 2030, and to 5.04 million (vs. HadGEM's 19.27 million) by 2045.

Table 3.11b: Projected Impact of Different R&D Investment Scenarios on Net Trade in Indonesia, 2030 and 2045 ('000 MT)

Food Commodity Group	HadGEM		R&D Investment Scenarios					
			IARCs		NARS		Hi-NARS	
	2030	2045	2030	2045	2030	2045	2030	2045
All Crops	12,204	15,967	18,245	25,861	18,871	28,769	21,607	29,208
All Cereals	(21,086)	(23,962)	(17,057)	(19,211)	(17,203)	(17,620)	(16,735)	(17,612)
Maize	(14,902)	(20,480)	(10,303)	(14,249)	(10,350)	(12,033)	(9,518)	(12,369)
Rice	4,093	9,529	3,972	9,311	4,015	9,069	4,069	9,393
Wheat	(10,199)	(12,911)	(10,630)	(14,146)	(10,772)	(14,524)	(11,189)	(14,505)
Fruits and Vegetables	(8,002)	(9,818)	(7,751)	(9,167)	(7,688)	(8,971)	(7,487)	(8,838)
Oil Crops	9,037	9,556	9,369	10,412	9,496	10,609	9,838	10,636
Pulses	(139)	(197)	(128)	(182)	(125)	(176)	(117)	(172)
Roots and Tubers	2,088	2,104	4,026	6,446	4,677	7,981	6,520	8,186
All Meat Products	(1,085)	(965)	(1,106)	(1,077)	(1,108)	(1,122)	(1,153)	(1,114)
Beef	(314)	(195)	(302)	(195)	(299)	(196)	(288)	(196)
Lamb/Goat	(55)	(105)	(62)	(131)	(65)	(139)	(72)	(139)
Poultry	(1,222)	(1,611)	(1,229)	(1,640)	(1,226)	(1,660)	(1,258)	(1,653)
Dairy Products	(2,142)	(2,372)	(2,193)	(2,525)	(2,210)	(2,588)	(2,267)	(2,584)

HadGEM = Hadley Centre Global Environmental Model (scenario), Hi-NARS = intensified NARS research (scenario), IARC = international agricultural research center (scenario), MT = metric ton, NARS = national agricultural research system (scenario), R&D = research and development. ( ) = negative. Negative net trade means net imports, positive net trade means net exports.

Source: IMPACT simulation results.

Table 3.11c: Projected Impact of Different R&D Investment Scenarios on Per Capita Consumption in Indonesia, 2030 and 2045 (kg per capita per year)

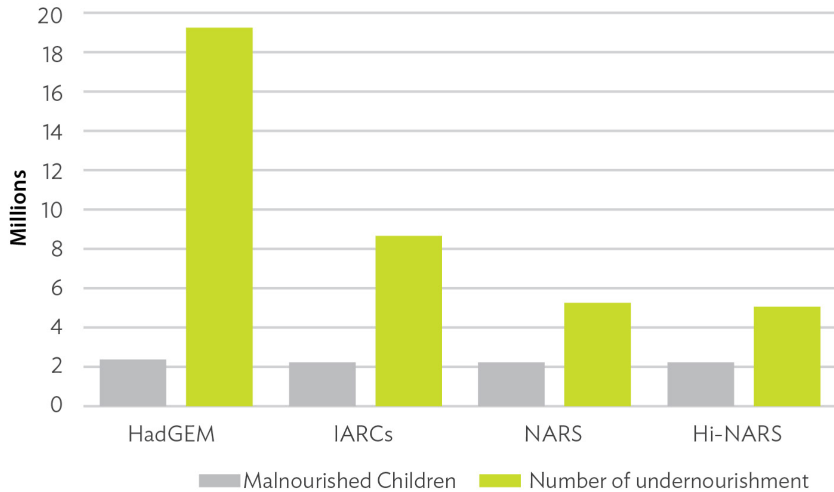
Food Commodity Group		HadGEM		IARCs		NARS		Hi-NARS	
	2015	2030	2045	2030	2045	2030	2045	2030	2045
All Crops	401.3	461.6	498.5	471.1	521.8	474.6	527.8	483.9	528.2
All Cereals	185.6	199.1	202.7	205.0	216.6	207.2	220.0	212.2	220.3
Maize	39.4	48.4	51.3	49.3	53.6	49.9	53.8	50.1	54.2
Rice	121.6	116.8	110.3	120.4	117.8	121.5	119.9	124.9	119.8
Wheat	24.6	33.8	41.0	35.3	45.1	35.8	46.3	37.2	46.2
Fruits and Vegetables	113.8	151.8	180.1	154.0	186.2	154.8	187.9	157.3	187.9
Oil Crops	16.4	16.7	15.6	17.0	16.3	17.1	16.5	17.5	16.5
Pulses	1.4	1.7	1.8	1.7	2.0	1.7	2.0	1.8	2.0
Roots and Tubers	53.1	51.8	50.6	52.8	52.9	53.2	53.6	54.4	53.5
All Meat Products	14.26	22.25	26.95	22.37	27.25	22.40	27.35	22.53	27.34
Beef	2.83	4.14	4.40	4.14	4.49	4.14	4.52	4.14	4.51

Food Commodity Group		HadGEM		IARCs		NARS		Hi-NARS	
	2015	2030	2045	2030	2045	2030	2045	2030	2045
Poultry	8.29	14.58	18.79	14.68	18.94	14.70	18.99	14.81	18.98
Dairy Products	10.94	12.84	14.09	13.08	14.68	13.14	14.87	13.38	14.86

HadGEM = Hadley Centre Global Environmental Model (scenario), Hi-NARS = intensified NARS research (scenario), IARC = international agricultural research center (scenario), MT = metric ton, NARS = national agricultural research system (scenario), R&D = research and development.

Source: IMPACT simulation results.

Figure 3.9c: Projected Impact of R&D Scenarios on Hunger and Malnutrition, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), Hi-NARS = intensified NARS research (scenario), IARC = international agricultural research center (scenario), NARS = national agricultural research system (scenario), R&D = research and development.

Source: IMPACT simulation results.

Table 3.11d: Projected Impact of Different R&D Investment Scenarios on Nutrition Indicators in Indonesia, 2030 and 2045

Nutrition Indicator				R&D Investment Scenarios					
		HadGEM		IARCs		NARS		Hi-NARS	
	2015	2030	2045	2030	2045	2030	2045	2030	2045
Energy consumption (kcal/ capita/day)	2,639	2,940	3,105	3,006	3,258	3,029	3,297	3,089	3,300
Malnourished children (million)	4.64	3.22	2.33	3.12	2.15	3.08	2.10	3.00	2.10
Number of undernourishment (million)	26.60	24.36	19.27	22.70	8.73	21.88	5.26	19.35	5.04
Prevalence of undernourishment (% of total population)	10.6	8.8	6.7	8.2	3.0	7.9	1.8	7.0	1.8

HadGEM = Hadley Centre Global Environmental Model (scenario), Hi-NARS = intensified NARS research (scenario), IARC = international agricultural research center (scenario), kcal = kilocalorie, NARS = national agricultural research system (scenario), R&D = research and development.

Investment in Land and Water Productivity

Increasing land area and productivity by expanding the irrigation system and improving water management offers another opportunity to invest in productivity growth. Irrigation serves as enabling resource for the application of productivity-enhancing technologies and farm management practices. It also serves as protection from climate variability and temperature extremes, and boosts the effective crop area by increasing cropping intensity.

Table 3.12 and Figure 3.10 present historical trends in Indonesian public expenditure on irrigation and irrigated wetland areas planted to rice. Government expenditure on irrigation declined by 6% yearly from 1990 to 2000 before accelerating by 13% from Rp729 billion ($87 million) in 2000 to Rp14.5 trillion ($1.1 billion) in 2015. The irrigated wetland area planted to rice, on the other hand, went through 5-year swings during the same period, declining by 4.8% between 2000 and 2005, increasing by 4.7% between 2005 and 2010, and then declining again by 2.9% between 2010 and 2015. The total irrigated wetland area planted to rice in 2015 was 3.2% (160,000 ha) smaller than the total area in 2000.

Irrigation Investment Scenarios

Two combinations of irrigation expansion and investment in irrigation modernization and water-use efficient technologies are presented and compared below.

a. IRREXP_WUE. A 10% expansion of the existing irrigation infrastructure in Indonesia with corresponding investment in the modernization of irrigation systems and the adoption of water-use efficiency (WUE) technologies and practices at the farm level to generate more effective water management systems at the reservoir and watershed levels. About 550,000 ha of new irrigated land area is added between 2015 and 2030 under this scenario, compared with the 260,000 ha increase projected under the HadGEM reference scenario.
b. IRREXP+_WUE. An accelerated 20% expansion of existing irrigated lands with corresponding investment in the modernization of irrigation systems and the adoption of WUE farm technologies and management systems at the reservoir and watershed levels. The investment in modernization and new technologies for WUE is important in expanding the availability of water to support the effective increase in irrigated area. Under this scenario, 1.1 million ha of new irrigated land area—double the area under the first scenario—is added between 2015 and 2030.

The new irrigated areas can comprise land converted from nonirrigated or rainfed agriculture or from nonagricultural use. In these irrigation expansion scenarios, new irrigation development is limited to existing nonirrigated agricultural land. The conversion of nonagricultural land into irrigated or nonirrigated agricultural land is considered in another investment scenario later on in this chapter.

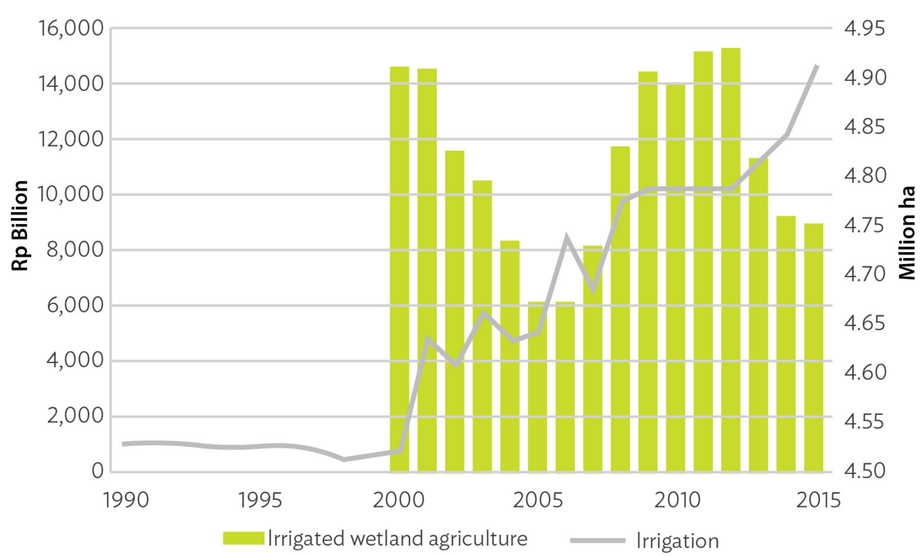
Table 3.12: Trends in Wetland Rice Production, by Irrigation Type, in Indonesia, 2000–2015 (million hectares)

Year	Irrigated Wetland			NonIrrigated Wetland			Total Wetland		
	Java Island	Outside Java	Indonesia	Java Island	Outside Java	Indonesia	Java Island	Outside Java	Indonesia
2000	2.58	2.33	4.91	0.76	2.18	2.94	3.34	4.50	7.85
2001	2.57	2.33	4.91	0.76	2.17	2.93	3.34	4.50	7.84
2002	2.53	2.29	4.82	0.78	2.20	2.98	3.32	4.49	7.81
2003	2.52	2.28	4.80	0.79	2.29	3.08	3.31	4.56	7.88
2004	2.50	2.23	4.73	0.79	2.32	3.11	3.29	4.55	7.84
2005	2.47	2.20	4.67	0.77	2.30	3.07	3.24	4.50	7.74
2006	2.46	2.21	4.67	0.78	2.34	3.12	3.24	4.55	7.79
2007	2.47	2.26	4.73	0.78	2.35	3.13	3.25	4.61	7.86
2008	2.48	2.34	4.83	0.79	2.38	3.16	3.27	4.72	7.99
2009	2.49	2.42	4.91	0.76	2.40	3.16	3.25	4.82	8.07
2010	2.49	2.40	4.89	0.76	2.35	3.11	3.25	4.75	8.00
2011	2.48	2.44	4.93	0.77	2.40	3.17	3.25	4.84	8.10
2012	2.48	2.45	4.93	0.77	2.43	3.20	3.24	4.88	8.13
2013	2.44	2.37	4.82	0.79	2.52	3.31	3.23	4.90	8.13
2014	2.44	2.32	4.76	0.81	2.55	3.36	3.25	4.87	8.12
2015	2.42	2.33	4.75	0.81	2.53	3.34	3.22	4.86	8.09
Annual Growth Rates (%)									
2000–2015	(0.33)	0.35	0.00	0.15	1.01	0.80	(0.21)	0.68	0.31

( ) = negative

Source: BPS, Land Area by Utilization (various years).

Figure 3.10: Trends in Government Expenditure on Irrigation and Irrigated Agriculture in Wetlands, Indonesia, 1990–2015



ha = hectare.

Note: No BPS online data available for government expenditure on irrigated wetland agriculture in 1990–1999.

Sources: BPS, Land Area by Utilization (various years, online); OECD, PSE Database for Indonesia (online).

Simulation Results for Irrigation Investment Scenarios

Figures 3.11a and 3.11b and Tables 3.12a–3.12d present the results of scenario simulations. Irrigation expansion increases the harvested irrigated crop area in two ways: by converting rainfed agricultural lands into irrigated areas, and by increasing cropping intensity. The combined average yield of irrigated and rainfed lands also increases, since higher-yielding irrigated lands make up a greater proportion of the crop area with the expansion.

Figures 3.11a and 3.11b and Table 3.12a show that substantial investment in irrigation—1.1 million ha under IRREXP+_ WUE and 550,000 ha under IRREXP_ WUE—is projected to increase the harvested crop area significantly in both irrigation investment scenarios. The highest increase in area is projected for rice and sugarcane. By 2045, the increase in harvested irrigated area over the HadGEM figure is projected to be highest for sugarcane (8.18%), followed by maize (7.19%) and rice (5.29%).

Projected marginal increases in crop yield are also substantial under both investment scenarios, but particularly under the IRREXP+_WUE scenario—three to four times higher for maize and rice, compared with IRREXP_WUE , and two times higher for oil crops. These yield gains are due in large part to the complementary impact of higher WUE in these scenarios, which reduces water stress and increases the productivity of water over both existing and expanded irrigated areas. Under IRREXP+_WUE, crop yield gains account for 36% of total crop production gains in 2045, compared with HadGEM.

Consequently, production levels are also projected to increase, except for pulses, which are projected to decline in area and yield. For rice, under IRREXP+_ WUE, the increase is high enough to improve net trade by 2045, with net exports of more than 2.3 million MT despite rising consumption and improvements in nutrition indicators. Positive effects on net trade are similarly projected for oil crops (with net exports increasing by as much as 1.3 million MT over the HadGEM figure by 2045) and for maize and fruits and vegetables (reducing net imports by 834,000 MT and 444,000 MT, respectively, by 2045). Wheat imports, though, are projected to continue to increase.

The net effects on production under the two irrigation investment scenarios are projected to lower domestic prices and increase income (both of these were simulated in the study but the results are not shown here), besides increasing per capita consumption (Table 3.12c) of all food crops. The country will continue to increase its wheat consumption by 1.95% in 2045, from rising wheat imports. For rice, on the other hand, while production is projected to increase by 6.78%, consumption will increase by only 2.63%, and the rest will be added to exports.

All nutrition and food security indicators under these two irrigation investment scenarios point to higher consumption and fewer malnourished and hungry people, with better values for IRR-EXP+_WUE. Compared with HadGEM scenario, by 2045, average daily calorie consumption per person is projected to increase from 3,105 kcal to 3,152 kcal (1.51% increase); the number of malnourished children, to decrease from

2.33 million to 2.27 million (1.5% decline); and the number of hungry people, to drop by 43% from19.27 million to 16.56 million (14% decrease).

Figure 3.11a: Projected Change in Food Crop Harvested Area and Production under Irrigation Investment Scenarios, Compared with HadGEM, Indonesia, 2045

HadGEM = Hadley Centre Global Environmental Model (scenario), IRREXP_WUE = irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements, IRREXP+_WUE = irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements.

Source: IMPACT simulation results.

Table 3.12a: Projected Impact of Irrigation Investment Scenarios on Productivity in Indonesia, 2030 and 2045 (% change from HadGEM)

Food Commodity Group	Irrigation Investment Scenarios			
	IRREXP_WUE		IRREXP+_WUE	
	2030	2045	2030	2045
Production				
All Crops	1.40	1.56	3.51	3.75
All Cereals	2.01	1.92	7.23	6.99
Maize	3.49	3.51	7.71	8.03
Rice	1.66	1.59	7.12	6.78
Fruits and Vegetables	1.34	1.21	3.41	3.13
Oil crops	1.31	1.54	2.72	3.10
Pulses	(0.73)	(0.90)	(0.88)	(1.05)
Roots and Tubers	0.47	0.50	0.69	0.70
Sugar	2.18	2.54	6.00	6.94
Harvested Area				
All Crops	0.94	0.83	2.86	2.47

Food Commodity Group	Irrigation Investment Scenarios			
	IRREXP_WUE		IRREXP+_WUE	
	2030	2045	2030	2045
Rice	1.33	1.25	5.69	5.29
Fruits and Vegetables	1.35	1.33	3.00	2.83
Oil Crops	0.58	0.46	1.32	0.95
Pulses	(0.50)	(0.45)	(0.78)	(0.72)
Roots and Tubers	0.64	0.71	0.99	1.04
Sugar	3.03	3.36	7.34	8.18
Yield				
All Crops	0.49	0.74	0.74	1.34
All Cereals	0.25	0.22	1.17	1.21
Maize	0.15	0.21	0.58	0.79
Rice	0.33	0.33	1.35	1.41
Fruits and Vegetables	(0.01)	(0.12)	0.40	0.30
Oil Crops	0.73	1.07	1.38	2.13
Pulses	(0.23)	(0.45)	(0.10)	(0.33)
Roots and Tubers	(0.16)	(0.21)	(0.30)	(0.33)
Sugar	(0.82)	(0.80)	(1.24)	(1.14)

HadGEM = Hadley Centre Global Environmental Model (scenario), IRREXP_WUE = irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements, IRREXP+_WUE = irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements.
( ) = negative

Source: IMPACT simulation results.

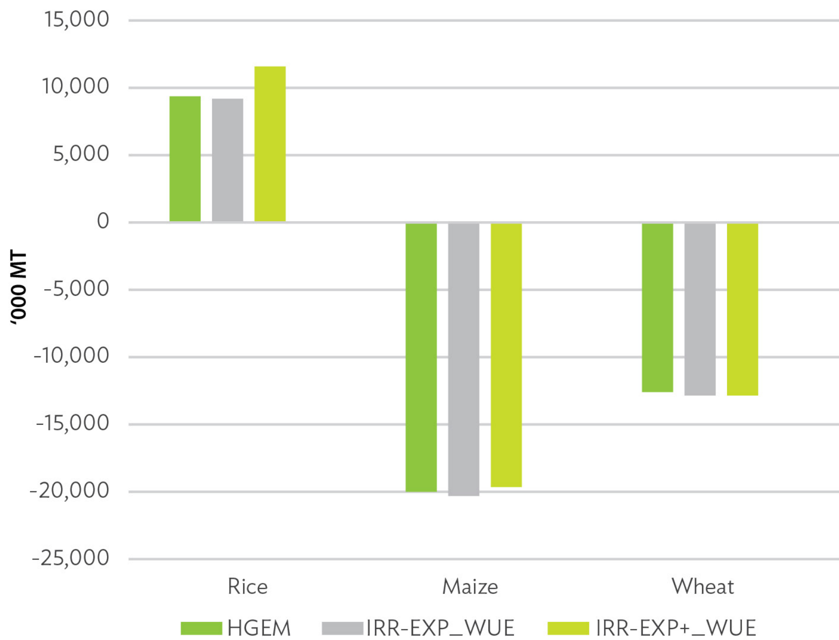
Table 3.12b: Projected Impact of Irrigation Investment Scenarios on Net Trade in Indonesia, 2030 and 2045 ('000 MT)

Food Commodity Group	HadGEM		Irrigation Investment Scenarios			
			IRREXP_WUE		IRREXP+_WUE	
	2030	2045	2030	2045	2030	2045
All Crops	12,204	15,967	13,117	16,774	18,184	22,476
All Cereals	(21,086)	(23,962)	(21,414)	(24,493)	(18,501)	(21,401)
Maize	(14,902)	(20,480)	(14,795)	(20,515)	(14,346)	(20,036)
Rice	4,093	9,529	3,806	9,247	6,273	11,864
Wheat	(10,199)	(12,911)	(10,348)	(13,127)	(10,350)	(13,131)
Fruits and Vegetables	(8,002)	(9,818)	(7,893)	(9,873)	(7,123)	(8,984)
Oil Crops	9,037	9,556	9,593	10,141	10,295	10,886
Pulses	(139)	(197)	(144)	(205)	(145)	(206)
Roots and Tubers	2,088	2,104	2,230	2,216	2,296	2,276

IRREXP_WUE = irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements, IRREXP+_WUE = irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements, MT = metric ton. ( ) = negative. Negative net trade = imports, positive net trade = exports

Source: IMPACT simulation results.

Figure 3.13b: Projected Net Trade in Cereals under Irrigation Investment Scenarios, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), IRREXP_WUE = irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements, IRREXP+_WUE = irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements, MT = metric ton.

Source: IMPACT simulation results.

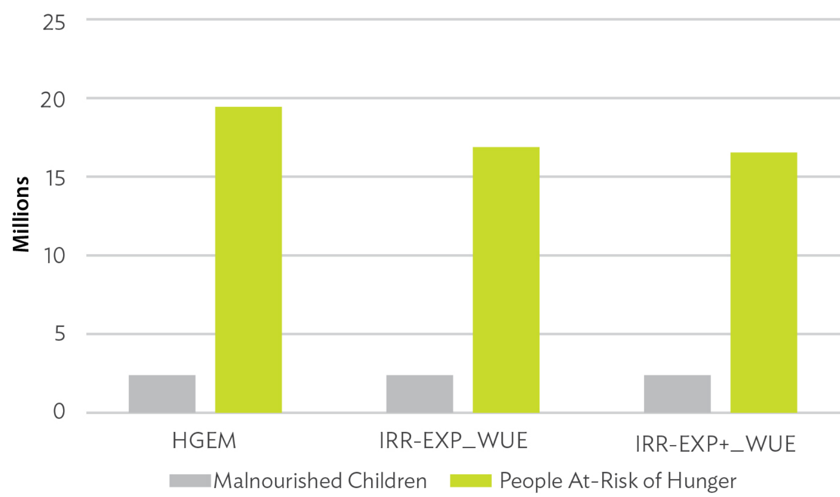
Table 3.12c: Projected Impact of Irrigation Investment Scenarios on Per Capita Consumption in Indonesia, 2030 and 2045 (kg per capita per year)

Food Commodity Group		HadGEM		Irrigation Investment Scenarios			
				IRREXP_WUE		IRREXP+_WUE	
	2015	2030	2045	2030	2045	2030	2045
All Crops	401.3	461.6	498.5	467.0	504.9	467.4	505.4
All Cereals	185.6	199.1	202.7	202.8	206.7	203.1	206.9
Maize	39.4	48.4	51.3	48.9	51.9	48.9	51.9
Rice	114	116.8	110.3	119.6	113.0	119.8	113.2
Wheat	24.6	33.8	41.0	34.3	41.7	34.3	41.8
Fruits and Vegetables	113.8	151.8	180.1	153.2	182.1	153.2	182.2
Oil Crops	16.4	16.7	15.6	16.8	15.7	16.8	15.7
Pulses	1.4	1.7	1.8	1.7	1.9	1.7	1.9
Roots and Tubers	53.1	51.8	50.6	51.8	50.7	51.8	50.7

HadGEM = Hadley Centre Global Environmental Model (scenario), IRREXP_WUE = irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements, IRREXP+_WUE = irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements, kg = kilogram.

Source: IMPACT simulation results.

Figure 3.13c: Projected Impact of Irrigation Investment Scenarios on Hunger and Malnutrition, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), IRREXP_WUE = irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements, IRREXP+_WUE = irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements.

Source: IMPACT simulation results.

Table 3.12d: Projected Impact of Irrigation Investment Scenarios on Nutrition Indicators, Indonesia, 2030 and 2045

Food Security Indicator	HadGEM			Irrigation Investment Scenarios			
				IRREXP_WUE		IRREXP+_WUE	
	2015	2030	2045	2030	2045	2030	2045
Energy consumption (kcal/capita/day)	2,639	2,940	3,105	2,980	3,148	2,983	3,152
Malnourished children (million)	4.64	3.22	2.33	3.16	2.27	3.15	2.27
Number of undernourishment (million)	26.60	24.36	19.27	23.46	16.77	23.36	16.56
Prevalence of undernourishment (% of population)	10.6	8.8	6.7	8.5	5.8	8.4	5.7

HadGEM = Hadley Centre Global Environmental Model (scenario), IRREXP_WUE = irrigation investment scenario involving 10% expansion in irrigated area with systems modernization and water-use efficiency improvements, IRREXP+_WUE = irrigation investment scenario involving 20% expansion in irrigated area with systems modernization and water-use efficiency improvements, kcal = kilocalorie.

Source: IMPACT simulation results.

Box 2: Investment in Irrigation and Water-Use Efficiency

Irrigation expansion increases the harvested irrigated crop area and crop yield by converting rainfed or fallow areas and by increasing cropping intensity.

Two irrigation scenarios were simulated: the development of 550,000 hectares (ha) (IRREXP_WUE) and 1.1 million ha (IRREXP+_WUE) of land up to 2030, both with efficient water-use technologies. By 2045, the increase in harvested area over the HadGEM figure is projected to be highest for sugarcane (8.18%), maize (7.19%), and rice (5.29%). Projected marginal gains in crop yield are also substantial under both investment scenarios, but particularly under the IRREXP+_WUE scenario—three to four times higher for maize and rice, compared with HadGEM, and two times higher for oil crops, because of the complementary impact of improved WUE in these scenarios.

Production levels are projected to increase for all crops, except for pulses. For rice, under IRREXP+_WUE, the increase is high enough to add 2.3 million metric tons to net exports, despite rising consumption and improvements in nutrition indicators. Positive net trade values are similarly projected for oil crops, maize, and fruits and vegetables.

The number of hungry people in the country is projected to improve substantially under these investment scenarios.

3.3.4 Investment in Rural Infrastructure to Reduce Postharvest Losses and Marketing Costs

Food losses can occur at any stage of crop production, marketing, and home consumption—through crop damage or spillage during production, attacks from insects or microorganisms during storage, spillage in the course of distribution, or table waste. Postharvest losses of agricultural commodities can be substantial, and marketing costs and margins are high in Indonesian agriculture. Smallholders make up a large percentage of farmers, as was shown in Chapter 2 of this report. These farmers are often poorly connected to markets, and value chains are long and involve many actors. As noted in OECD (2012), additional marketing challenges include "poor roads, fraud, corruption, and the lack of cold storage and logistic services. Emerging cold chains are further plagued by the presence of blackouts and rolling brownouts."

Investment in rural infrastructure to reduce postharvest losses (PHL) and increase the effective food supply available to domestic consumers and to export demand is therefore a priority. Such investment can also reduce marketing costs through efficient transport and road systems, higher milling rates, and effective storage facilities, all of which contribute to more efficient value changes. More efficient and effective markets will deliver input to farmers at lower cost and provide higher prices for farm output, improving incentives and income.

Postharvest Investment Scenario

One investment scenario is geared toward reducing both PHL and marketing costs. PHL/Mktg involves increased investment in rural infrastructure, including rural roads and railways, electricity generation, postharvest facilities, and storage, processing, and marketing infrastructure—either publicly financed or in the form of a joint venture with rural cooperatives or private entrepreneurs. These investments can reduce PHL and marketing costs. The PHL/Mktg scenario is modeled in IMPACT as reduction of marketing margins and reductions in PHL that increase total consumer receipts of farm produce. Investments under this category include more efficient post-processing facilities (e.g., higher milling rates, less spoilage during storage), lower transport costs (e.g., more and better roads and transport systems), and market information services, applied to both crops and livestock products. In this scenario, PHL and marketing costs are reduced by 50% in 15 years.

Results of Simulations

Results of the simulations are presented in Figures 3.14a–3.14d and Tables 3.13a–3.13d.

Supply Increases

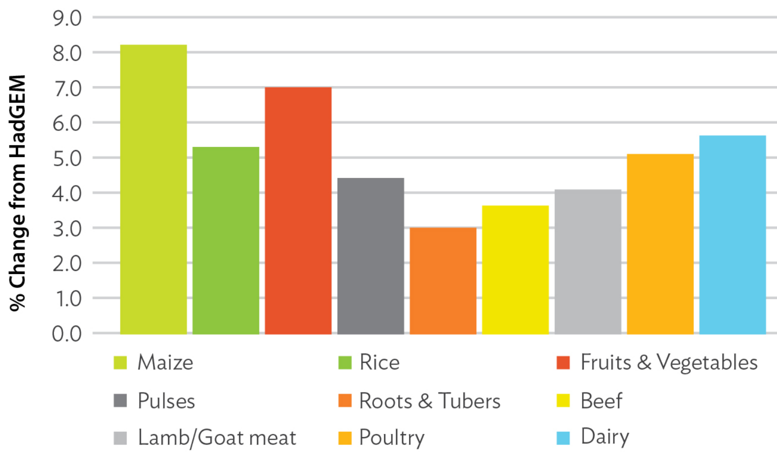
Figure 3.14a and Table 3.13a show that PHL/Mktg investments are projected to increase the supply (production) available for consumption by 3.25% for crops and by 5.20% for meat products by 2045. The increase will be achieved both directly (by reducing PHL) and indirectly (by improving the profitability of producers through lower marketing costs, thus providing them with incentives to produce more).

The highest increases are projected for maize (8.19%) and rice (5.34%), both benefiting from better milling rates and from improvements in storage and transport facilities and marketing. Livestock products are also projected to benefit because of their shorter shelf life and stringent storage and transport requirements.

Net Trade Effects

These effective increases in domestic supply are projected to improve Indonesia's net trade position and increase domestic consumption by 2030 and 2045. Maize imports are projected to decrease by 6.9 million MT by 2045, and rice exports, by 374,000 MT (Figure 3.14b and Table 3.13b), because of increased production exceeding the projected increase in consumption (Table 3.13c). Imports of fruits and vegetables are likewise projected to decline by 0.96 million MT, and exports of roots and tubers, to increase by 4.2 million MT. Imports of meat products are foreseen to increase slightly, by 85,000 MT, because of increased consumption. Imports of lamb/goat meat and dairy products are also projected to increase, but a slight decline is expected for poultry meat imports.

Figure 3.12a: Projected Supply Changes for Selected Food Commodities under the PHL/Mktg Scenario, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), PHL/Mktg = postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs.

Source: IMPACT simulation results.

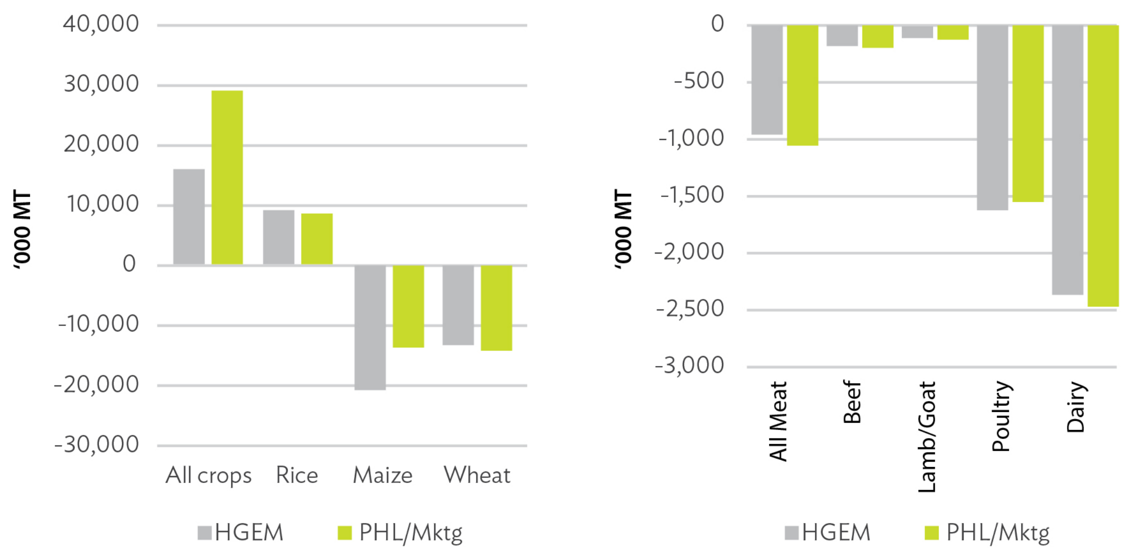
Table 3.13a: Projected Impact of PHL/Mktg Investment Scenario on Agricultural Production in Indonesia, 2030 and 2045 (% change from HadGEM)

Food Commodity Group	2030	2045
Production		
All Crops	2.27	3.25
All Cereals	6.04	5.83
Maize	8.25	8.19
Rice	5.53	5.34
Fruits and Vegetables	7.15	7.11
Oil Crops	1.90	0.30
Pulses	4.41	4.43
Roots and Tubers	3.04	3.02
All Meat Products	5.19	5.20
Beef	3.70	3.70
Lamb/Goat	4.07	4.07
Poultry	5.13	5.12
Dairy	5.56	5.56

HadGEM = Hadley Centre Global Environmental Model (scenario), PHL/Mktg = postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs.

Source: IMPACT simulation results.

Figure 3.12b: Projected Net Trade in Cereals and Meat under the PHL/Mktg Scenario, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), MT = metric ton, PHL/Mktg = postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs.

Source: IMPACT simulation results

Table 3.13b: Projected Impact of PHL/Mktg Investment Scenario on Net Trade in Indonesia, 2030 and 2045 ('000 MT)

Food Commodity Group	HadGEM		PHL/MKtg	
	2030	2045	2030	2045
All Crops	12,204	15,967	21,440	29,140
All Cereals	(21,086)	(23,962)	(17,173)	(18,257)
Maize	(14,902)	(20,480)	(10,332)	(13,498)
Rice	4,093	9,529	4,018	9,155
Wheat	(10,199)	(12,911)	(10,959)	(13,779)
Fruits and Vegetables	(8,002)	(9,818)	(7,381)	(8,862)
Oil Crops	9,037	9,556	9,672	10,614
Pulses	(139)	(197)	(131)	(201)
Roots and Tubers	2,088	2,104	5,422	6,336
All Meat Products	(1,085)	(965)	(1,095)	(1,050)
Beef	(314)	(195)	(287)	(194)
Lamb/Goat	(55)	(105)	(70)	(134)
Poultry	(1,222)	(1,6110)	(1,205)	(1,574)
Dairy Products	(2,142)	(2,372)	(2,191)	(2,481)

HadGEM = Hadley Centre Global Environmental Model (scenario), MT = metric ton, PHL/Mktg = postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs. ( ) = negative. Negative net trade = imports. Positive net trade = exports.

Source: IMPACT simulation results.

Food Security

The projected net effects of investment in PHL/Mktg efficiencies are an increase in food/energy consumption per capita per day, a reduction in the number of malnourished children, and an overall decline in the number of chronically hungry people. Projections for 2045 show a 4.3% increase in energy consumption by 2045, resulting in a sizable decrease in the number of malnourished children (by 160,000) and in 9.1 million fewer hungry people (Figure 3.12c and Table 3.13d), compared with HadGEM in 2045.

Table 3.13c: Projected Impact of PHL/Mktg Investment Scenario on Per Capita Consumption in Indonesia, 2030 and 2045 (kg per capita per year)

Food Commodity Group	2015	HadGEM		PHL/MKtg	
		2030	2045	2030	2045
All Crops	401.3	461.6	498.5	480.2	527.0
All Cereals	185.6	199.1	202.7	206.6	212.2
Maize	39.4	48.4	51.3	45.8	49.3
Rice	114	116.8	110.3	123.3	116.8
Wheat	24.6	33.8	41.0	36.4	43.9
Fruits and Vegetables	113.8	151.8	180.1	159.5	187.4
Oil Crops	16.4	16.7	15.6	17.2	16.5
Pulses	1.4	1.7	1.8	1.6	1.7
Roots and Tubers	53.1	51.8	50.6	45.2	41.4
All Meat Products	14.3	22.3	27.0	23.7	28.9
Beef	2.8	4.1	4.4	4.2	4.5
Lamb/Goat	0.7	1.1	1.4	1.2	1.6
Poultry	8.3	14.6	18.8	15.4	19.9
Dairy Products	10.9	12.8	14.1	13.8	15.5

HadGEM = Hadley Centre Global Environmental Model (scenario), kg = kilogram, PHL/Mktg = postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs.

Source: IMPACT simulation results.

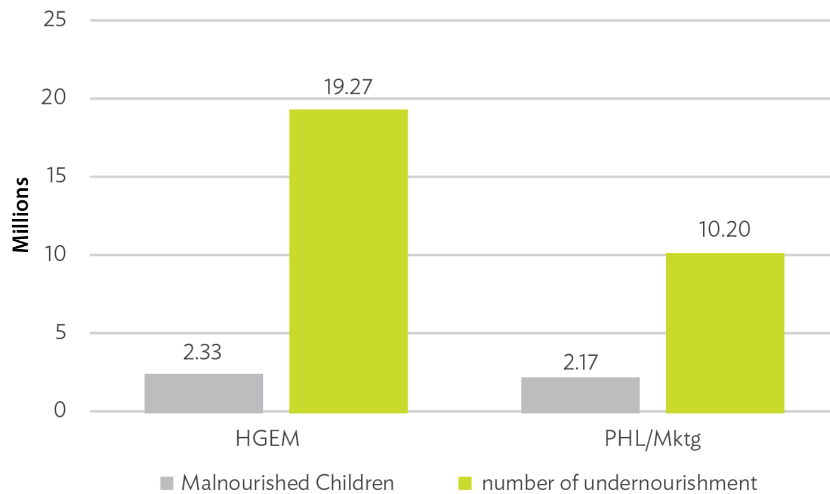
Table 3.13d: Projected Impact of PHL/Mktg Investment Scenario on Nutrition Indicators, Indonesia, 2030 and 2045

Food Security Indicator	2015	HadGEM		PHL/MKtg	
		2030	2045	2030	2045
Energy consumption (kcal/capita/day)	2,639	2,940	3,105	3,055	3,240
Malnourished children (million)	4.64	3.22	2.33	3.05	2.17
Number of undernourishment (million)	26.6	24.36	19.27	20.88	10.20
Prevalence of undernourishment (% of population)	10.6	8.8	6.7	7.5	3.5

HadGEM = Hadley Centre Global Environmental Model (scenario), kcal = kilocalorie, PHL/Mktg = postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs.

Source: IMPACT simulation results.

Figure 3.12c: Projected Impact of PHL/Mktg Scenario on Hunger and Malnutrition, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), PHL/Mktg = postharvest investment scenario involving increased investment in rural infrastructure to reduce postharvest losses and marketing costs.

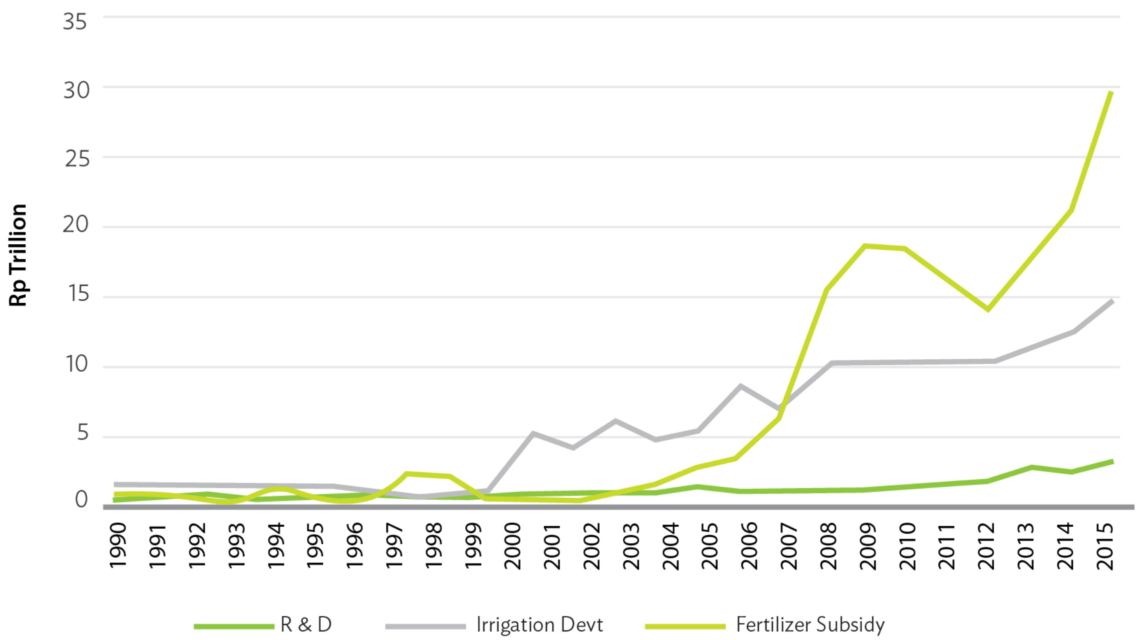
Source: IMPACT simulation results.

3.3.5 Investment in Efficiency and Competitiveness

Removal of Fertilizer Subsidies

Fertilizer subsidies have been a cornerstone of Indonesian food production policy. In 2015, the fertillzer subsidy reached Rp30 trillion ($2.5 billion) , substantially higher than the expenditure on irrigation development and the expenditure on agricultural research and extension. However, investment in agricultural technology, especially research and development, has more significant impact on the long-run output response in Indonesia (Rosegrant, Kasryno, and Perez 1998). An examination of historical sources of growth using an econometric approach showed the predominance of technology in the growth of food crop production in Indonesia. The share of output growth due to public investment in research, extension, and irrigation is more than 70% for all four crops (i.e., rice, maize, soybean, and cassava). Changes in relative prices contribute as well to output growth, but the impact is secondary compared with the contribution of technology. Expenditure on fertilizer subsidies also has much less impact on production than investment in technology. The high output response to public investment in technology, combined with the very low output response to fertilizer prices, shows that eliminating fertilizer subsidies and transferring the funds thus saved to investments in research, extension, and irrigation would have large benefits.

Figure 3.13: Historical Government Expenditure on R&D, Irrigation, and Fertilizer Subsidy



R&D = research and development.

Sources: OECD, PSE Database for Indonesia (online).

Investment in production efficiency and competitiveness in the food sector qualifies as investment in food security, as it improves access to high-quality food. The fertilizer subsidy of the government misallocates food production resources by not allowing the market-price system to operate efficiently in fertilizer production and use. As a result, the agriculture sector remains inefficient and less competitive.

One of the objectives of the government is to make the agriculture sector more competitive. Removing the fertilizer subsidy presents an opportunity to make the sector not only competitive but profitable.

Reinvestment in R&D

Savings from fertilizer subsidies, which reached Rp30 trillion ($2.5 billion) in 2015 (Figure 3.13), can be reinvested in other public investment like infrastructure (e.g., farm-to-market roads), postharvest facilities, rural finance and credit, crop insurance, or even direct cash transfers to farmers. Any of these types of investment can benefit farmers affected by the change in the subsidy policy. However, the direct and immediate effect of removing the subsidy is a reduction in yield from the contraction in fertilizer supply, on the one hand, and a reduction in fertilizer demand due to an increase in prices, on the other. Reinvestment in R&D is seen to directly counteract this loss of productivity.

This section presents a simulation of a series of interconnected scenarios: the removal of the fertilizer price subsidy gradually over 3 years, and reinvestment in productivity-enhancing R&D, as presented in the previous section.

The aim is to simulate the effects of removing the subsidy for the agriculture sector on both producers and consumers, and to evaluate whether investment in R&D can partially or fully compensate for the initial loss of productivity and how fast the sector can recover from the expected initial productivity shocks.

a. **No Fert-Sub.** Gradual removal of the fertilizer subsidy over 3 years, without accompanying reinvestment in R&D. This scenario simulates the impact of having farmers pay the full price of fertilizers and having fertilizer manufacturers pay the full costs of production.
b. **Scenarios involving the reinvestment of the subsidy amount in R&D.** In both simulations, the fertilizer subsidies are removed and replaced with productivity-enhancing technologies from the R&D network.
c. **Re-NARS.** This scenario simulates the impact of investing the savings obtained by scrapping the fertilizer subsidies, in the national agricultural research system (NARS). Analyses pertain to the ability of the agriculture sector to recover from initial productivity losses from the removal of the subsidy, with this type of reinvestment.
d. **Re-Hi-NARS.** This scenario is similar to the Re-NARS scenario, except that the subsidy amount is reinvested in the highly efficient and high-investment NARS R&D presented earlier, which involves higher investment growth rates across the research systems in the short term (to 2030), tapering over the next 15 years, with shorter gestation and increased research efficiency in the development of productivity-enhancing technologies. Comparative analyses continue to be on the increased resilience of the agriculture sector due to this type of reinvestment.

The price subsidy to farmers was estimated at 50%–65%. Once it is removed, the price of fertilizer will double after the third year.

Results of Simulations

Removal of Fertilizer Subsidy

Results of the simulations are presented in Tables 3.14a–3.14d and Figures 3.14a–3.14d. The removal of the fertilizer subsidy can have the immediate impact of reducing average crop yield by 2.45% starting in 2025, and the reduction is projected to persist with minimal signs of recovery up to 2045 and beyond. The projected yield reduction is highest for cereals (3.64%)—4.04% for maize and 3.53% for rice. Area and production will also decline for all crops, except for oil crops.

Subsidy removal without reinvestment will worsen the trade situation for all commodities. By 2045, the country would be exporting 2.25 million MT less of rice, 913,000 MT less of roots and tubers, and 689,000 MT less of oil crops, while importing 1.7 million MT more of fruits and vegetables, 615,000 MT more of maize, and about 3,000 MT more of wheat.

On the other hand, changes in the country's net trade in food, seen earlier as adversely affecting the country's trade situation, also serve to minimize the projected drop in consumption and food security resulting from the decline in productivity after the fertilizer subsidy is removed. The decline in exports and increase in imports maintain access to food and thus help keep domestic food prices from going up, consumption from falling off, and food insecurity from intensifying.

Reinvestment in R&D

R&D investment has a time lag and the technology itself has a longer gestation period, so that by 2025, five years after the projected subsidy removal, yield levels will still be lower than the baseline level.

However, in the medium and long run, the rice and maize industries can recover from the impact of the initial yield loss from subsidy removal with much higher yields by 2030 and 2045. Investment in NARS R&D is a better option than subsidy removal without reinvestment.

While the removal of subsidy is projected to reduce yield for cereals by 3.64% by 2025—4.04% for maize and 3.53% for rice—reinvesting in R&D (Re-NARS) is projected to improve productivity starting in 2025, with better results seen by 2030 and 2045. Under this scenario, the projected yield decline for all cereals by 2025 is only around 2.15%, and recovery is projected by 2030 with an increase of 1.42%, improving further to a 6.77% increase by 2045. For maize, the values are 2.52% lower in 2025, but 1.11% higher in 2030 and 6.60% higher in 2045, and for rice, the recovery rates are similar (2.05% lower in 2025, followed by increases of 1.50% by 2030 and 6.85% by 2045).

The projections under the Re-Hi-NARS scenario are even more impressive, with cereals declining by 1.39% by 2025 relative to HadGEM, before quickly recovering with a projected 4.05% increase by 2030 and 12.38% by 2045 compared with the HadGEM reference. These changes are due mainly to changes in rice yield of –1.30% in 2025, 4.09% in 2030, and 12.39% in 2045, and changes in maize yield of –1.75%, 3.77%, and 12.30% for those years relative to HadGEM.

Similar yield recovery pathways are projected for all other crops under both scenarios, especially for pulses and roots and tubers, which could increase yield by up to 32% and 29%, respectively, by 2045 under Re-Hi-NARS.

For all commodities, subsidy removal with reinvestment in R&D changes the projected trade situation for the better. By 2045, exports are projected to increase by 8.6 million MT for rice, by 10.0 million MT for roots and tubers, and by 279,000 MT for oil crops, while imports decrease by 4.3 million MT for fruits and vegetables and by 2.0 million MT for maize, and increase by only about 11,000 MT for wheat.

Box 3: Fertilizer Subsidy Removal and Reinvestment in Research and Development

Removing the fertilizer subsidy can have the immediate impact of reducing crop yield by 2.45% by 2025 and the reduction can persist beyond 2045. The projected yield reduction is highest for cereals—4.04% for maize and 3.53% for rice.

Subsidy removal without reinvestment worsens the trade situation for all commodities. By 2045, Indonesia would be exporting 2.25 million metric tons (MT) less of rice, while importing 615,000 MT more of maize and about 3,000 MT more of wheat. But the decline in exports and increase in imports also maintain access to food and thus help to keep domestic food prices from going up, consumption from falling off, and food insecurity from intensifying.

Research and development investment has a time lag, such that 5 years after the projected subsidy removal, yield levels will still be lower than the baseline level. But yield can recover in the longer term, with better results seen by 2030 and 2045. Re-NARS is projected to improve productivity starting in 2025. Under this scenario, the projected yield decline for all cereals by 2025 is only around 2.15%, and recovery is projected by 2030 with a yield increase of 1.42%, improving further to a 6.77% increase by 2045 compared with HadGEM. Projected yield changes for cereals under the Re-Hi-NARS scenario are a 1.39% decline by 2025, before a quick recovery with a projected 4.05% increase by 2030 to 12.38% by 2045.

For all commodities, subsidy removal with reinvestment in research and development changes the projected trade situation for the better. By 2045, exports are projected to increase by 8.6 million MT for rice and by 279,000 MT for oil crops, while imports decrease by 2.0 million MT for maize and increase by only about 11,000 MT for wheat.

A dramatic reduction in the number of hungry people by 2045 is foreseen under the reinvestment scenarios, compared with both HadGEM and 2015 hunger levels.

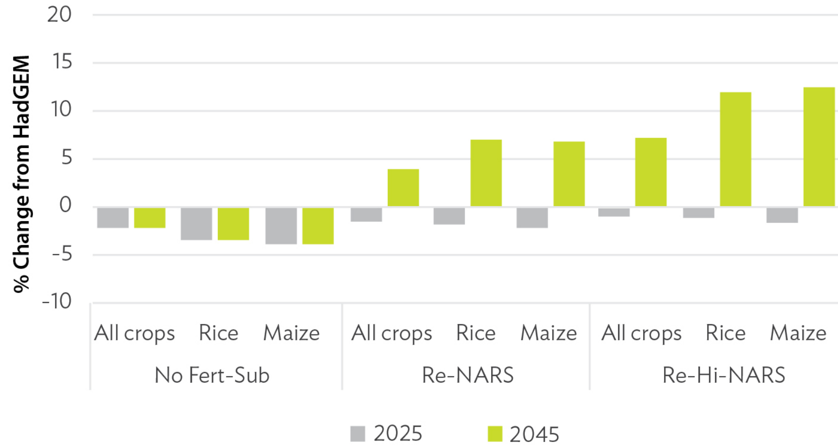
Table 3.14a: Projected Impact of Fertilizer Subsidy Removal and Reinvestment Strategy on Productivity in Indonesia, 2025 and 2045 (% change from HadGEM)

Food Commodity Group	No Fert-Sub			Re-NARS			Re-Hi-NARS		
	2025	2030	2045	2025	2030	2045	2025	2030	2045
Production									
All Crops	(2.50)	(2.50)	(2.52)	(1.67)	0.32	3.66	(1.25)	1.79	6.97
All Cereals	(4.74)	(4.75)	(4.69)	(2.74)	2.12	9.60	(1.73)	5.70	17.44
Maize	(5.68)	(5.76)	(5.73)	(3.50)	1.78	10.17	(2.40)	5.76	19.07
Rice	(4.47)	(4.52)	(4.47)	(2.52)	2.19	9.49	(1.54)	5.69	17.10
Fruits and Vegetables	(3.71)	(3.75)	(3.74)	(2.72)	(0.16)	4.35	(2.21)	1.85	9.45
Oil Crops	(1.62)	(1.64)	(1.73)	(1.13)	0.01	2.51	(0.89)	0.81	4.53
Pulses	(3.79)	(3.82)	(3.79)	0.02	9.50	24.85	1.98	16.77	42.06
Roots and Tubers	(2.94)	(2.97)	(2.94)	0.01	7.36	19.23	1.52	12.92	32.21
Yield									
All Crops	(0.17)	(0.15)	(0.13)	(0.13)	(0.07)	0.03	(0.12)	(0.03)	0.10
All Cereals	(1.15)	(1.19)	(1.20)	(0.61)	0.68	2.66	(0.34)	1.61	4.60
Maize	(1.71)	(1.80)	(1.82)	(1.01)	0.67	3.35	(0.66)	1.91	6.02
Rice	(0.97)	(1.03)	(1.03)	(0.49)	0.69	2.46	(0.25)	1.53	4.20
Fruits and Vegetables	(0.70)	(0.75)	(0.76)	(0.58)	(0.23)	0.46	(0.52)	0.02	1.10
Oil Crops	1.31	1.29	1.20	0.77	(0.53)	(2.02)	0.50	(1.44)	(3.67)
Pulses	(0.59)	(0.63)	(0.64)	0.17	2.00	4.76	0.55	3.32	7.55
Roots and Tubers	(0.23)	(0.26)	(0.27)	0.04	0.71	1.76	0.18	1.18	2.76
Harvested Area									
All Crops	(2.45)	(2.45)	(2.49)	(1.60)	0.44	3.79	(1.17)	1.94	7.20
All Cereals	(3.64)	(3.61)	(3.53)	(2.15)	1.42	6.77	(1.39)	4.02	12.28
Maize	(4.04)	(4.04)	(3.99)	(2.52)	1.11	6.60	(1.75)	3.77	12.30
Rice	(3.53)	(3.53)	(3.48)	(2.05)	1.50	6.85	(1.30)	4.09	12.39
Fruits and Vegetables	(3.03)	(3.03)	(3.00)	(2.15)	0.08	3.87	(1.70)	1.83	8.26
Oil Crops	(2.89)	(2.89)	(2.89)	(1.88)	0.55	4.62	(1.38)	2.29	8.51
Pulses	(3.22)	(3.21)	(3.17)	(0.15)	7.36	19.17	1.42	13.02	32.09
Roots and Tubers	(2.71)	(2.71)	(2.68)	(0.03)	6.61	17.17	1.35	11.60	28.67

HadGEM = Hadley Centre Global Environmental Model (scenario), No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development, ( ) = negative.

Source: IMPACT simulation results.

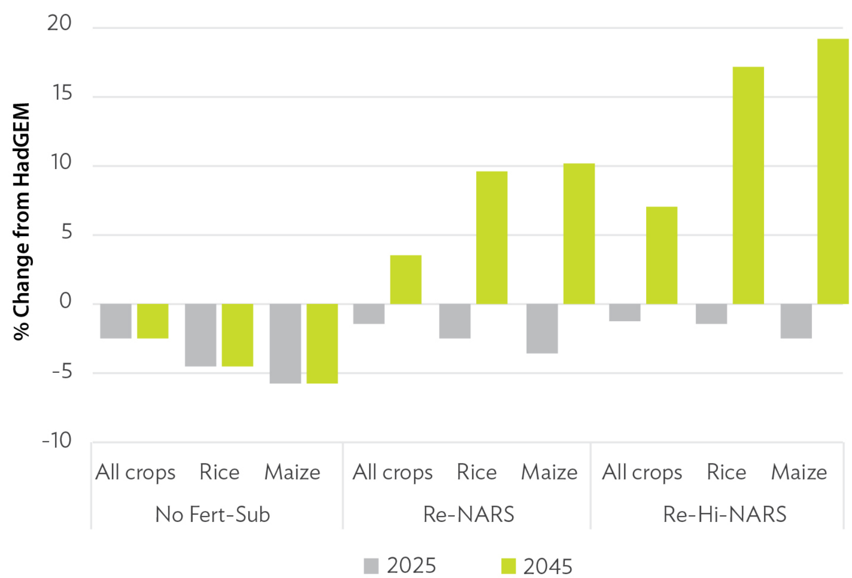
Figure 3.14a: Projected Impact of Fertilizer Policies on Yield, Indonesia, 2025 and 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development.

Source: IMPACT simulation results.

Figure 3.14b: Projected Impact of Fertilizer Policies on Production, Indonesia, 2025 and 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development.

Source: IMPACT simulation results.

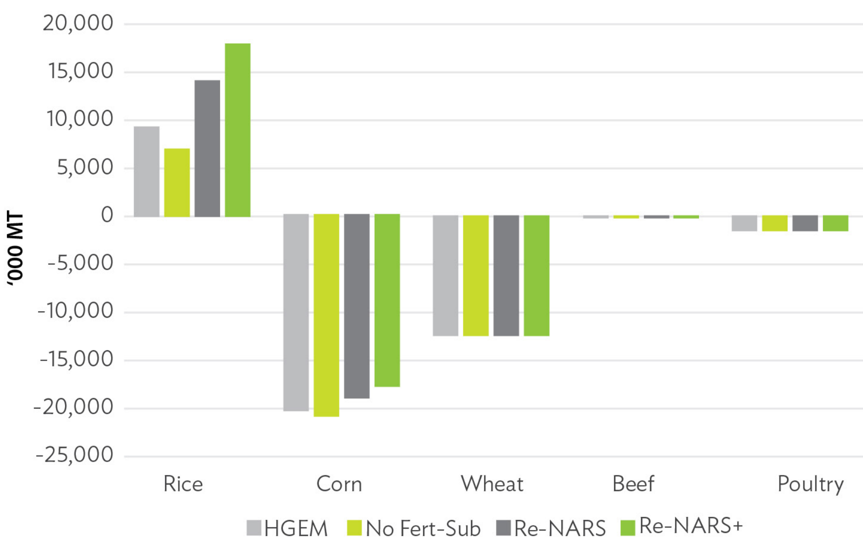
Table 3.14b: Projected Impact of Fertilizer Subsidy Removal and Reinvestment Strategies on Net Trade in Indonesia, 2030 and 2045 ('000 MT)

Food Commodity Group	HadGEM			Efficiency and Competitiveness Investment Scenarios								
				No Fert-Sub			Re-NARS			Re-Hi-NARS		
	2025	2030	2045	2025	2030	2045	2025	2030	2045	2025	2030	2045
All Crops	13,877	12,204	15,967	7,722	5,633	8,526	10,222	14,829	30,661	11,496	19,725	43,276
All Cereals	(15,441)	(21,086)	(23,962)	(18,043)	(23,746)	(26,827)	(16,947)	(19,907)	(18,097)	(16,391)	(17,902)	(13,311)
Maize	(8,445)	(14,902)	(20,480)	(9,165)	(15,523)	(21,095)	(8,889)	(14,715)	(19,398)	(8,749)	(14,289)	(18,449)
Rice	2,073	4,093	9,529	189	2,051	7,275	1,010	5,085	14,317	1,425	6,665	18,159
Wheat	(8,994)	(10,199)	(12,911)	(8,992)	(10,196)	(12,908)	(8,993)	(10,199)	(12,917)	(8,993)	(10,201)	(12,922)
Fruits and Vegetables	(6,152)	(8,002)	(9,818)	(7,433)	(9,417)	(11,563)	(7,097)	(8,082)	(7,836)	(6,923)	(7,334)	(5,481)
Oil Crops	8,609	9,037	9,556	7,988	8,376	8,867	8,052	8,621	9,439	8,085	8,765	9,830
Pulses	(109)	(139)	(197)	(124)	(154)	(213)	(109)	(101)	(92)	(102)	(72)	(19)
Roots and Tubers	470	2,088	2,104	(368)	1,189	1,191	474	4,318	8,076	903	6,003	12,107

HadGEM = Hadley Centre Global Environmental Model (scenario), MT = metric ton, No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development, ( ) = negative, Negative net trade = imports, Positive net trade = exports.

Source: IMPACT simulation res

Figure 3.14c: Projected Impact of Fertilizer Policies on Net Trade, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), MT = metric ton, No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development.

Source: IMPACT simulation results.

Table 3.14c: Projected Impact of Fertilizer Subsidy Removal and Reinvestment Strategies on Per Capita Consumption in Indonesia, 2030 and 2045 (kg per capita per year)

Food Commodity Group	HadGEM				Efficiency and Competitiveness Investment Scenarios								
					No Fert-Sub			Re-NARS			Re-Hi-NARS		
	2015	2025	2030	2045	2025	2030	2045	2025	2030	2045	2025	2030	2045
All Crops	401.3	438.6	461.6	498.5	438.2	461.1	498.0	438.4	461.8	499.5	438.5	462.2	500.3
All Cereals	185.6	191.2	199.1	202.7	191.0	198.9	202.5	191.1	199.2	203.2	191.1	199.4	203.6
Maize	39.4	42.9	48.4	51.3	42.9	48.4	51.3	42.9	48.4	51.4	42.9	48.5	51.4
Rice	114	117.7	116.8	110.3	117.4	116.6	110.1	117.5	116.9	110.8	117.6	117.1	111.1
Wheat	24.6	30.6	33.8	41.0	30.6	33.8	41.0	30.6	33.8	41.1	30.6	33.8	41.1
Fruits and Vegetables	113.8	138.9	151.8	180.1	138.8	151.7	180.0	138.8	151.9	180.4	138.9	152.0	180.6
Oil Crops	16.4	16.7	16.7	15.6	16.6	16.6	15.6	16.6	16.7	15.6	16.7	16.7	15.6
Pulses	1.4	1.6	1.7	1.8	1.6	1.7	1.8	1.6	1.7	1.8	1.6	1.7	1.8
Roots and Tubers	53.1	53.0	51.8	50.6	53.0	51.7	50.6	53.0	51.8	50.8	53.0	51.9	50.9

HadGEM = Hadley Centre Global Environmental Model (scenario), kg = kilogram, No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS+ = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development.

Source: IMPACT simulation results.

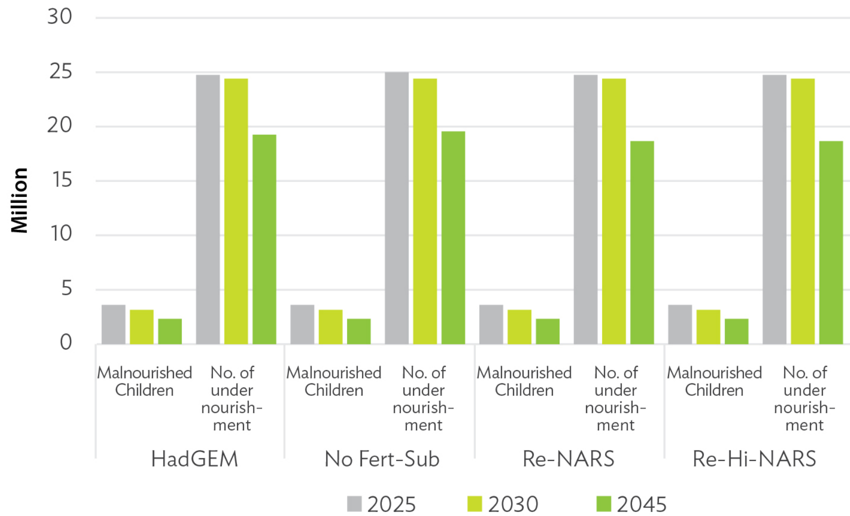
Table 3.14d: Projected Impact of Fertilizer Subsidy Removal and Reinvestment Strategies on Food Nutrition Indicators in Indonesia, 2030 and 2045

Food Security Indicator	HadGEM				No Fert-Sub			Re-NARS			Re-Hi-NARS+		
	2015	2025	2030	2045	2025	2030	2045	2025	2030	2045	2025	2030	2045
Energy consumption (kcal/capita/day)	2,639	2,814	2,940	3,105	2,811	2,937	3,102	2,812	2,942	3,112	2,813	2,944	3,118
Malnourished children (million)	4.64	3.68	3.22	2.33	3.69	3.22	2.33	3.69	3.21	2.32	3.69	3.21	2.31
Number of undernourishment (million)	26.60	24.73	24.36	19.27	24.75	24.42	19.44	24.74	24.33	18.89	24.74	24.28	18.57
Prevalence of undernourishment (% of population)	10.6	9.1	8.8	6.7	9.2	8.8	6.8	9.2	8.8	6.6	9.1	8.8	6.4

HadGEM = Hadley Centre Global Environmental Model (scenario), kcal = kilocalorie, No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS+ = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development.

Source: IMPACT simulation results.

Figure 3.14d: Projected Impact of Fertilizer Policies on Nutrition and Food Security, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS+ = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development.

Source: IMPACT simulation results.

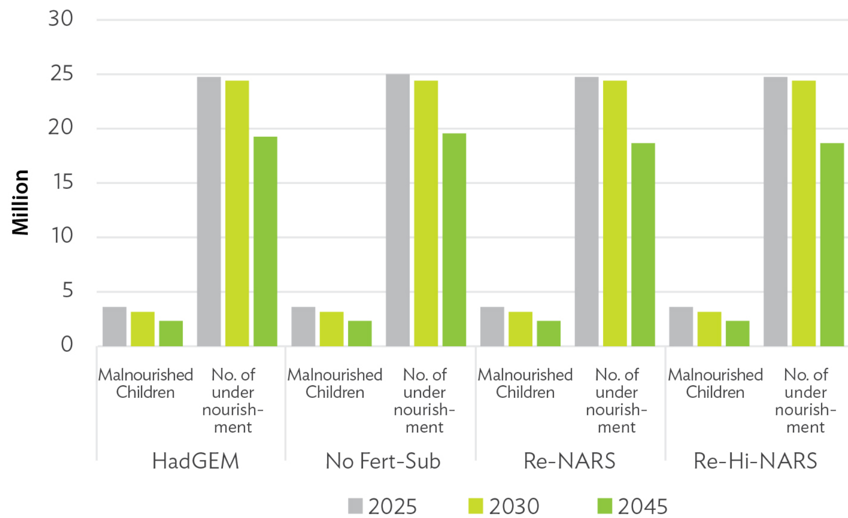
3.3.6 Investment in Agricultural Enterprise Development

Besides investments in agricultural R&D, irrigation, and rural infrastructure, more comprehensive investment combinations that can help strengthen food security in the future are possible. Developing concerted investment programs to make the agriculture sector more competitive and profitable, and to provide employment for the expanding labor force, especially the youth, while at the same time boosting employment opportunities in the industry, might be a better proposition.

Projections foresee a sustained rise in the urban population and a continuing decline in agricultural employment (Figure 3.15), with the labor force aged 15–65 expanding (Figure 3.16) but agriculture offering fewer jobs (Figure 3.17). In 2015–2045, the labor force is expected to grow by 40 million, or by about 1.33 million per year; more than a third of these new entrants will be in the rural areas. Although a country's development goal is for industry and services to absorb any increase in the labor force, in the short term, investment in agriculture can facilitate the absorption of additions to the rural labor force. Over the longer term, there can be a shift in labor force participation from agriculture to industry and services, including the agribusiness and processing sectors.

The foregoing investment opportunities in agricultural R&D, irrigation, and rural infrastructure for lower PHL and marketing costs, and the possibility of reducing the fertilizer subsidy or eliminating it outright and reinvesting the amount saved in R&D, can be combined with other investment programs and policies to create a positive enabling environment for a competitive and profitable agriculture sector. Such a financially viable sector can lead not only to a food-secure future but also to the development of a strong farm-based industry.

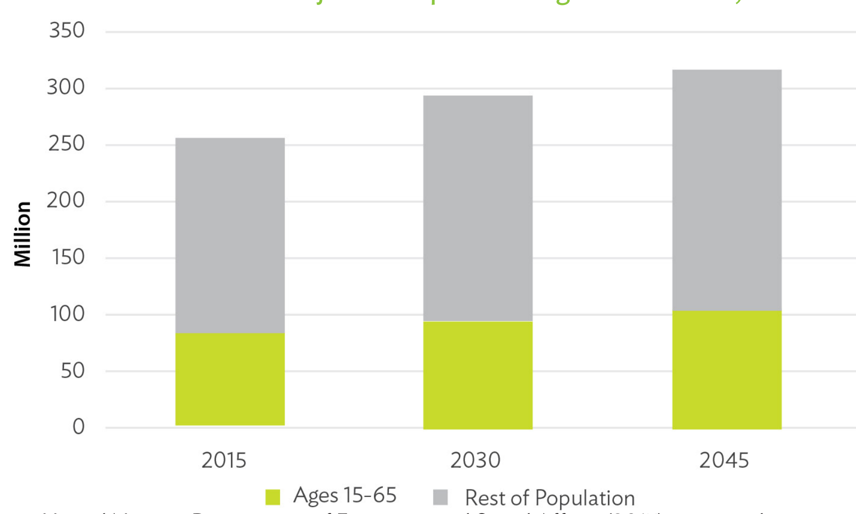
Figure 3.15: Historical and Projected Rural–Urban Population, Indonesia, 2050



HadGEM = Hadley Centre Global Environmental Model (scenario), No Fert-Sub = efficiency and competitiveness investment scenario involving gradual fertilizer subsidy removal without accompanying reinvestment in R&D, Re-NARS = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in the national agricultural research system, Re-Hi-NARS+ = efficiency and competitiveness investment scenario involving reinvestment of the amount of the removed subsidy in highly efficient and high-investment research and development.

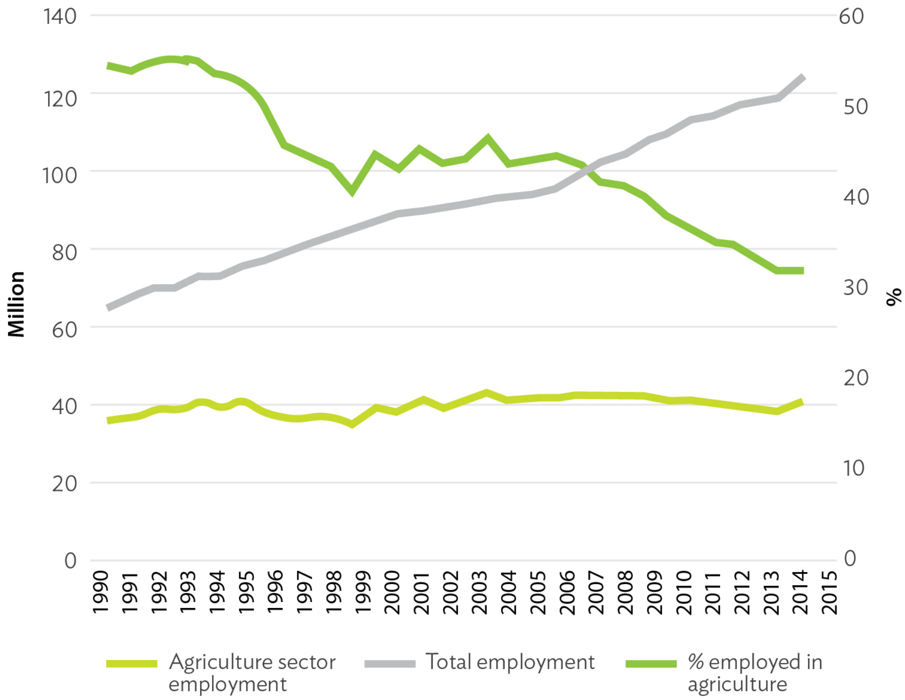
Source: United Nations Department of Economic and Social Affairs (2017), custom data acquired via website.

Figure 3.16: Historical and Projected Population Age Distribution, Indonesia, 2050



Source: United Nations Department of Economic and Social Affairs (2017), custom data acquired via website.

Figure 3.17: Trends in Agricultural Employment, Indonesia, 2050



Source: BPS, *Statistical Yearbook of Indonesia* (various years).

The following investment possibilities support the program approach to investment in food security. The synergies generated by their adoption in concerted investment programs are identified, simulated, and analyzed in this section, which explores different types of rural enterprise development scenarios.

In addition to the investments described above, investments and policies that support rural enterprise development are the following:

- **Opening new land for agriculture (LandExp).** This program has already been started by the government and can be combined with other investments like irrigation expansion and R&D support. In this investment scenario, idle public lands are converted to rainfed agriculture, increasing the total rainfed cropland area by 15% over the next 30 years. This expansion is over and above the market-induced expansion initiated by the farmers themselves to capitalize on improving market trends. The latter is endogenous to the model simulation, while the former is an exogenous policy option added to the simulation.

- **Promoting SMEs in the livestock sector (LiveStock).** This is equivalent to opening new land for the livestock sector, to increase livestock herd size and livestock farms by 10% over the next 15 years. This program complements R&D in livestock and postharvest facilities for livestock. But it also includes providing entrepreneurial training to livestock farmers and minimizing the bureaucracy, regulation, and transaction costs associated with establishing new and smaller livestock and poultry farms, thus removing the existing bias toward bigger corporate and commercial livestock firms and facilities.

- **Providing policy support for the growth of small to medium farms.** This whole support package to promote farm enterprises may include (i) clear and enforceable land and water rights; (ii) minimized government control and regulations to allow the market to work; and (iii) government assistance provided to address market failures, including monopoly and barriers to market entry. These policy measures were not simulated in the study but are necessary conditions for achieving the food security goals implicit in each policy scenario and concerted investment program.

These scenarios can be combined with previously discussed investments in R&D, irrigation, rural infrastructure, and removal of fertilizer subsidy, to create the environment needed for the following investment programs or development strategies to progress toward the achievement of the country's food security objectives:

Investment Programs for Enterprise Development: Crop-Farm or Livestock-Farm Enterprises

Investment programs under this category are for crop-based or livestock-based farm enterprises. Though applicable nationwide, these programs give priority to provinces and districts with proven comparative advantage in crop production systems (for crop-farm enterprise development) or in livestock production systems (for livestock-farm enterprise development).

- Crop-Farm Enterprise Program (Crop-Farm). This is a program of concerted investment scenarios promoting the development of crop-based farm enterprises. It is focused on, but not limited to, crop-farming systems and postharvest processing. This farm enterprise program assigns top priority to the establishment of crop-based production systems around the country, before any vertical integration with the livestock sector is undertaken, with efficient resource allocation as guiding principle.

  In terms of geographic targets for implementation, provinces and districts with existing comparative advantage in crop production are given priority.

  Individual investment opportunities in this program are as follows:

  - LandExp. Opening new land for agriculture. Under this program, idle public lands are converted to rainfed agriculture, increasing the total rainfed cropland area by 15% over the next 30 years.

  - IRREXP+_WUE. Expanding the irrigated area by 20%, modernizing irrigation systems, and improving the efficiency of water use.

- NARS-Crop. Carrying out NARS R&D work complementing R&D by the IARCs, and boosting the extension of technologies to farmers and the rate of technology adoption by farmers. This program is focused solely on crops.

- PHL/Mktg. Investing in rural infrastructure—postharvest, storage, processing, and marketing facilities—and thus reducing postharvest losses and marketing costs by 50% over 15 years.

- No Fert-Sub. Gradually removing the fertilizer subsidy over 3 years, without reinvesting the funds saved in R&D.

- Livestock-Farm Enterprise (Lives-Farm). This program takes an opposite approach to farm-based enterprise development. It is focused on, but not limited to, livestock farming systems and postharvest processing activities for livestock commodities. The program gives top priority to establishing livestock-based production systems around the country, ahead of vertical integration with the crop sector.

  Priority areas for implementation are provinces and districts with existing comparative advantage in livestock production.

  Individual investment opportunities in this program are as follows:

  - LiveStock. Promoting the development of SMEs in the livestock sector, and thus increasing the number of livestock farms by 10% over the next 15 years.

  - NARS-Lives. Undertaking NARS R&D work that complements the IARCs' R&D, and boosting the extension of technologies to farmers and the rate of technology adoption by farmers. This program is focused solely on livestock.

  - PHL/Mktg. Investing in rural infrastructure and reducing postharvest losses and marketing costs by 50% over 15 years.

  - No Fert-Sub. Gradually removing the fertilizer subsidy over 3 years, without reinvesting the funds saved in R&D.

Results of Simulations: Crop-Farm and Livestock-Farm Enterprises

Tables 3.15a–3.15d and Figures 3.18a–3.18d present the results of the simulation for crop-farm and livestock-farm enterprise development. Some show the results for either crops or livestock, highlighting the investment strategy of focusing on one type of farm. Yield, area, and production are all projected to increase substantially by 2030 and 2045.

For crop-farm enterprises, the projected increase in production by 2045 is highest for root crops and tubers (26.27%), followed by rice (21.80%) and pulses (21.07%). A production increase of 7.41% is projected for all crops. For livestock-farm enterprises, average meat production is projected to increase by 15% by 2045. The projected increase is highest for beef (16.48%), followed by poultry (15.84%) and lamb/goat (14.56%). Dairy production is set to have the lowest production increase, at 7.07%, compared with HadGEM values.

Yield increases are generally projected to be higher for livestock commodities than for their cereal counterparts. Meat yield increase is within the 10%–11% range, compared with 8.2% for cereals. The highest yield increases, however, are projected for roots and tubers (21.11%) and pulses (19.20%).

Net trade projections are all positive for both programs, except for wheat, with imports continuing to increase by 1.88 million MT by 2045, and for dairy products, with a 61,000 MT increase in imports. Rice exports are projected to increase by 9.9 million MT, oil crops by 2.4 million MT, and root crops by 5.7 million MT, while imports of maize are seen to decline by 6.6 million MT, fruits and vegetables by 4.5 million MT, and pulses by 13,000 MT. On the other hand, imports of poultry meat are projected to decline by 557,000 MT by 2045, beef by 152,000 MT, and lamb/goat meat by 16,000 MT.

Consumption and food security indicators are likewise projected to improve under both farm enterprise development scenarios. Consumption is foreseen to increase by 8.75% for crop commodities as a whole, by 13.02% for cereals, by 16.67% for pulses, and by 7.11% for roots and tubers. On the livestock enterprise side, an increase in consumption is projected for meat products in general (by 1.11%), beef (by 2.27%), lamb/goat meat (by 7.14%), and dairy (by 4.26%).

By combining the key investments in agricultural R&D, irrigation and water-use efficiency, and rural infrastructure to reduce PHL and marketing costs with targeted crop or livestock programs, these farm enterprise scenarios can have a strongly beneficial impact on food security. The crop-farm enterprise scenario is seen to have the biggest impact, nearly eliminating hunger by 2045. Crop-farm enterprises are projected to increase average calorie consumption to 3,340 kcal per capita per day by 2045, compared with 3,256 kcal per capita per day for livestock-farm enterprises. The crop-farm scenario is also projected to result in fewer malnourished children (2.0 million vs. 2.15 million) and fewer people at risk of hunger (1.14 million, equivalent to 0.4% of the population, vs. 8.87 million, or 3.1%).

Table 3.15a: Projected Impact of Crop and Livestock Enterprise Development on Productivity in Indonesia, 2030 and 2045

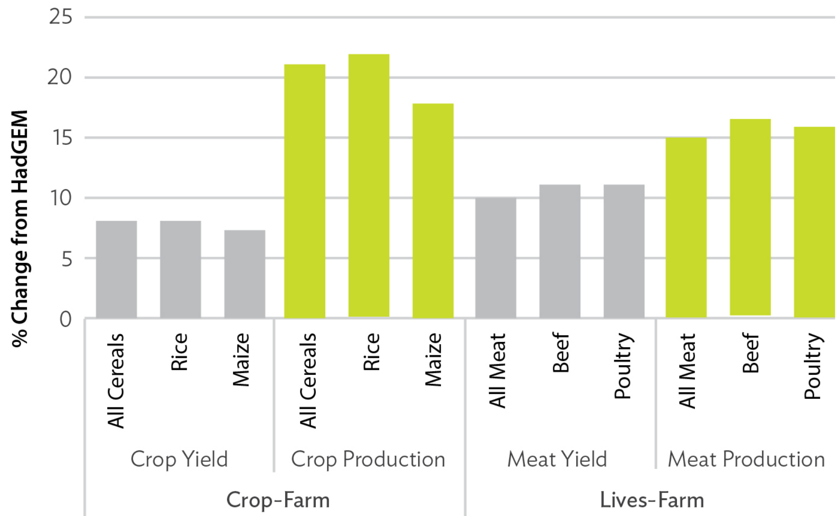
Food Security Indicator	Enterprise Development			
	Crop-Farm		Lives-Farm	
	2030	2045	2030	2045
Production				
All Cereals	14.70	21.14		
Maize	21.88	17.95		
Rice	13.04	21.80		
Fruits and Vegetables	10.01	17.19		

Food Security Indicator	Enterprise Development			
	Crop-Farm		Lives-Farm	
	2030	2045	2030	2045
Roots and Tubers	10.61	26.27		
All Meat Products			10.49	15.08
Beef			10.33	16.49
Lamb/Goat			9.79	14.56
Poultry			10.91	15.84
Dairy			6.77	7.07
Harvested Area (Cereals)/Number of head (Livestock)				
All Cereals	10.98	11.94		
Maize	17.34	9.81		
Rice	9.27	12.54		
Fruits and Vegetables	8.38	12.85		
Oil Crops	(0.38)	(1.29)		
Pulses	0.24	1.57		
Roots and Tubers	2.06	4.26		
All Meat Products			5.34	4.50
Beef			4.72	4.95
Lamb/Goat			4.22	3.22
Poultry			5.33	4.46
Dairy			1.32	(3.58)
Yield				
All Cereals	3.35	8.21		
Maize	3.87	7.41		
Rice	3.45	8.22		
Fruits and Vegetables	1.51	3.85		
Oil Crops	1.11	3.51		
Pulses	8.39	19.20		
Roots and Tubers	8.38	21.11		
All Meat Products			4.88	10.13
Beef			5.35	11.00
Lamb/Goat			5.35	10.99
Poultry			5.30	10.89
Dairy			5.37	11.04

Crop-Farm = concerted investment scenario promoting crop-based farm enterprise development, HadGEM = Hadley Centre Global Environmental Model (scenario), Lives-Farm = concerted investment scenario promoting livestock-based farm enterprise development. ( ) = negative.

Source: IMPACT simulation results.

Figure 3.18a: Projected Yield and Production of Selected Food Commodities, Indonesia, 2045



Crop-Farm = concerted investment scenario promoting crop-based farm enterprise development, HadGEM = Hadley Centre Global Environmental Model (scenario), Lives-Farm = concerted investment scenario promoting livestock-based farm enterprise development.

Source: IMPACT simulation results.

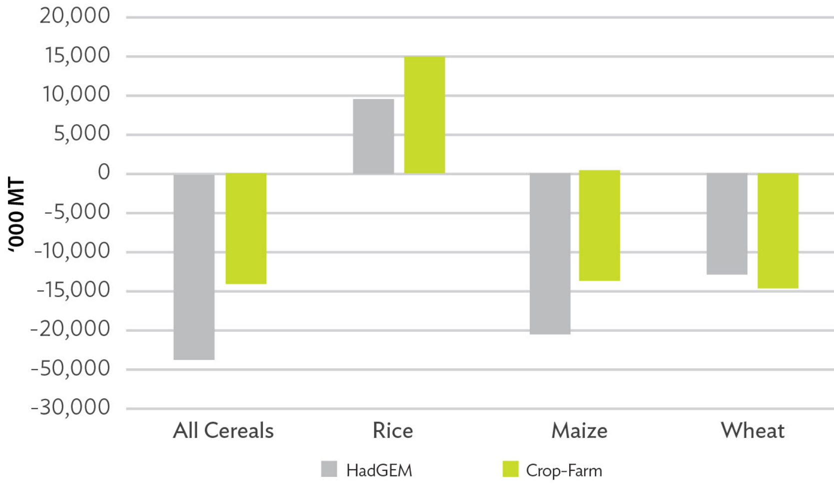
Table 3.15b: Projected Impact of Crop and Livestock Enterprise Development on Net Trade in Indonesia, 2030 and 2045 ('000 MT)

Food Commodity Group	HadGEM		Enterprise Development			
			Crop-Farm		Lives-Farm	
	2030	2045	2030	2045	2030	2045
All Cereals	(21,086)	(23,962)	(18,062)	(13,987)		
Maize	(14,902)	(20,480)	(13,911)	(13,819)		
Rice	4,093	9,529	6,884	14,759		
Wheat	(10,199)	(12,911)	(10,955)	(14,799)		
Fruits and Vegetables	(8,002)	(9,818)	(5,630)	(5,315)		
Oil Crops	9,037	9,556	9,889	11,991		
Pulses	(139)	(197)	(135)	(184)		
Roots and Tubers	2,088	2,104	4,107	7,881		
All Meat Products	(1,085)	(965)			(586)	(30)
Beef	(314)	(195)			(229)	(43)
Lamb/Goat	(55)	(105)			(40)	(89)
Poultry	(1,222)	(1,611)			(941)	(1,054)
Dairy	(2,142)	(2,372)			(2,113)	(2,433)

Crop-Farm = concerted investment scenario promoting crop-based farm enterprise development, HadGEM = Hadley Centre Global Environmental Model (scenario), Lives-Farm = concerted investment scenario promoting livestock-based farm enterprise development, MT = metric ton, ( ) = negative, Negative net trade = imports, Positive net trade = exports.

Source: IMPACT simulation results.

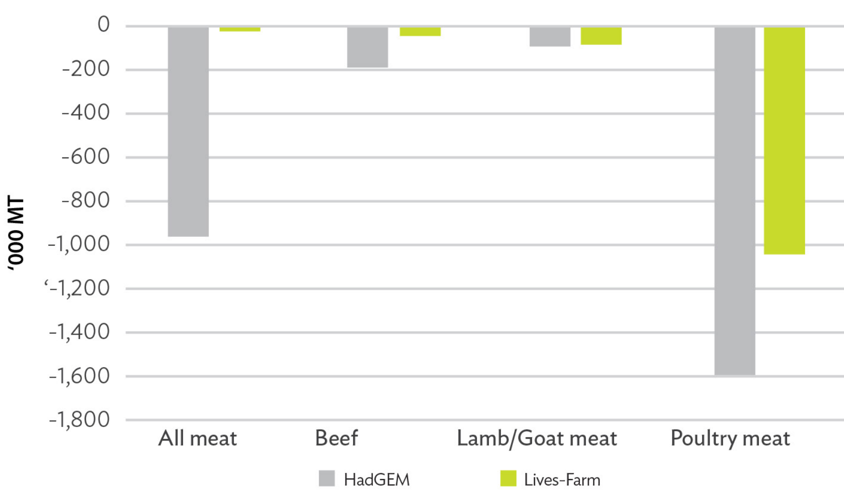
Figure 3.18b: Projected Impact of Crop-Farm Enterprise Development on Net Trade Volumes of Selected Food Commodities, Indonesia, 2045



Crop-Farm = concerted investment scenario promoting crop-based farm enterprise development, HadGEM = Hadley Centre Global Environmental Model (scenario), MT = metric ton.

Source: IMPACT simulation results.

Figure 3.18c: Projected Impact of Livestock-Farm Enterprise Development on Net Trade Volumes of Selected Food Commodities, Indonesia, 2045



HadGEM = Hadley Centre Global Environmental Model (scenario), Lives-Farm = concerted investment scenario promoting livestock-based farm enterprise development, MT = metric ton.

Source: IMPACT simulation results.

Table 3.15c: Projected Impact of Crop-Farm and Livestock-Farm Enterprise Development on Per Capita Consumption in Indonesia, 2030 and 2045
(kg per capita per year)

Food Commodity Group		HadGEM		Crop-Farm		Lives-Farm	
	2015	2030	2045	2030	2045	2030	2045
All Crops	401.3	461.6	498.5	481.7	542.1		
All Cereals	185.6	199.1	202.7	211.2	229.1		
Maize	39.4	48.4	51.3	49.8	58.4		
Rice	114	116.8	110.3	125.0	123.6		
Wheat	24.6	33.8	41.0	36.4	47.1		
Fruits and Vegetables	113.8	151.8	180.1	156.6	191.5		
Oil Crops	16.4	16.7	15.6	17.3	16.7		
Pulses	1.4	1.7	1.8	1.8	2.1		
Roots and Tubers	53.1	51.8	50.6	53.9	54.2		
All Meat Products	14.3	22.3	27.0			22.4	27.3
Beef	2.8	4.1	4.4			4.1	4.5
Lamb/Goat	0.7	1.1	1.4			1.1	1.5
Poultry	8.3	14.6	18.8			14.7	19.0
Dairy	10.9	12.8	14.1			13.1	14.7

Crop-Farm = concerted investment scenario promoting crop-based farm enterprise development, HadGEM = Hadley Centre Global Environmental Model (scenario), kg = kilogram, Lives-Farm = concerted investment scenario promoting livestock-based farm enterprise development.

Source: IMPACT simulation results.

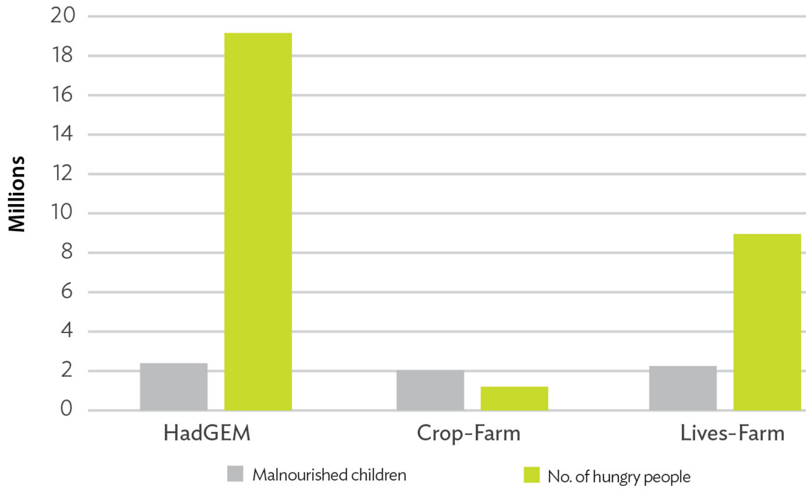
Table 3.15d: Projected Impact of Crop-Farm and Livestock-Farm Enterprise Development on Nutrition Indicators for Indonesia, 2030 and 2045

Food Security Indicator		HadGEM		Crop-Farm		Lives-Farm	
	2015	2030	2045	2030	2045	2030	2045
Consumption (kcal/capita/day)	2,639	2,940	3,105	3,076	3,340	3,004	3,256
Malnourished children (million)	4.64	3.22	2.33	3.02	2.00	3.12	2.15
Number of undernourishment (million)	26.60	24.36	19.27	19.97	1.14	22.75	8.87
Prevalence of undernourishment (% of population)	10.6	8.8	6.7	7.2	0.4	8.2	3.1

Crop-Farm = concerted investment scenario promoting crop-based farm enterprise development, HadGEM = Hadley Centre Global Environmental Model (scenario), kcal = kilocalorie, Lives-Farm = concerted investment scenario promoting livestock-based farm enterprise development.

Source: IMPACT simulation results.

Figure 3.18d: Projected Impact of Crop-Farm and Livestock-Farm Enterprise Development on Nutrition and Food Security, Indonesia, 2045



Crop-Farm = concerted investment scenario promoting crop-based farm enterprise development, HadGEM = Hadley Centre Global Environmental Model (scenario), Lives-Farm = concerted investment scenario promoting livestock-based farm enterprise development.

Source: IMPACT simulation results.

Investment Programs for Enterprise Development: Crop–Livestock Farm Enterprises

Investment programs under this category are for both crop- and livestock-based farm enterprises. Application is also nationwide, with priority assigned to provinces and districts with proven comparative advantage in both crop and livestock production systems, whether on integrated crop–livestock farms or on separate farms within the same province or district.

The major difference between this program category and the Crop-Farm or Livestock-Farm Enterprise Development Program is the balance between crop and livestock enterprises in this program category. The strategy is to have simultaneous and balanced development focus on crop and livestock enterprises, not necessarily on the same farm, but within the same province or district.

This category has two subcategories, differentiated according to the level of intensity of development: a balanced crop–livestock enterprise development program and a more intensive crop–livestock enterprise development program.

- Balanced Crop–Livestock Enterprise (Bal-Crop-Lives). This is a balanced, less investment-intensive crop and livestock farm enterprise development program (NARS instead of Hi-NARS, and IRREXP_WUE instead of IRREXP+_WUE), which comprises the following individual investments:

- NARS. Carrying out NARS R&D work that complements the IARCs' R&D and boosts the extension of technologies to farmers and the rate of adoption by farmers. For this program, the focus is on both crops and livestock.

- IRREXP_WUE. Expanding the irrigated area by 10%, and making corresponding investments in systems modernization and water-use efficiency improvements.

- LandExp. Opening new land for agriculture, resulting in a 15% increase in rainfed area over the next 30 years.

- LiveStock. Promoting the development of SMEs in the livestock sector, thus increasing the number of livestock farms by 10% over the next 15 years.

- No Fert-Sub. Removing the fertilizer subsidy over 3 years, without reinvesting the funds saved in R&D.

- Intensive Crop–Livestock Enterprise (Int-Crop-Lives). This investment program promotes the development of semicommercial and commercial crop and livestock farms around the country. It is more intensive than the Balanced Crop-Livestock Enterprise (Bal-Crop-Lives) program above, in terms of R&D (Hi-NARS instead of NARS) and irrigation (IRREXP+_WUE instead of IRREXP_WUE), and comprises the following individual investments:

    - Hi-NARS. Undertaking high-investment and highly efficient NARS R&D in both crops and livestock.

    - IRREXP+_WUE. Expanding the irrigated area by 20%, and making corresponding investments in systems modernization and water-use efficiency improvements.

    - LandExp. Opening new land for agriculture, resulting in a 15% increase in rainfed area over the next 30 years.

    - LiveStock. Promoting the development of SMEs in the livestock sector, thus increasing the number of livestock farms by 10% over the next 15 years.

    - PHL/Mktg. Investing in rural infrastructure—postharvest, storage, processing, and marketing facilities—and thus reducing postharvest losses and marketing costs by 50% over the next 15 years.

    - No Fert-Sub. Removing the fertilizer subsidy over in 3 years, without reinvesting the funds saved in R&D.

Results of Simulations: Crop–Livestock Farm Enterprises

Tables 3.16a–3.16d and Figures 3.19a–3.19d show the results of the simulation of the two crop–livestock enterprise scenarios. Since these scenarios are focused on both crops and livestock, results were derived and are presented here for both.

Convergence in livestock productivity. These two crop–livestock scenarios differ mainly in R&D and irrigation expansion intensity. For the livestock portion of the crop–livestock enterprise, the rate of irrigation expansion has minor indirect impact on production through the effects on the prices of feed ingredients such as maize and soybeans. For R&D, the higher-intensity scenario results in higher growth in yield through 2030, with a tendency to converge toward similar values by 2045.

This productivity convergence is presented for livestock yield in Table 3.15a and Figure 3.18a. For 2030, changes in livestock yield values relative to HadGEM are higher for Int-Crop-Lives than for Bal-Crop-Lives: 11.88% vs. 7.01% for beef, 11.87% vs. 7.00% for lamb/goat meat, 11.76% vs. 6.94% for poultry meat, and 11.93% vs. 7.03% for dairy products. For 2045, very similar values are projected: increases of 14.2%–14.6% relative to the HadGEM scenario across the livestock products and scenarios. Production growth follows similar convergence patterns (Table 3.16a).

Divergence in crop productivity. Higher crop yield is projected for Int-Crop-Lives by 2030 because of more intensive R&D and irrigation expansion, and by 2045 mainly because of the higher rate of irrigation expansion after 2030. In 2045, yield gains are projected to be highest for roots and tubers (22.25%) and pulses (20.67%), followed by maize (10.62%), rice (8.60%), fruits and vegetables (4.41%), and oil crops (4.33%). With accelerated irrigation expansion, production values for Int-Crop-Lives are projected to be even higher by 2045 compared with HadGEM: 36.71% for maize, 27.42% for roots and tubers, 22.35% for pulses, and 19.87% for rice.

Net trade positions are projected to improve under the two crop–livestock scenarios, except for wheat and dairy products. A continued increase in demand for wheat and dairy imports, due to the minimal increase in domestic production and the demand-boosting increase in household incomes, is foreseen. Improvements are projected to be higher for Int-Crop-Lives enterprises, with total crop exports increasing by 24.3 million MT by 2045, rice exports by 4.4 million MT, oil crop exports by 2.2 million MT, and root and tuber exports by 6.5 million MT. Imports, on the other hand, are projected to decline by 9.9 million MT for maize, by 4.6 million MT for fruits and vegetables, and by 26,000 MT for pulses. Meat imports are expected to decline by 871,000 MT by 2045.

Better consumption and food security indicators are likewise projected under both crop–livestock enterprise scenarios. By 2045, under the Int-Crop-Lives scenario, consumption of crop commodities is projected to increase by 7.22%. Consumption figures are foreseen to increase by 10.56% for cereals, by 11.11% for pulses, and by 5.93% for roots and tubers. For meat products, a 1.48% increase in total consumption is projected, including a 2.27% increase for beef, 7.14% for lamb/goat meat, and 5.67% for dairy products.

Int-Crop-Lives farm enterprises are foreseen to increase calorie consumption slightly more—to 3,342 kcal per capita per day, compared with 3,337 kcal per capita per day for Bal-Crop-Lives farm enterprises. The Int-Crop-Lives farm enterprise scenario is also projected to reduce the number of malnourished children (to 2.05 million), and to be more effective than Bal-Crop-Lives enterprises in reducing the number of people at risk of hunger (to 0.9 million, or 0.3% of the population, for Int-Crop-Lives vs. 1.44 million, or 0.5%, for Bal-Crop-Lives).

Table 3.16a: Projected Impact of Crop–Livestock Farm Enterprises on Productivity in Indonesia, 2030 and 2045 (% change from HadGEM)

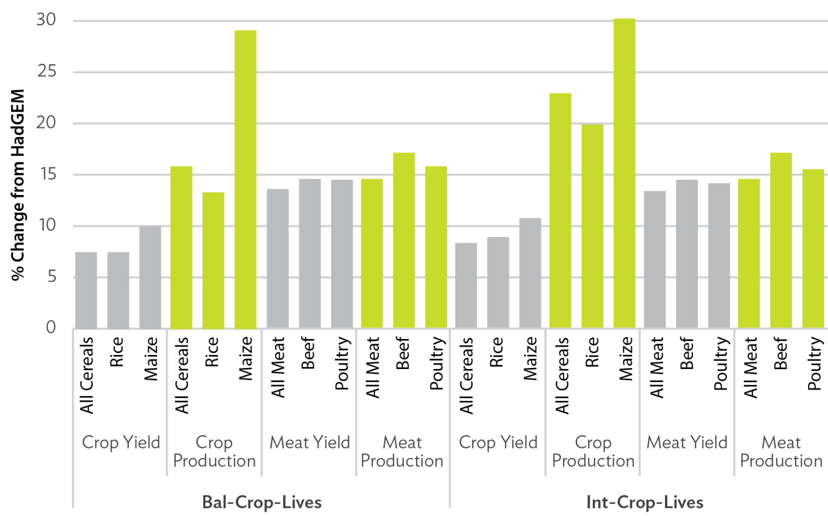
Food Commodity Group	Enterprise Development			
	Bal-Crop-Lives		Int-Crop-Lives	
	2030	2045	2030	2045
Production				
All Cereals	8.36	15.78	18.62	22.76
Maize	15.20	28.79	26.91	36.71
Rice	6.78	13.08	16.71	19.87
Fruits and Vegetables	6.78	13.06	12.55	16.40
Oil Crops	(1.08)	0.15	0.40	1.86
Pulses	7.81	20.46	15.45	22.35
Roots and Tubers	10.82	26.19	20.60	27.42
All Meat Products	10.24	14.61	10.36	14.59
Beef	10.94	17.18	12.08	17.17
Lamb/Goat	9.76	14.37	10.20	14.37
Poultry	10.68	15.50	11.25	15.42
Dairy	7.42	7.47	8.14	7.46
Harvested Area/Number				
All Cereals	5.59	7.98	10.75	13.27
Maize	11.35	17.34	17.79	23.59
Rice	4.05	5.35	8.87	10.38
Fruits and Vegetables	5.57	8.95	8.97	11.48
Oil Crops	(2.02)	(3.34)	(3.06)	(2.37)
Pulses	(0.48)	0.49	(0.35)	1.40
Roots and Tubers	1.76	3.43	3.04	4.23
All Meat Products	3.53	1.04	(0.42)	1.16
Beef	3.68	2.32	0.17	2.51
Lamb/Goat	2.58	(0.11)	(1.49)	0.07
Poultry	3.50	0.99	(0.46)	1.10
Dairy	0.37	(6.20)	(3.39)	(6.04)
Yield				
All Cereals	2.62	7.22	7.11	8.37
Maize	3.46	9.75	7.74	10.62
Rice	2.62	7.34	7.21	8.60
Fruits and Vegetables	1.14	3.77	3.28	4.41
Oil Crops	0.95	3.61	3.57	4.33
Pulses	8.33	19.87	15.85	20.67
Roots and Tubers	8.90	22.00	17.05	22.25

Food Commodity Group	Enterprise Development			
	Bal-Crop-Lives		Int-Crop-Lives	
	2030	2045	2030	2045
Lamb/Goat	7.00	14.50	11.87	14.29
Poultry	6.94	14.38	11.76	14.16
Dairy	7.03	14.58	11.93	14.37

Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock.

Source: IMPACT simulation results.

Figure 3.19a: Projected Impact of Crop–Livestock Farm Enterprises on Productivity in Indonesia, 2045



Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock.

Source: IMPACT simulation results.

Table 3.16b: Projected Impact of Crop–Livestock Farm Enterprises on Net Trade in Indonesia, 2030 and 2045 ('000 MT)

Food Commodity Group	HadGEM		Enterprise Development			
			Bal-Crop-Lives		Int-Crop-Lives	
	2030	2045	2030	2045	2030	2045
All Crops	12,204	15,967	13,483	31,704	27,206	40,219
All Cereals	(21,086)	(23,962)	(22,135)	(16,389)	(13,484)	(11,870)
Maize	(14,902)	(20,480)	(15,077)	(11,903)	(9,186)	(10,916)
Rice	4,093	9,529	4,001	10,464	7,200	13,965
Wheat	(10,199)	(12,911)	(10,977)	(14,810)	(11,398)	(14,780)
Fruits and Vegetables	(8,002)	(9,818)	(6,840)	(6,808)	(5,395)	(5,180)

Food Commodity Group	HadGEM		Enterprise Development			
			Bal-Crop-Lives		Int-Crop-Lives	
	2030	2045	2030	2045	2030	2045
Roots and Tubers	2,088	2,104	4,386	8,204	6,660	8,615
All Meat Products	(3,577)	(4,394)	(3,695)	(4,452)	(3,548)	(4,289)
Beef	(1,085)	(965)	(617)	(93)	(637)	(94)
Lamb/Goat	(314)	(195)	(223)	(44)	(214)	(44)
Poultry	(55)	(105)	(43)	(97)	(50)	(97)
Dairy	(1,222)	(1,611)	(964)	(1,084)	(968)	(1,087)

Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock; MT = metric ton.

Source: IMPACT simulation results.

Table 3.16c: Projected Impact of Crop–Livestock Farm Enterprises on Per Capita Consumption in Indonesia, 2030 and 2045 (kg per capita per year)

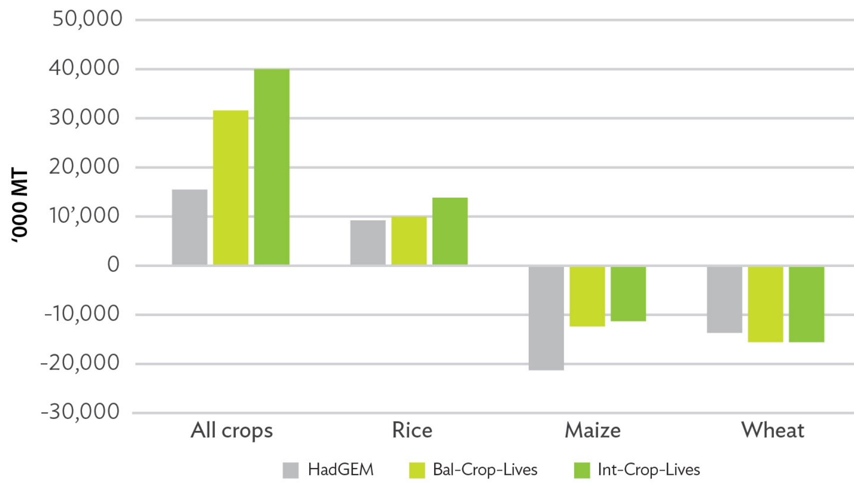
Food Commodity Group		HadGEM		Enterprise Development			
				Bal-Crop-Lives		Int-Crop-Lives	
	2015	2030	2045	2030	2045	2030	2045
All Crops	401.3	461.6	498.5	480.8	534.7	490.9	534.5
All Cereals	185.6	199.1	202.7	210.9	224.2	217.0	224.1
Maize	39.4	48.4	51.3	49.9	54.4	51.0	54.2
Rice	114	116.8	110.3	124.6	122.7	128.1	122.8
Wheat	24.6	33.8	41.0	36.4	47.1	37.8	47.0
Fruits and Vegetables	113.8	151.8	180.1	156.5	190.0	159.0	189.9
Oil Crops	16.4	16.7	15.6	17.2	16.6	17.6	16.6
Pulses	1.4	1.7	1.8	1.7	2.1	1.8	2.0
Roots and Tubers	53.1	51.8	50.6	53.6	53.7	54.5	53.6
All Meat Products	14.3	22.3	27.0	22.4	27.4	22.5	27.4
Beef	2.8	4.1	4.4	4.1	4.5	4.1	4.5
Lamb/Goat	0.7	1.1	1.4	1.1	1.5	1.1	1.5
Poultry	8.3	14.6	18.8	14.7	19.0	14.8	19.0
Dairy	10.9	12.8	14.1	13.2	14.9	13.4	14.9

Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock; kg = kilogram.

Source: IMPACT simulation results.

This chapter has shown that there are investment opportunities that can significantly improve the performance of the agriculture sector and increase food security. Investment in agricultural R&D is particularly effective in boosting productivity and improving food security, and reductions in postharvest losses and marketing costs also substantially improve food security. Removing the fertilizer subsidy and investing the fiscal savings in research would have large benefits. To further enhance the sustainability and profitability of the food system, a set of complementary investments can also be combined into a more comprehensive portfolio; the development of rural enterprises is one such investment portfolio that can be considered. The broader economic impact of these scenarios is explored in the next chapter.

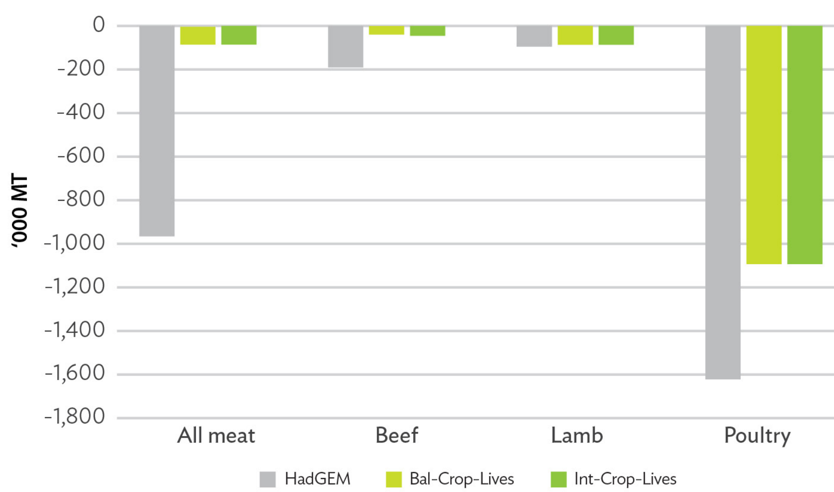
Figure 3.19b: Projected Impact of Crop–Livestock Farm Enterprises on Net Trade, Indonesia, 2045



Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock; MT = metric ton.

Source: IMPACT simulation results.

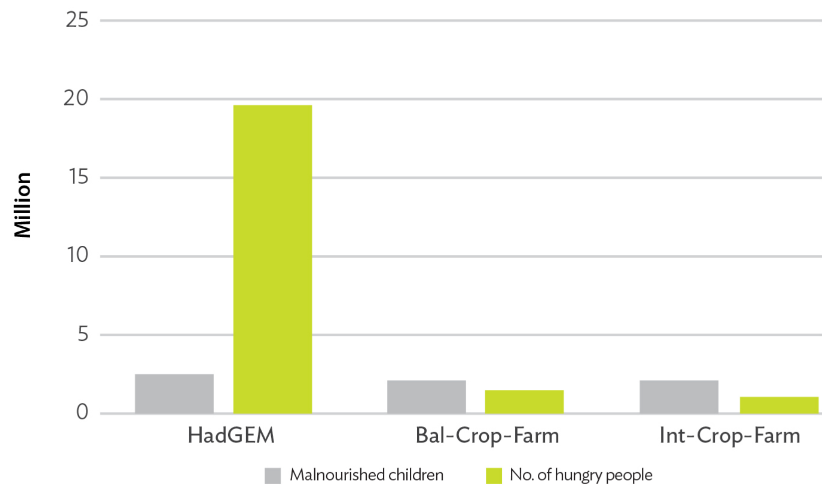
Figure 3.19c: Projected Impact of Crop–Livestock Farm Enterprises on Net Trade, Indonesia, 2045



Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock; MT = metric ton.

Source: IMPACT simulation results.

Figure 3.19d: Projected Impact of Crop–Livestock Farm Enterprises on Nutrition and Food Security, Indonesia, 2045



Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock.

Source: IMPACT simulation results.

Table 3.16d: Projected Impact of Crop–Livestock Farm Enterprises on Food Security Indicators for Indonesia, 2030 and 2045

Food Security Indicator	HadGEM			Enterprise Development			
				Bal-Crop-Lives		Int-Crop-Lives	
	2015	2030	2045	2030	2045	2030	2045
Energy consumption (kcal/capita/day)	2,639	2,940	3,105	3,071	3,337	3,139	3,342
Malnourished children (million)	4.64	3.22	2.33	3.02	2.05	2.93	2.05
Number of undernourishment (million)	26.60	24.36	19.27	20.20	1.44	16.71	0.90
Prevalence of undernourishment (% of population)	10.6	8.8	6.7	7.3	0.5	6.0	0.3

Bal-Crop-Lives = balanced, less investment-intensive program promoting the development of both crop and livestock enterprises; HadGEM = Hadley Centre Global Environmental Model (scenario); Int-Crop-Lives = intensive investment program with a simultaneous and balanced development focus on both crops and livestock; kcal = kilocalorie.

Source: IMPACT simulation results.

Chapter 4: Economy-Wide Impact of Agricultural Investment Opportunities and Challenges in Indonesia

4.1 Introduction

The Indonesian economy has made significant strides since independence. Strong growth has promoted a structural transformation and refashioned the agrarian economy into an industrial one. However, a significant number of people are still engaged in traditional agriculture, trapped in low-paid and less productive activities. Many of them do not get enough food and their children are prone to stunting, keeping them in a vicious cycle for generations. Today, about 20 million people in Indonesia still endure hunger.

Increased investment in agriculture to modernize food systems and markets and make them more efficient is key to breaking this vicious cycle. Such investment will not only help improve the country's food production but will also enable households to engage in more productive sectors and earn a better income. Given the significant influence of the country's food policy on the domestic market, this effort needs innovative government support. Synergies between investment and policy goals must be attained to create more opportunities and efficiencies in achieving food security for the society as a whole.

This chapter specifically assesses the challenges and impact of investment options in the agriculture sector and the spillover effect on the rest of the economy. The discussion is linked to and extends the assessment made in the previous chapter, which provided a detailed analysis of the agriculture sector but did not address its impact on other sectors. The pivotal role of food policy in driving the market economy demands further evaluation to understand better how the investment and policy options interact. This will help shed light on how agricultural investments will play out in improving long-term economic growth and household welfare under different policy regimes.

4.2 Methodology and Modeling Framework

The complex relationships between the agriculture sector and the rest of the economy can be better analyzed through proper structural modeling that captures various production linkages connecting upstream with downstream industries and services. General equilibrium modeling is an ideal tool for capturing this complex relationship as it allows the analyst to scrutinize the economy-wide impact of certain economic shocks or policies that have significant spillover effect on the rest of economy.

The Dynamic Economy-Wide Model for Indonesia (DEWI) developed for this study is based on a dynamic structural general equilibrium model patterned after IFPRI's standard computable general equilibrium (CGE) model with inter-period solution to capture the effect of changes in investment and capital accumulation (Diao and Thurlow 2012). The model is solved recursively on the basis of past information acquired by agents, who are assumed to have no information about the future. This type of model has been used to assess the economic impact of investment and growth strategy at the country level in a number of cases (e.g., Benin et al. 2008; Pauw and Thurlow 2015; Morley and Piñeiro 2011).

DEWI was specifically constructed to replicate the latest Indonesian economic structure, with 2015 as base year for the model. Social accounting matrix data based on the most recent input–output table (BPS 2015) and supported by various other macro- and micro-level data sets are used in the model to portray the economy. The model comprises 33 primary agricultural subsectors, 4 mining subsectors, 17 food-industry subsectors, 18 other manufacturing subsectors, and 12 service subsectors (Appendix).

Factors are assumed to be mobile across sectors, except for capital, which is classified as either agricultural or nonagricultural. Four classes of labor are defined by level of education, with unskilled labor at one extreme and highly skilled labor at the other. Households are defined by income source and location in rural or urban areas. In total, 15 specific household types are included, providing information about income distribution at both national and subnational levels.

As stated in Chapter 3, DEWI is linked with the IMPACT model, with parameters provided from IMPACT to DEWI being solved endogenously within the linked models. Two categories of IMPACT output are transferred to DEWI as exogenous parameters that directly drive production and the consumption behavior of economic agents. Under the first output category, world prices, the IMPACT model generates estimates of world prices under different scenarios. Under the second category, yield changes, land, and production variables solved in IMPACT are processed to capture the potential yield changes across crops and fed into DEWI as productivity changes. Both parameter changes from IMPACT are compared against the baseline scenario, and crop yield and world-price effects are measured as changes from the baseline levels. Combining these two shocks provides an estimation of the total impact of certain economic or policy shocks on the agriculture sector and on the economy as a whole.

The scenarios are solved under the same macro closures, with the wage rate allowed to adjust, and full employment assumed for all factors. Factors are also assumed to be mobile across sectors, consistent with the long-run focus of the analysis. A balanced macro closure is specified; this assumes that the macro demand aggregates (consumption, investment, and government) are fixed shares of total absorption. Savings rates (including those of government) are assumed to adjust to achieve macro balance. Foreign savings are fixed, and the real exchange rate adjusts to maintain the fixed trade balance.

Table 4.1: Climate, Investment, and Policy Scenarios

No.	Scenario	Description
Climate scenarios		
1.	Crop-yield effect	Changes in productivity for all agricultural commodities
2.	World-price effect	Changes in international agricultural and food commodity prices
3.	Combined climate effect	Combination of results from the crop-yield and world-price scenarios
Investment options		All investment simulations are based on the combined climate effect (scenario 3)
4.	Comprehensive investment I	Higher yield for crops and livestock due to higher efficiency of R&D, extensive irrigation expansion (20%), basin efficiency, and livestock development
5.	Comprehensive investment II	Higher yield for crops and livestock due to higher efficiency of R&D, extensive irrigation expansion (20%), basin efficiency, livestock development, and land expansion
6.	Comprehensive investment III	Higher yield for crops and livestock due to higher efficiency of R&D, extensive irrigation expansion (20%), basin efficiency, livestock development, land expansion, and reduction of postharvest losses.
Policy options		All policy simulations are based on the comprehensive investment III (Scenario 6)
7.	Rice and trade policy reform	Reduction in rice import price by 50% to close price gap between domestic and world rice price; cutting of import tariff rate for agricultural commodities by half
8.	Fertilizer policy reform	Abolition of fertilizer subsidy and reallocation/reinvestment of funds in R&D to improve crop productivity
9.	Trade and fertilizer policy reform combined	Combination of scenarios 8 and 9

R&D = research and development.

The model simulations undertaken for this study explore three climate scenarios capturing individual climate effects on crop productivity and world-price changes. The RCP8.5 climate scenarios are used to pick the worst climate effect scenario for Indonesia, based on the HadGEM climate model. The first three scenarios represent climate challenges that the country would face in the next 30 years. The full (third) climate scenario is then set as the baseline against which the investment scenarios under simulations 4–6 (Table 4.1) are compared. These three investment scenario designs incorporate the IMPACT results for the same scenarios, as discussed in the previous section. The analysis is focused mainly on these three comprehensive investment options, considering the significant potential economic impact offered.

The last-three scenarios (scenarios 7–9) are designed to assess the government's food policy that could enhance the impact of agricultural investment on the economy. The comprehensive investment III (scenario 6) is combined with two different policy environments—agricultural trade and fertilizer subsidy reform. Scenario 7 explores the first policy reform, and assumes that the government eases trade restrictions on rice to close the widening price gap between imported and domestic rice. As pointed out in section 2.3.3, the price gap between imported and domestic rice has more than doubled in the last few years. To capture the trade policy reform, the import price of rice is reduced by 50% to close this price gap. The agricultural import tariff rate on all crops and livestock is also cut by half. This trade liberalization policy is needed to help

Indonesia focus on producing commodities with the highest comparative advantage while offering consumers lower food prices.

Scenario 8 focuses on the fertilizer subsidy program, which is one of the largest government support programs in the agriculture sector. Recent studies summarized in Chapter 2 found that the benefit of fertilizer subsidy accrues mainly to large farmers, while most small farmers apply much more fertilizer than the recommended amount, leading to inefficient production (Osorio et al. 2011). The modeling scenario tries to capture this inefficiency and introduce policy reform. In the policy reform scenario, the fertilizer subsidy is eliminated and the subsidy fund is used to finance the government's agricultural R&D program to increase crop productivity. As a result, the price of fertilizer goes up, but greater yield gains are seen across crops because of the increased investment in R&D. Finally, scenario 9 combines the two policy reforms set in scenarios 7 and 8 to facilitate understanding of the full impact of the policy reforms on agricultural investments.

It should be noted that although the policy and investment levers are specified differently in a CGE model compared with a partial equilibrium model, the assumptions in DEWI are set to preserve close equivalence between the investment scenarios designed in Chapters 3 and 4. The first comprehensive investment scenario in this chapter (scenario 4) is equivalent to the crop-based farm enterprise scenario presented in Chapter 3, while the second and third comprehensive investment scenarios (scenarios 5 and 6) follow the balanced and intensified crop-livestock enterprise scenarios, respectively, as also described in Chapter 3.

4.3 Baseline Scenario

Before any simulation analysis is conducted, the model parameters in the model are set to capture the current and plausible future condition of the economy so that the model generates the proper baseline in this calibration process. This is done by defining the long-term GDP growth rate in the model that reflects the plausible future path that the country would achieve by looking at long-term past achievement. Between 1960 and 2015, Indonesia managed to maintain 5.4% annual GDP growth on average, with the agriculture sector growing by around 3% (Table 4.2). The industry and service sectors showed remarkable annual growth rates averaging 6.3% and 6.8%, respectively.

These growth rate numbers became the anchor in calibrating the model. The growth rate was calibrated to closely match the historical growth rate data shown in Figure 4.1. Industry and services remain the leading economic growth engine, while agriculture grows moderately. In total, GDP is set to grow by around 5.5% yearly for 30 years after 2015. As a result, a reduction is seen in the share of agriculture in the economy, from 13.4% to 8.3% of total GDP by 2045. This means that the sector's contribution to the economy is expected to decline by almost 40%. On the other hand, the contribution of industry and services to the economy becomes increasingly dominant over time, accounting for 89.6% of total GDP by 2030 and 91.7% by 2045.

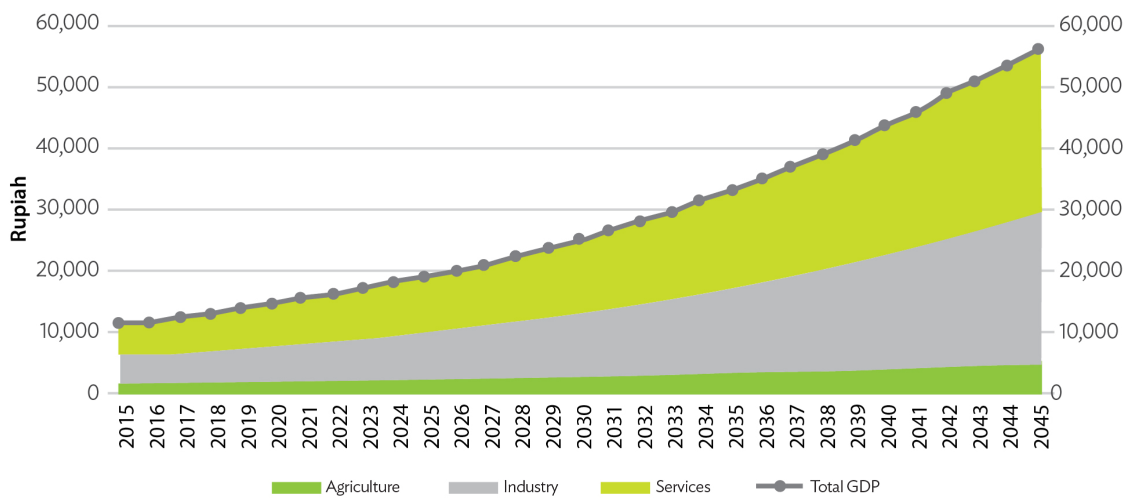
Table 4.2: Baseline GDP Projections, by Major Sector, and Historical Growth Rate

Sector	2015 GDP (Rp trillion)	GDP Share (%)			Annual Growth Rate (%)		Historical Growth Rate (%)
		2015	2030	2045	2015–2030	2015–2045	1960–2015
Agriculture	1,474	13.4	10.2	8.3	3.63	3.89	3.14
Industry	4,512	41.0	43.1	44.7	5.87	5.87	6.81
Services	5,019	45.6	46.7	47.0	5.69	5.67	6.33
Total GDP	11,005	100.0	100.0	100.0	5.52	5.56	5.44

GDP = gross domestic product.

Source: Constructed by authors from DEWI simulation results. Historical data are from BPS.

Figure 4.1: GDP, by Sector, across Simulation Years



GDP = gross domestic product.

Source: Constructed by authors from DEWI calibration results.

Within the agriculture sector, crop production activities were more dominant than livestock and fishery activities in 2015. Food and other crops contributed 28.4% and 46.7%, respectively, while livestock and fishery contributed only 24.9% in total. As the national income increases over time, the rate of growth in demand for food crops and other crops is expected to decline, leading to a reduction in their share of agricultural GDP by 2.9% and 6.8%, respectively, by 2045. On the other hand, the contribution of the livestock and fishery subsectors to the economy is seen to increase by 4.9% and 5.6%, respectively. This production shift also shows that as income increases, agricultural production moves toward more expensive sources of energy from meat and fish.

At the macro level, all GDP components, by expenditure, are seen to grow proportionally (Table 4.3). Household demand, the largest contributor to GDP, grows by 5.7% annually, on average, from 2015 to 2045. The share of food consumption,

Table 4.3: Baseline GDP Projections, by Expenditure

GDP Component	GDP Share (%)			GDP Share (%)	
	2015	2030	2045	2015–2030	2015–2045
Absorption	99.7	99.9	99.9	5.51	5.53
Household Consumption	57.0	56.4	56.7	5.52	5.67
Food share	39.0	32.0	28.0	(1.25)	(1.04)
Non-food share	61.0	68.0	72.0	0.37	0.23
Government Consumption	9.4	10.2	9.9	4.98	4.73
Investment	33.3	33.3	33.4	5.62	5.47
Exports	20.9	20.1	19.6	5.49	5.73
Imports	(20.6)	(20.0)	(19.6)	5.55	5.77
GDP	100.0	100.0	100.0	5.52	5.56

GDP = gross domestic product, ( ) = negative.

Source: Constructed by authors from DEWI simulation results.

however, declines, while the share of non-food items in total household consumption goes up over time. The consumption share of food in Indonesia, already moderate in 2015, goes down to 32% by 2030 and 28% by 2045. The reduction trend in the share of food as income increases is in line with Engel's Law, given the lower income elasticity of food compared with non-food commodities. In 2045, the share of non-food commodities reaches 72% of household consumption. This suggests that food consumption will have less effect on household welfare in the future.

4.4 Challenges from Climate Change

A major challenge that could threaten long-run food security in Indonesia is climate change. Reduction in crop productivity due to a combination of higher temperature and lower precipitation could push down agricultural production. At the global level, reduction in agricultural supply across countries means that world prices of agricultural products will go up. This trend will benefit exporting countries, but it will hurt countries that depend on food imports.

Both domestic productivity and global world-price effects are analyzed below through a comparison of the simulation results for scenarios 1–3 with the benchmark results above (Table 4.4). Results for each variable of interest are presented as percentage changes from baseline values in 2030 and 2045. However, only the results for scenario 3 for the year 2045 are presented. Macro-level changes are discussed first, followed by micro-level changes, which include impact on national agricultural production levels and their effect on income distribution across different types of households. Finally, the welfare cost of climate change is estimated through an assessment of the impact on the economy as a whole, including both direct and indirect effects.

The total climate effect on Indonesia is relatively modest, with GDP reduced by 0.58% by 2045—although this impact still results in significant economic losses, as

Table 4.4: Projected Impact of Climate Change on Real Value Added, by Sector (% change from baseline levels)

Sector	Crop-Yield Effect by 2030 (Scenario 1)	World-Price Effect by 2030 (Scenario 2)	Combined Effect by 2030 (Scenario 3)	Combined Effect by 2045 (Scenario 3)
Agriculture	(0.89)	0.18	(0.70)	(1.34)
Industry	(0.03)	(0.15)	(0.17)	(0.48)
Services	(0.17)	(0.10)	(0.27)	(0.55)
Total GDP	(0.18)	(0.09)	(0.27)	(0.58)

GDP = gross domestic product, ( ) = negative.

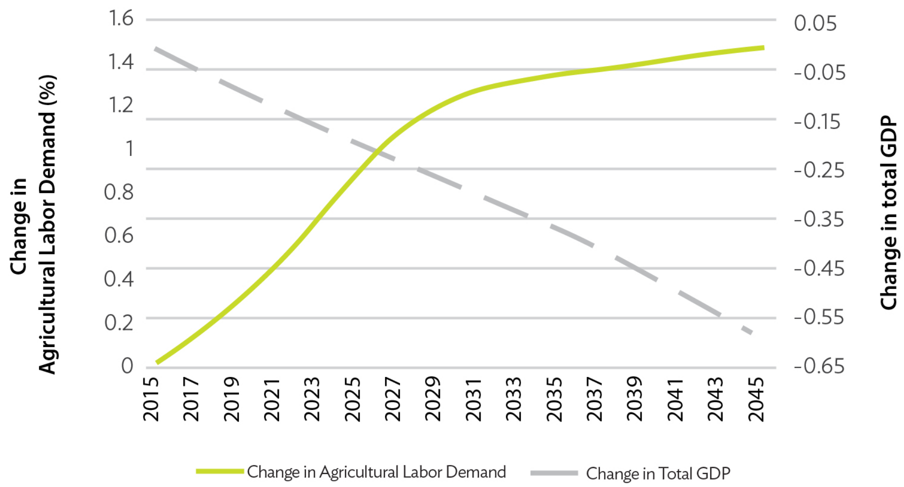
Source: Constructed by authors from DEWI simulation results.

will be shown below. The impact will obviously be greatest on agriculture, but some spillover effects on other sectors can be seen, with the industry and services sectors also declining by 0.48% and 0.55%, respectively. Between the two climate change effects (scenarios 1 and 2), impact on crop productivity losses is projected to be higher than the world-price changes by 2030. A similar trend is observed by 2045, but only the combined climate effect for that year is presented in this analysis. One thing worth noting is that the agriculture sector benefits under the world-price effect (scenario 2). The model shows that agriculture value added increases by 0.18% by 2030. However, when the repercussion effect on industry and services is considered, the total impact on GDP by 2030 is still negative.

Given that labor is able to move across sectors, the climate shock introduced in the model induces labor markets to adjust. Under the combined climate change scenario (scenario 3), the lower agricultural productivity and higher international world prices cause demand for labor in agriculture to increase by about 1.4% by 2045 (Figure 4.2). This means that in the long run, climate change causes labor to remain in agriculture instead of moving to the nonagricultural sector. As a result, GDP values decline over time, mainly because the laborers who stay in agriculture earn less than those in the nonagricultural sector. This result highlights the need for continued improvements in agricultural productivity in the long run to promote the structural transformation process, so that labor can move out of agriculture and work in more productive sectors.

The production of staple crops (dominated by rice) is projected to decline under climate change. Under scenarios 1 and 2, the model shows a 1.28% reduction in yield and a 0.04% reduction in world prices for staple crops by 2030 (Table 4.5). This suggests that the crop-yield effect is the main driver of production losses. A decline in the production of other crops is also projected, but not as much as the projected decline for staple crops. The main reason is not only the lesser significance of the negative shocks on crop yield but the actual positive gains (by 0.1%) from world-price changes by 2030.

Figure 4.2: Change in Agricultural Labor Demand and GDP under Climate Change



Source: Constructed by authors from DEWI simulation results.

Table 4.5: Projected Impact of Climate Change on Agricultural Production (% change from baseline levels)

Sector	Crop-Yield Effect by 2030 (Scenario 1)	World-Price Effect by 2030 (Scenario 2)	Combined Effect by 2030 (Scenario 3)	Combined Effect by 2045 (Scenario 3)
Staple crops	(1.28)	(0.04)	(1.29)	(2.47)
Other crops	(0.61)	0.10	(0.51)	(0.83)
Livestock	(0.82)	(0.25)	(1.07)	(2.18)
Fishery	(0.85)	(0.31)	(1.12)	(1.25)
Agriculture	(0.80)	(0.09)	(0.86)	(1.22)

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

In total, the production of other crops decreases by only 0.83% by 2045, compared with 2.47% for staple crops (Table 4.6). This projection shows that concerns about the climate challenges confronting food security are warranted, given the more significant losses in staple crops that are essential to household consumption, especially among the lower-income groups. At the same time, livestock and fishery output is projected to decline as well by 2030, under scenarios 1 and 2. However, the reduction in these two subsectors is primarily due to disruptions in feed supply resulting from a decrease in crop production, and will mainly affect the higher-income household groups, which allocate more of their consumption budget to protein-source commodities.

Changes in returns to factor input (labor, land, livestock, agricultural and nonagricultural capital) indicate the impact of climate change on income distribution. Changes in wage rates have a bigger impact on lower-income households,

Table 4.6: Projected Impact of Climate Change on Real Returns to Factor Input (% change from baseline levels)

Factor Input	Location	Education Level	Crop-Yield Effect by 2030 (Scenario 1)	World-Price Effect by 2030 (Scenario 2)	Combined Effect by 2030 (Scenario 3)	Combined Effect by 2045 (Scenario 3)
Labor	Rural	No education	(0.44)	0.24	(0.22)	(1.70)
		Primary education	(1.45)	(0.80)	(2.22)	(4.13)
		Secondary	(1.07)	(0.07)	(1.14)	(2.67)
		education	(0.98)	0.06	(0.93)	(2.34)
		Tertiary education				
	Urban	No education	1.03	2.58	3.53	3.31
		Primary education	(0.22)	0.33	0.07	(2.59)
		Secondary	(0.80)	(0.80)	(1.59)	(3.43)
		education	(1.40)	(0.97)	(2.34)	(3.82)
		Tertiary education				
	Land		1.03	2.58	(0.44)	0.24
Capital		Agriculture	(0.22)	(1.45)	(0.80)	(2.22)
		Livestock	(0.80)	(1.07)	(0.07)	(1.14)
		Non-agriculture	(1.40)	(0.98)	0.06	(0.93)

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

Table 4.7: Projected Impact of Climate Change on Real Household Incomes (% change from baseline levels)

Household Category	Crop-Yield Effect by 2030 (Scenario 1)	World-Price Effect by 2030 (Scenario 2)	Combined Effect by 2030 (Scenario 3)	Combined Effect by 2045 (Scenario 3)
National	(1.14)	(0.54)	(1.67)	(3.21)
Rural	(0.66)	0.09	(0.57)	(1.88)
Lower income	(0.57)	0.19	(0.39)	(1.79)
Upper income	(0.69)	0.05	(0.64)	(1.92)
Urban	(1.46)	(0.96)	(2.39)	(4.25)
Lower income	(1.41)	(0.80)	(2.18)	(4.10)
Upper income	(1.47)	(0.98)	(2.42)	(4.27)

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

which derive most of their livelihood from unskilled labor (no specific education requirement), mostly in the agriculture sector. Individuals with higher education levels are assumed to be more highly skilled and are employed mainly in industry and services.

Climate change is projected to have a negative impact on the wage rates of laborers in both rural and urban areas. The impact will be more significant on urban workers than on their rural counterparts, for the main reason that climate change creates more demand for land and workers in the rural areas as more resources are needed to produce the same amount of output. Wage reductions are therefore less severe for rural workers than for urban workers. In the case of land, climate change induces higher returns, given the limited supply of this factor in the future. For nonagricultural capital, the reduction in factor returns is largely a response to the declining demand for labor in the urban areas, typically for jobs in the nonagricultural sector. As discussed earlier, this is a spillover effect of the impact of climate change on the agriculture sector.

As regards income changes, households are categorized here as lower- or upper-income, on the basis of per capita income quintiles. The first and second quintiles (the bottom 40%) are classified as lower-income households, and the top three quintiles (the remaining 60%), as upper-income households (Table 4.7). As expected, by 2030 the positive effect of climate change on household income will come mainly from world-price effects. Higher returns to land and unskilled labor will cause income levels to rise among rural households. The lower gains received by upper-income households, however, are due to some factor ownership of nonagricultural capital, which brings down the positive earnings from land. Overall, all households suffer under the climate change scenario, but the rural households are less severely affected.

The net benefits or costs of climate change estimated in this study refer to changes in welfare parameters: positive values are benefits and negative values are costs. Besides the calculation of net economic benefits or costs at the national level, welfare is assessed at the household level on the basis of changes in real household incomes across geographic regions. The economic benefit or cost of a climate shock is measured by the change in total real absorption (total value of final demand, comprising aggregate consumption, investment, and government spending) compared with the baseline values. Under climate change, the economy contracts by Rp74.9 trillion by 2030, mostly because of a reduction in private consumption caused by higher commodity prices and lower income levels among urban upper-income households, as discussed previously (Table 4.8). In 2045, the projected cost of the climate shock is up to Rp400 trillion, three-quarters of this contributed by the reduction in household consumption.

Table 4.8: Projected Effects of Climate Change on Total Absorption
(change from baseline levels, Rp trillion)

Welfare Component	Crop-Yield Effect by 2030 (Scenario 1)	World-Price Effect by 2030 (Scenario 2)	Combined Effect by 2030 (Scenario 3)	Combined Effect by 2045 (Scenario 3)
Total Absorption	(51.22)	(24.15)	(74.92)	(401.11)
Household Consumption	(41.58)	(18.65)	(59.85)	(299.24)
Government Consumption	(3.49)	(6.34)	(9.68)	(17.21)
Investment	(6.14)	0.84	(5.38)	(84.65)

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

Table 4.9: Projected Impact of Climate Change on Household Welfare
(change from baseline levels, Rp trillion)

Household Category	Crop-Yield Effect by 2030 (Scenario 1)	World-Price Effect by 2030 (Scenario 2)	Combined Effect by 2030 (Scenario 3)	Combined Effect by 2045 (Scenario 3)
National	(45.04)	(21.09)	(65.90)	(367.41)
Rural	3.47	24.71	27.43	3.25
Lower income	(0.73)	6.68	5.72	(15.29)
Upper income	4.20	18.02	21.71	18.55
Urban	(48.51)	(45.79)	(93.33)	(370.66)
Lower income	(7.08)	(4.96)	(11.95)	(60.14)
Upper income	(41.44)	(40.83)	(81.38)	(310.52)

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

Following Blonigen, Flynn, and Reinert (1997), the welfare cost of climate change at the household level is calculated in terms of changes in equivalent variation from baseline values. EV is the amount of money a consumer would have to receive after a price change to maintain new utility level if prices had not changed—hence, changes in welfare are measured in baseline prices. The pattern of welfare change at the household levels will not exactly follow the pattern of income changes discussed previously, but urban upper-income households are generally more adversely affected by climate change than other households, for the most part because of their much higher initial income. This household group incurs the biggest loss from climate change, amounting to Rp310 trillion by 2045 (Table 4.9). In contrast, rural upper-income households gain most from the effects of climate change, with incomes increasing by around Rp19 trillion. In total, the gains accruing to rural households are much less than the losses borne by urban households, ultimately leading to total household welfare losses of around Rp367 trillion, compared with baseline levels, by 2045.

4.5 Investment Opportunities

To focus the analysis of agricultural investment, only the three comprehensive investment scenarios are assessed here. These investment options are analyzed against the climate challenges discussed above. This approach will provide a better understanding of the significant role of agricultural investment in mitigating the impact of climate change and promoting structural transformation in the country.

Simulation results show that all three investment options will have a highly positive effect on agricultural GDP. Introducing the first comprehensive investment, which includes investment in R&D for crops and livestock as well as irrigation expansion, can overcome the impact of climate change on sector GDP. As expected, investments were found to have hierarchical impact across the three scenarios, with scenario 6 having the highest impact, followed by scenarios 5 and 4. Under scenario 6, GDP could potentially increase by 2.9% by 2045, mostly as a result of agriculture sector expansion. The spillover effects on nonagricultural sectors are also quite significant, allowing the industry and service sectors to expand by 1.4% and 2.4%, respectively.

Among the three investment simulation results, the differential value between scenarios 5 and 4 shows the impact of land expansion, as discussed in the methodology section (Table 4.10). The difference between scenarios 6 and 4 includes not only additional investment in land, but also new investment in postharvest loss reduction. As shown in Table 4.11, additional investment in land under scenario 5 generates a 9.6% increase in the production of staple crops. An even higher increase of 11.5% in staple crop production is possible under scenario 6. Also under scenario 6, even though no additional investment is made in the livestock and fishery subsectors, both are seen to make gains, increasing production by 3.8% and 4.1%, respectively, by 2045, because of spillover effects. It should be noted that this analysis excludes any negative environmental cost from the land expansion effort.

Table 4.10: Projected Impact of Climate Change Investment Options on Sectoral GDP, 2045 (% change from baseline levels)

Sector	Combined Climate Effect (Scenario 3)	Comprehensive Investment I (Scenario 4)	Comprehensive Investment II (Scenario 5)	Comprehensive Investment III (Scenario 6)
Agriculture	(1.34)	6.76	11.80	13.22
Industry	(0.48)	1.10	1.24	1.38
Service	(0.55)	1.47	2.16	2.43
GDP	(0.58)	1.75	2.55	2.86

GDP = gross domestic product, ( ) = negative.

Source: Constructed by authors from DEWI simulation results.

Table 4.11: Projected Impact of Climate Change Investment Options on Agricultural Production, 2045 (% change from baseline levels)

Commodity Group	Combined Climate Effect (Scenario 3)	Comprehensive Investment I (Scenario 4)	Comprehensive Investment II (Scenario 5)	Comprehensive Investment III (Scenario 6)
Staple crops	(2.47)	7.13	16.78	18.59
Other crops	(0.83)	3.36	6.33	7.06
Livestock	(2.18)	15.17	16.55	19.01
Fishery	(1.25)	3.71	7.07	7.82

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

Table 4.12: Projected Impact of Climate Change Investment Options on Total Absorption, 2045 (change from baseline levels, Rp trillion)

Sector	Combined Climate Effect (Scenario 3)	Comprehensive Investment I (Scenario 4)	Comprehensive Investment II (Scenario 5)	Comprehensive Investment III (Scenario 6)
Total Absorption	(401)	1081	1639	1834
Private consumption	(299)	692	1122	1271
Investment	(85)	81	92	102
Government consumption	(17)	308	425	462

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

Table 4.13: Projected Impact of Climate Change Investment Options on Household Welfare, 2045 (change from baseline levels, Rp trillion)

Household Category	Combined Climate Effect (Scenario 3)	Comprehensive Investment I (Scenario 4)	Comprehensive Investment II (Scenario 5)	Comprehensive Investment III (Scenario 6)
National	(367)	813	1325	1491
Rural	3	35	28	33
Lower income	(15)	(3)	50	54
Upper income	19	37	(22)	(20)
Urban	(371)	778	1297	1458
Lower income	(60)	124	222	249
Upper income	(311)	654	1076	1209

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

The impact of comprehensive agricultural investment on national welfare can be derived from changes in absorption value, as discussed earlier. Total absorption under scenario 4 increases by Rp1,252 trillion by 2045 compared with scenario 3 (Table 4.12). This means that investment under scenario 4 not only cancels out the climate change effect but also increases total economic welfare. As expected, the largest gain accrues mainly to private consumption, dominated by urban households (Table 4.13). This distribution pattern, where urban upper-income households get most of the benefits while rural households experience only a slight improvement in welfare, was found across all investment scenarios.

This welfare pattern emerges because agricultural investment that raises productivity across all crops tends to lessen the use of agricultural input factors like low-skilled labor and land. Factor payments for agricultural input thus drop below factor payments for nonagricultural input like high-skilled labor and capital, and urban households, especially those with higher incomes, derived mostly from the nonagriculture sector, benefit much more than rural households.

4.6 Role of Food Policy

The analysis now turns to how the policy environment in the country interacts with the investment effort discussed above. Comprehensive investment III is chosen as the reference point since it represents a combination of all the investment schemes analyzed in this study. New policy environments are introduced on top of the comprehensive investment strategy (scenario 6) to enable an assessment of the impact of market adjustments in response to policy changes. Policy scenarios 7 and 8, representing policy reform in agricultural trade and fertilizer subsidy, respectively, are specified. Scenario 9 combines the two policies to measure the total impact.

The difference between each policy scenario and comprehensive investment III (scenario 6) gives the net impact of each policy reform. The policy reforms each have a positive impact on GDP, given the positive differences (Table 4.14). Implementing the two policy reforms together could increase the GDP gains from the investment by 0.64%. The largest gain comes mainly from the fertilizer subsidy, where GDP increases by 0.6%. One of the main reasons for the small GDP gains generated by agricultural trade policy reform is its negative impact on the agriculture sector.

Table 4.14: Projected Impact of Total Investment Policy Options on Sectoral GDP, 2045 (% change from baseline levels)

Sector	Comprehensive Investment III (Scenario 6)	Rice and Trade Policy Reform (Scenario 7)	Fertilizer Policy Reform (Scenario 8)	Policy Reforms Combined (Scenario 9)
Agriculture	13.22	12.18	15.08	14.08
Industry	1.38	1.49	1.82	1.91
Services	2.43	2.63	2.97	3.15
GDP	2.86	2.91	3.46	3.50

GDP = gross domestic product.

Source: Constructed by authors from DEWI simulation results.

Table 4.15: Projected Impact of Total Investment Policy Options on Agricultural Production, 2045 (% change from baseline levels)

Sector	Comprehensive Investment III (Scenario 6)	Rice and Trade Policy Reform (Scenario 7)	Fertilizer Policy Reform (Scenario 8)	Policy Reforms Combined (Scenario 9)
Staple crops	18.59	13.21	21.88	16.77
Other crops	7.06	7.42	8.47	8.80
Livestock	19.01	19.44	20.33	20.72
Fishery	7.82	8.36	9.16	9.65

Source: Constructed by authors from DEWI simulation results.

Table 4.16: Projected Impact of Total Investment Policy Options on Total Absorption, 2045 (change from baseline levels, Rp trillion)

Sector	Comprehensive Investment III (Scenario 6)	Rice and Trade Policy Reform (Scenario 7)	Fertilizer Policy Reform (Scenario 8)	Policy Reforms Combined (Scenario 9)
Total Absorption	1,834	1,913	2,209	2,281
Private consumption	1,271	1,332	1,491	1,548
Investment	102	114	142	152
Government consumption	462	467	577	581

Source: Constructed by authors from DEWI simulation results.

Table 4.15 shows the impact of the policy on agricultural production. The main driver of the reduction in agricultural GDP is the reduction in staple crop production, from an 18.6% increase to a 13.2% increase in 2045. This also means that resources are released from staple crop production into other sectors within and outside agriculture. Within agriculture, the production of other crops and the livestock and fishery subsectors can be seen to go up. Outside agriculture, industry and services also expand, by 0.11% and 0.2%, respectively. As a result, there is still a positive impact on GDP, given the spillover effect of factor movement across sectors.

The impact of fertilizer subsidy reform on the agriculture sector is positive across the board, allowing the sector to expand by 1.86% (15.08%–13.22%) by 2045. The productivity gains under the fertilizer subsidy reform scenario arise from the reallocation of the fertilizer subsidy to finance the agricultural R&D program. There are lags in the impact of this policy reform because it takes time for the increased investment in R&D to produce innovation and impact. However, in the medium and long run, the payoffs are high as technologies spread out across the country. The spillover effect on other sectors is larger under fertilizer subsidy reform (scenario 9) than under trade reform (scenario 8). Overall, the GDP gains from investment under fertilizer subsidy reform are 0.6% (3.46%–2.86%) higher.

To assess the net benefit or cost of each policy reform, the absorption value of each policy was compared with the absorption value under the comprehensive investment III scenario (scenario 6). The higher the absorption value of the policy, the more successful it is in enhancing investment impact. From calculations based on Table 4.16, while the first policy reform (scenario 7) will result in Rp79 trillion in benefits, the benefits to be gained from the second policy reform (scenario 8) will be much larger—Rp375 trillion. In total, when the two policies are implemented together, investment gains can increase by Rp447 trillion.

Welfare distribution across households is captured by the equivalent variation indicator, as shown in Table 4.17. Among all households, only the upper-income households suffer under policy reforms. This shows that the reforms do not go against the interests of the marginalized households in the rural areas, who are mainly poor and landless. On the other hand, upper-income urban households benefit the most, while lower-income urban households also gain, although not as much. Again, this is mainly because the policy reforms promote a structural transformation process that brings more resources from agriculture into the non-agriculture sector.

Table 4.17: Projected Impact of Policy Options on Household Welfare, 2045
(change from baseline levels, Rp trillion)

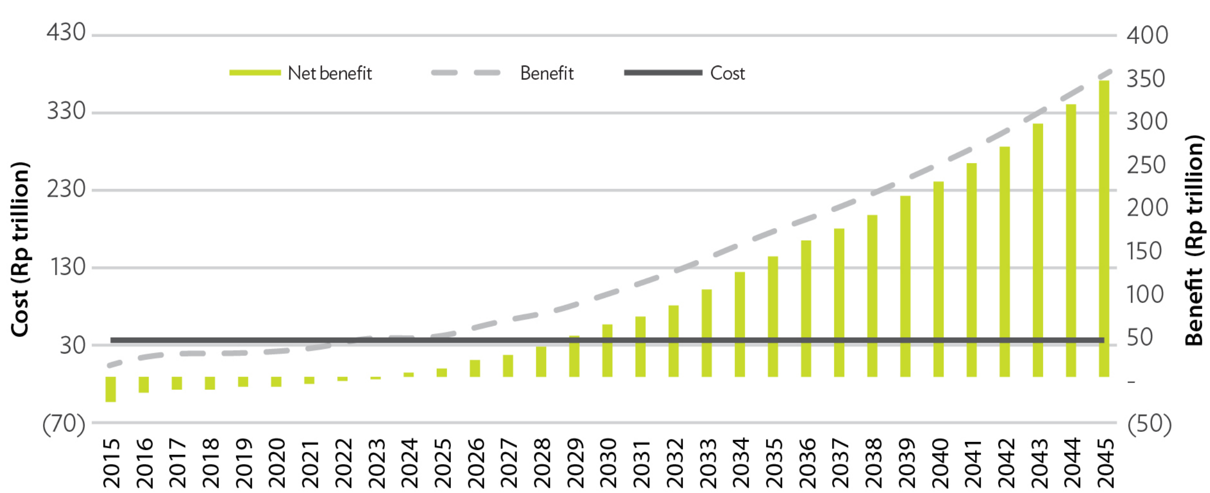
Household Category	Comprehensive Investment III (Scenario 6)	Rice and Trade Policy Reform (Scenario 7)	Fertilizer Policy Reform (Scenario 8)	Policy Reforms Combined (Scenario 9)
National	1,491	1,671	1,726	1,792
Rural	33	35	38	6
Lower income	54	55	68	63
Upper income	(20)	(20)	(29)	(57)
Urban	1,458	1,636	1,687	1,786
Lower income	249	260	290	306
Upper income	1,209	1,375	1,397	1,480

( ) = negative.

Source: Constructed by authors from DEWI simulation results.

In measuring the net gains from policy reform, the cost of the policy itself must be included. The explicit cost of fertilizer subsidy in this analysis is about Rp30 trillion per year. Government spending on fertilizer has been rising in recent years, but it is assumed here that the subsidy will stay the same in the future. Figure 4.3 shows the results of the benefit–cost analysis. The gray horizontal line represents the cost of the subsidy, and the broken line, the benefits generated, which are calculated in terms of the changes in absorption value under scenario 8, as discussed above (Table 4.16). The diagram indicates that a positive return on investment (net benefit) will begin within a few years; after that, the total net benefits will increase rapidly. It will take about 8–9 years for the benefits of investment in R&D to outstrip the costs.

Figure 4.3: Net Benefit (Cost) of Fertilizer Subsidy Reform



Source: Constructed by authors from DEWI simulation results.

Chapter 5: Policy Recommendations on Agriculture Development and Investment in Indonesia for 2020–2045

This report has provided a review of Indonesian agricultural policy and assessed the impact of alternative investments and policies using a scenario assessment approach that links a partial equilibrium agricultural sector model with a general equilibrium economy-wide model. This chapter presents policy recommendations derived from the policy review and the scenario modeling, together with a proposed road map with time phasing for the implementation of these policies.

- **Expenditure on agricultural R&D, especially crop and livestock breeding, should be increased significantly.** Investment in agricultural R&D had the strongest impact in reducing hunger and childhood malnutrition and should be substantially increased. It is important to increase the investment in broad-based yield-enhancing research, but more focus should also be given to stresses that are likely to increase with climate change, including heat, drought, pests, and diseases. Research should target increased yield with respect to both land and water. Although it is challenging, improvement in crop yield per unit of water is a necessary breeding goal. Research systems should be modernized and wider use should be made of biotechnology tools such as marker-assisted selection, cell and tissue culture, gene editing, and possibly transgenic breeding. The expansion of livestock production to meet growing demand must balance trade-offs among food security, poverty, and environmental sustainability. Key innovations are needed in breeding and feeding programs that will focus not only on production and productivity, but also on product quality, animal welfare, disease resistance, and reduction in water and land use, greenhouse gas (GHG) emissions, and other environmental impact. R&D areas for livestock include management concerns such as diet optimization, improvements in pasture quality and feed digestibility, water management, and high-quality grain concentrates. Improved technologies for livestock include waste management, use of by-products for energy production, recycling, and integrated management of mixed livestock–crop systems, which could lead to substantial water savings and better livestock productivity (Thornton 2010).

- **Increased investment in irrigation expansion and in improvement of existing irrigation systems is warranted, but careful attention should be paid to cost-effectiveness.** More investment in irrigation expansion and improvement will increase crop yield and area, boost the returns to other agricultural technologies, and promote the adoption of advanced technologies. The modeling results show that increased investments will lead to rising agricultural and total income. The cost per hectare of irrigation is substantial: $4,000–$6,500 for new irrigation construction, $1,200–$1,600 for substantial rehabilitation, $500–$1,200 for moderate rehabilitation, and $32 for operation and maintenance (O&M) (ADB 2016). To raise enough funds, greater efforts should be made to collect irrigation service fees (ISF) to generate operating funds for O&M and to finance the rehabilitation of irrigation systems. Incentives for the collection of ISF would increase if the cost of O&M and rehabilitation were shared between the central and local governments and the water users associations (WUAs), with the size of the central government funding conditioned on the O&M funding provided at the local and WUA level (OECD 2012). More broadly speaking, fee collection and water management would also improve if WUAs were more empowered. This could be achieved by upgrading the existing organization of irrigating farmers into empowered WUA federations that are capable of investing in and managing tertiary irrigation infrastructure, to ensure adequate water supply and give all farmers access to the tertiary irrigation scheme. The move to empower WUAs will require institutional support, such as improving the WUAs' legal status, developing by-laws for WUAs and their federations, assigning roles and responsibilities acceptable to all farmers involved, and complying with government policies and procedures.

- **Extension services need to be upgraded to expand the adoption of both conventional and advanced agricultural technology such as precision farming.** The rapid dissemination of technologies and their proper adoption and use is a critical step beyond intensified agricultural R&D. Extension systems should seek to improve knowledge and increase capacity, and there should be wider use of innovative forms of extension, including radio, mobile phone, and other advanced ICT. For greater coherence in extension, the central government should provide more direction and improve the coordination of public extension with private sector and NGO extension services. The Indonesian consumer market increasingly demands higher-quality, safer food, and enhanced product standards. Failure to meet such standards will reduce farm income and create nontariff barriers to international markets, limiting the potential for market expansion, which is of increasing importance to more diversified farming and farming systems. Extension services—whether those of government or of the private sector or NGOs—must contribute to the dissemination and adoption of higher standards and provide more specialized advice to specific regions and localities. Extension and seed industry reforms must address bottlenecks in the adoption of improved technologies, evidenced by the slow adoption of new crop varieties described in Chapter 2. Stronger organizational, information, and extension strategies will give smallholders access to both domestic and international trade. The government, in partnership with the private sector, should also promote more rapid adoption of precision agriculture. Guided and managed with the help of advanced digital technologies and supported by satellite imaging, remote sensing, and in-field sensors, precision agriculture enables farming management based on observation of, and response to, intra-field variations to guide the efficient application of input and improve productivity and farm income. Satellite-based information will also assist in monitoring crop development.

- **Infrastructure investments, including rural roads, electricity cell phone towers, markets, cold chains, and processing facilities, should be expanded in partnership with the private sector.** These investments are needed to reduce marketing margins and postharvest losses of food, and thus generate substantial production and income gains, and significantly reduce hunger, as shown in the modeling. Increased investments can also stimulate rural ventures in agribusiness, leading to small- and medium-scale entrepreneurships and encouraging the young to stay in agriculture. Private sector investments will be critical to meeting higher investment targets, but as noted above, restrictions on investment have held back foreign direct investments and domestic private investments. The loosening of these restrictions, together with the provision of government guarantees or risk sharing, could incentivize the private sector to fund infrastructure investments. Blended finance, which strategically uses public funding to mobilize private sector finance, is a promising approach to scaling up rural infrastructure investment that has yet to be used widely in Indonesia or other Asian countries.

- **In conjunction with investments in improved extension and rural infrastructure, there should be increased funding for agricultural education to develop the ability to use advanced agricultural technology and ICT.** This combination of policies will promote the participation of youth and entrepreneurial farmers, and foster innovative start-ups. Education can focus on strengthening human resource capacity, especially within local government agencies, for better-organized delivery of rural services and other extension support. In addition, effective and efficient agricultural extension programs require active roles for local government agencies in increasing the adaptive capacity of vulnerable farmers through training and other capacity-building activities.

- Legal and regulatory reforms should be implemented to reduce barriers to the adoption of new seed varieties and other agricultural technologies. Constraints on new technology transfer, including barriers to foreign direct investment, excessive testing and certification requirements, and ad hoc biosafety decision making, should be reduced. More effective safeguards for intellectual property rights, such as patents and licenses and less burdensome licensing requirements and procedures, would encourage private investment in R&D and the dissemination of modern farming technologies across the value chain. Policy reforms that improve the functionality of biotechnology regulation and reduce the time lag between the development of beneficial solutions and their commercial release are critical to generating potentially large positive impact from science and technology advances and to improving the returns to both public and private investment in R&D for developing-country agriculture.

- **Fertilizer subsidies have distorted farmer production decisions and encouraged excess use of fertilizer that is not economically justified and that results in higher runoff pollution and more GHG emissions, and should be phased out.** Larger farmers capture most of the subsidies, and the subsidy cost is significantly higher than the value of the resulting crop production generated. Fiscal savings from the phase-out of subsidies should be invested in increased agricultural R&D and non-distorting income support for small farmers. Both the agriculture sector modeling and the economy-wide modeling show the large benefits from implementing this policy. Concerns about the welfare effects on small farmers can be met through the use of some of the funds saved to transfer money to small farmers to compensate for losses due to the removal of the subsidies. Given the relatively low share of fertilizer in farm production costs, these transfers should not be a burden on government budgets. Smart cards or phones can be used for efficient funds transfer.

- **Security of farmers' land and water rights should be strengthened.** The registration of formal land rights should be speeded up and customary land rights should be recognized and protected. Stronger property rights would provide security for obtaining credit and increasing on-farm investment, and improve the flexibility of production systems to respond to climate change and shocks and to changing incentives, including new economies of scale arising from advanced technologies. Effective rights will also promote investment in small- and medium-scale agro-enterprises. Tenure insecurity and uncertainties about the future undermine incentives for longer-term investments and discourage farmers from trying out innovative programs such as the partnership initiatives being implemented in Yogyakarta, which are aimed at improving consolidated land management for food crop production, as described in Chapter 2. Secure and well-defined water rights protect against water expropriation and provide incentives for investment in more efficient management technology, since farmers are assured of benefiting from these investments. Making those water rights tradable provides additional incentives to optimize the economic value of water. Although some water rights systems operate in virtually any setting where water is scarce, systems that are not firmly grounded in formal or statutory law are likely to be more vulnerable to expropriation. Effective development of well-defined water rights—and eventually water trading—would be enhanced by improvements in irrigation technology for conveyance, diversion, and metering, as well as in irrigation management, and by the WUA reforms described in the second recommendation.

- **Trade restrictions and related food self-sufficiency policies should be phased out.** As shown in the policy review and the economy-wide analysis, these policies impose large costs on the economy and undermine the reforms recommended above that will significantly improve food security. Self-sufficiency policies have resulted in high food prices that hurt consumers, including the substantial share of farmers who are net food consumers. The protection provided to the agriculture sector has reduced incentives to modernize the sector and improve productivity growth. Reforming these

Table 5.1: Summary Road Map for Reforming Agricultural Policy in Indonesia

Policy Action	Short Term (1–2 years)	Medium Term (3–4 years)	Long Term (5–6 years)
1. Increasing expenditure on agricultural R&D: crop and livestock breeding	MOA and MRTHE, including qualified universities, develop platform and encourage research targeted at abiotic stresses (heat and drought) and biotic stresses (pests and diseases). MOA and MRTHE increase investments in broad-based research for improved yield with respect to both land and water.	MOA and MRTHE encourage new social–economic research to inform policies for meeting growing food demand and demand for higher-quality food; for providing poorer consumers with better access to food, to benefit from increased food consumption and for reducing the impact of food production on the environment.	MOA and MRTHE develop more advanced research systems and biotechnology techniques, including marker-assisted selection, cell and tissue culture, gene editing, and possibly transgenic breeding.
	MOA and MRTHE develop recommended management practices for livestock, such as optimized diets, improved feed digestibility, and high-quality feed.	MOA and MRTHE improve technologies for livestock waste management, use of by-products for energy production, and recycling.	MOA and MRTHE develop innovations in product quality, animal welfare, disease resistance, and reduction in water and land use, greenhouse gas (GHG) emissions, and other environmental impact.
2. Increasing investment in irrigation expansion and improvement in existing irrigation systems	MPWH increases budgets for dams, primary and secondary irrigation expansion, and irrigation modernization. MOA increases budgets for tertiary irrigation and promotes the adoption of advanced technologies.	BAPPENAS and MPWH continue improving procedures for the collection of irrigation service fees (ISF) to generate operating funds for O&M and finance the rehabilitation of irrigation systems. MOHA develops the legal basis for the sharing of O&M and rehabilitation costs between central, provincial, and local governments and water users associations (WUAs).	MPWH and civil society organizations engage in dialogue for reforming the Law on Water Resources, to replace Law 7/2004, which was revoked by the Constitutional Court.
3. Upgrading extension services to expand adoption of agricultural technology	MOA develops programs to improve knowledge and increase capacity in extension agencies. MOA and MCIT promote the use of innovative forms of extension, through radio, mobile phone, and other advanced information and communication technology.	MOA and MOHA improve coherence in extension services and coordination of public extension work with private sector and NGO extension services. MOA, MCIT, and MPWH, in partnership with the private sector, promote more rapid adoption of precision agriculture supported by satellite imaging, remote sensing, and sensors.	MOA and MRTHE develop agreements for integrating existing extension services with community services available in universities.

Policy Action	Short Term (1–2 years)	Medium Term (3–4 years)	Long Term (5–6 years)
	MOA develops exchange programs between public extension and the seed industry to address bottlenecks in the adoption of improved technologies.	MOA and MOHA develop stronger organizational, information, and extension strategies that give smallholders access to both domestic and international trade.	
4. Making infrastructure investments (rural roads, cellphone towers, markets, cold chains, and processing facilities)	MPWH and MCIT work together to increase investment in rural infrastructure and promote the use of ICT solutions to reduce marketing costs and postharvest losses.	MOA and provincial governments stimulate rural ventures in agribusiness, leading to small- and medium-scale entrepreneurships and encouraging the young to stay in agriculture.	
	CMEA develops a system of blended finance, which strategically uses development finance or public funding to mobilize additional private finance toward sustainable development.	CMEA lowers barriers to foreign direct investments and private sector investments to meet higher investment targets and attract foreign direct investments and domestic private investments.	
5. Investing in agricultural education to develop the ability to use advanced agricultural technology and ICT	MOA and CMEA promote the participation of youth and entrepreneurial farmers, and foster innovative start-ups.	MOA and MOEC develop education programs to strengthen human resource capacity, especially within local government agencies, to improve the efficiency of rural service delivery and extension support.	MOA and MOHA encourage the active participation of local governments in increasing the adaptive capacity of vulnerable farmers through training and other capacity-building activities.
6. Undertaking legal and regulatory reform to reduce barriers to the approval and release of new seed varieties and other agricultural technologies	MOA and MLHR work together to remove impediments to new technology transfer, such as barriers to foreign direct investment, excessive testing and certification requirements, and ad hoc biosafety decision making.	MOA and MLHR provide better safeguards for intellectual property rights such as patents and licenses and less burdensome licensing requirements and procedures. CMEA develops incentives for private investment in R&D and for the dissemination of modern technologies throughout the value chain.	CMEA improves the functionality of biotechnology regulations to reduce the time lag between the development of beneficial solutions and their commercial release.
7. Phasing out fertilizer subsidies	MOA, MOF, and MSOE work together to reduce fertilizer subsidies and to invest the fiscal savings in increased agricultural R&D and non-distorting income support for small farmers.	MOA and the local governments cooperate in facilitating the transition process. MOF determines the fiscal savings from the phase-out of subsidies and reallocates these to increased agricultural R&D and income support for small farmers.	

Policy Action	Short Term (1–2 years)	Medium Term (3–4 years)	Long Term (5–6 years)
8. Strengthening the security of land and water rights	MOA and MRTHE work together to scale up partnership initiatives for consolidated land management.	MOA and MRTHE encourage students in their final year to serve as facilitators empowering smallholder farmers for consolidated land management and contributing to the capacity building of farmers' organizations.	
	MOA and MPWH develop incentive systems for investment in more efficient water management technology to ensure benefits for farmers.	MOA and MPWH work together for institutional improvements in irrigation systems management, and for WUA improvements. MOA and MPWH improve the seasonal allocation of water, together with registration of water rights.	MOA and MPWH develop improved irrigation technology for conveyance, diversion, and metering. MOA, MPWH, and BAPPENAS develop procedures for implementing tradable water rights.
9. Phasing out trade restrictions	MOA and MOT work together on policy reforms for trade protection.	MOA aims to generate rice exports through productive investments in the medium to long term once all trade restrictions have been removed.	

BAPPENAS = Badan Perencanaan Pembangunan Nasional (National Development Planning Agency); CMEA = Coordinating Ministry for Economic Affairs; ICT = information and communication technology; MCIT = Ministry of Communication and Information Technology; MLHR = Ministry of Law and Human Rights; MOA = Ministry of Agriculture; MOEC = Ministry of Education and Culture; MOF = Ministry of Finance; MOHA = Ministry of Home Affairs; MOT = Ministry of Trade; MPWH = Ministry of Public Works and Housing; MRTHE = Ministry of Research, Technology and Higher Education; MSOE = Ministry of State-Owned Enterprises; O&M = operation and maintenance; R&D = research and development; WUA = water users association.

Appendix: Subsectors in the Dynamic Economy-Wide Model for Indonesia

No.	Subsector
1	Maize
2	Rice
3	Other cereals
4	Pulses
5	Groundnuts
6	Other oilseeds
7	Cassava
8	Irish potatoes
9	Sweet potatoes
10	Other roots
11	Leafy vegetables
12	Other vegetables
13	Sugarcane
14	Tobacco
15	Cotton and fibers
16	Nuts
17	Bananas and plantains
18	Other fruits
19	Leaf tea
20	Coffee
21	Cocoa
22	Cut flowers
23	Rubber
24	Other crops
25	Cattle
26	Raw milk
27	Poultry
28	Eggs
29	Small ruminants
30	Other livestock

No.	Subsector
31	Forestry
32	Aquaculture
33	Capture fisheries
34	Coal and lignite
35	Crude oil
36	Natural gas
37	Other mining
38	Meat processing
39	Fish and seafood processing
40	Dairy
41	Fruit and vegetable processing
42	Fats and oils
43	Maize milling
44	Sorghum and millet milling
45	Rice milling
46	Wheat and barley milling
47	Other grain milling
48	Sugar refining
49	Coffee processing
50	Tea processing
51	Other foods
52	Animal feed
53	Beverages
54	Tobacco processing
55	Cotton yarn
56	Textiles
57	Clothing
58	Leather and footwear
59	Wood products
60	Paper products and publishing

No.	Subsector
61	Petroleum products
62	Fertilizers and herbicides
63	Other chemicals
64	Non-metal minerals
65	Metals and metal products
66	Machinery and other equip.
67	Electrical equipment
68	Vehicles and transport equip.
69	Other manufacturing
70	Electricity, gas, and steam
71	Water supply and sewerage
72	Construction
73	Wholesale and retail trade
74	Transportation and storage
75	Accommodation
76	Restaurants and food services
77	Information and communication
78	Finance and insurance
79	Real estate activities
80	Business services
81	Public administration
82	Education
83	Health and social work
84	Other services

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Policies to Support Investment Requirements of Indonesia's Food and Agriculture Development during 2020-2045

Agriculture in developing countries faces major economic, institutional, environmental challenges. Prioritized investments in different areas are required to face these challenges. The analysis of the investment and policy required to achieve food security targets in Indonesia is the subject of this report. The analysis projected different key indicators under different agricultural scenarios and analyzed their impacts. By evaluating the economy-wide impacts of the alternative agricultural scenarios, the study prioritized the need of investment in different agricultural subsectors.

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