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REORIENTING PUBLIC AGRICULTURE AND FOOD RESEARCH AND DEVELOPMENT FOR ACHIEVING SUSTAINABLE, NUTRITIOUS, AND CLIMATE RESILIENT FOOD SYSTEMS IN INDONESIA




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REORIENTING PUBLIC AGRICULTURE AND FOOD RESEARCH AND DEVELOPMENT FOR ACHIEVING SUSTAINABLE, NUTRITIOUS, AND CLIMATE RESILIENT FOOD SYSTEMS IN INDONESIA

Tahlim Sudaryanto, BRIN

Achmad Suryana, APPERTANI

Iqbal Rafani, APPERTANI

Wahida, ICASEPS-MoA

Helena J. Purba, BRIN

Rangga Ditya Yofa, ICASEPS-MoA

Sheila Savitri, ICASEPS-MoA

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PREFACE

Food and agriculture sector is confronted with the global challenges related to climate change, environment, and nutrition. The sector should also meet the target of Sustainable Development Goals (SDGs) toward the year of 2030. Indonesia's agriculture has shifted from food crops toward high-value and commercial commodities. On consumption side, similar trend has occurred on the increasing trend on consumption of horticulture, fishery and livestock products. Agriculture R&D has a role to play in supporting these dynamic changes on the food and agriculture sector.

This research aims to propose recommendations on reorienting future agriculture R&D responding to the emerging challenges on global and domestic food and agriculture. The data was collected mainly from Indonesian Agency for Agricultural Research and Development (IAARD), other related Ministries/Agencies, Universities, and the private sector. Quantitative data was enriched by interviews with selected experts from research centers and universities. Two validation meetings of the draft reports were organized to seek comments and responses from key stakeholders, namely BRIN, Ministry of Agriculture, Ministry of Finance, Bappenas, Universities, and international agencies.

The research team wish to thank related agencies who provided data, information and sharing policy insight, in particular IAARD Secretariate and research institutes, some public universities, and representative of the private sector. Special appreciation is extended to Syngenta Foundation for Sustainable Agriculture for providing financial and advisory support to implement this research. Appreciation is also extended to the manajemen of Appertani for coordination and administrative support.

Finally, we hope that the result and recommendation of this research contributes to the process of reorienting food and agriculture R&D in responding to the emerging challenges.

Bogor, 24 November 2022

Tahlim Sudaryanto
Research Team Leader

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ABREVIATIONS AND ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
APBN	*Anggaran Pendapatan dan Belanja Negara* (State-owned Budget)
Appertani	*Aliansi Peneliti Pertanian Indonesia* (Indonesian Agricultural Researcher's Alliance)
ASEAN	Association of South East Asian Nations
ASTI	Agricultural Science and Technology Indicators
Bapanas	*Badan Pangan Nasional* (National Food Agency/NFA)
Bappenas	*Badan Perencanaan Pembangunan Nasional* (National Development Planning Agency)
Batan	*Badan Tenaga Nulir Nasional* (National Nuclear Energy Agency)
BI	Bank of Indonesia
BKP	*Badan Ketahanan Pangan* (Food Security Agency)
BP POM	*Badan Pengawas Obat dan Makanan* (Agency of Drug and Food Control/ADFC)
BP2TP	*Balai Pengkajian dan Pengembangan Teknologi Pertanian* (Indonesian Center for Agricultural Technology Assessment and Development/ICATAD)
BPPT	*Badan Pengkajian dan Penerapan Teknologi* (Agency for Assessment and Application of Technology)
BPS	*Badan Pusat Statistik (Central Bureau of Statistics)*
BPTP	*Balai Pengkajian Teknologi Pertanian* (Assessment Institutes for Agricultural Technology/AIAT)
BRIDA	*Badan Riset dan Inovasi Daerah* (Regional Research and Innovation Agency)
BRIN	*Badan Riset dan Inovasi Nasional* (National Research and Innovation Agency)
BSIP	*Badan Standarisasi Instrumen Pertanian (*Agency for Agriculture Standardized Instruments)
Bulog	*Badan Urusan Logistik* (State Logistic Agency)
BUMD	*Badan Usaha Milik Daerah* (Regional-owned Enterprises)
BUMN	*Badan Usaha Milik Negara* (State-owned Enterprises)
CGIAR	Consultative Group on International Agricultural Research
DG	Directorate General
FAO	Food and Agriculture Organization
FIES	Food Insecurity Experience Scale
FOLU	Food and Land Use Coalition
GDP	Gross Domestic Product
GoI	Government of Indonesia
IAARD	Indonesian Agency for Agricultural Research and Development

IAAEHRD	Indonesian Agency for Agricultural Extension and Human Resources Development
IDR	Indonesian Rupiah (Indonesian currency)
IFPRI	International Food Policy Research Institute
IRRI	International Rice Research Institute
ICADIS	Indonesian Center for Agricultural Data and Information System
ICASEPS	Indonesian Center for Agricultural Socioeconomic and Policy Studies
Kemen ATR/BPN	*Kementerian Agraria dan Tata Ruang/Badan Pertanahan Nasional* (Ministry of Agrarian Affairs and Spatial Planning/National Land Agency/MoAASP-NLA)
Kemen BUMN	*Kementerian Badan Usaha Milik Negara* (Ministry of State-Owned Enterprises/MoSOEs)
Kemen PUPR	*Kementerian Pekerjaan Umum dan Perumahan Rakyat* (Ministry of Public Works and Housing Profile/MoPWHP)
Kemendag	*Kementerian Perdagangan* (Ministry of Trade/MoT)
Kemenkeu	*Kementerian Keuangan* (Ministry of Finance/MoF)
Kemenperin	Kemeterian Perindustrian (Ministry of Industry/MoI)
Kemenristek Dikti	*Kementerian Riset Kementerian Riset, Teknologi, dan Pendidikan Tinggi* (Ministry of Research, Technology, and Higher Education/ MoRTHE)
Kementan	*Kementerian Pertanian* (Ministry of Agrculture/MoA)
KKP	*Kementerian Kelautan dan Perikanan* (Ministry of Marine Affairs and Fisheries/MoMAF)
KLHK	Ministry of Environment and Forestry (MoEF)
KUB	*Kampung Unggul Balitbangtan* (Kampung Superior Chicken Agency for Agricultural Research and Development)
Lapan	*Lembaga Penerbangan dan Antariksa Nasional* (Indonesia's National Institute of Aeronautics and Space)
LIPI	*Lembaga Ilmu Pengatahuan Indonesia* (Indonesian Institute of Sciences)
LPTP	*Loka Pengkajian and Penerapan Teknologi* (Assessment Locus for Agricultural Technology)
MoA	Ministry of Agriculture
MoT	Ministry of Trade
NARS	National Agricultural Research Systems
NFA	National Food Agency
NGO	Non-Government Organization
NP	National Program
NTB	*Nusa Tenggara Barat* (west Nusa Tenggara)
OECD	Organization for Economic Co-operation and Development
PNBP	*Penerimaan Negara Bukan Pajak* (Non-Tax State Revenue)
PoU	Prevalence of Undernourishment
PP	Priority Program

PSBB	*Pembatasan Sosial Berskala Besar* (Large-scale Social Restriction)
Pusdatin	*Pusat Data dan Sistem Informasi Pertanian* (Center of Data and Agricultural System Information)
R&D	Research and Development
RC	Research Center
RO	Research Organizations
RPJMN	*Rencana Pembangunan Jangka Menengah Nasional* (National Medium-Term Development Plan)
Sakernas	*Survei Tenaga Kerja Nasional* (National Labor Force Survey/Sakernas)
SDGs	Sustainable Development Goals
Sisnas Iptek	*Sistem Nasional Ilmu Pengetahuan dan Teknologi* (National System of Science and Technology)
SPI	*Sistem Pengawasan Internal* (Internal Control Unit)
Susenas	*Survei Sosial Ekonomi Nasional* (National Socioeconomic Survey)
UB	*Universitas Brawijaya* (Brawijaya Universiaty)
Unej	*Universitas Jember* (Jember University)
UNFSS	United Nations Forum on Sustainability Standards
Unhas	*Universitas Hasanuddin* (Hasanuddin University)
Unpad	*Universitas Padjadjaran* (Padjadjaran University)
USD	United States Dollar (United States currency)

EXECUTIVE SUMMARY

The agriculture sector is the backbone of the Indonesian economy as it can increase farmers' welfare, reduce poverty, and support manufacturing sector growth. It is also key to food and nutrition security. Agricultural practices today have to comply with sustainable development principles and support the pillars of the Sustainable Development Goals (SDGs) targeted to be achieved by 2030, one of which is 'no poverty and zero hunger'. Achieving this goal depends on food provision and agricultural performance, which rely on technological change, markets, institutions, climate change mitigation, and government policies.

Indonesia has shifted the structure of agricultural production from traditional to modern agriculture with higher value, more commercialized, and market-oriented commodities. The agriculture sector in Indonesia needs to be transformed to meet the consumption demand of the growing population and provide safe and healthy food, with a balanced nutritional composition and high economic value. The government plays a major role in agricultural innovation through investment in agriculture research and development (R&D). Both public and private sectors create a mutually exclusive function in developing basic research and innovation, as well as improving the dissemination process. Public R&D in Indonesia was led by National Agricultural Research Agency (BRIN) or the Indonesian Agency for Agriculture Research and Development (IAARD) on the agricultural side and other regional and local research organizations. Meanwhile, the private sector focuses more on product research and market delivery.

The main R&D development policy areas of IAARD were directed to science and technology, comprising three activities: (1) Plant, livestock, and veterinary; (2) Agricultural resource systems; and (3) Agricultural technology development. This agency also supported the provisions of technology packages and policy recommendations, as well as the planning, implementation, and assistance with various strategic program policies by the Ministry of Agriculture (MoA).

Over a decade (2010-2020), the budget allocated for national R&D spending was extremely low (less than 0.2% of the agricultural GDP or less than 0.01% of the national GDP), which was dominated by the public budget. The R&D budget contributions from the private sector and overseas funding (grants and loans) were insignificant. Over six years (2015-2020), in terms of thematic areas, agricultural R&D spending focused on developing breeding technology. Regarding impact areas, the focus was on increasing productivity.

Smallholder farmers and food consumers face gaps that are not addressed by the current public R&D system. Small-scale farmers face limitations in procuring productive assets, financing, adopting new technologies and innovations, and accessing input and output markets. In other words, making new technology available alone will not suffice. The production of new technology should be coupled with effective dissemination mechanisms. Meanwhile, the challenges faced by food consumers include low purchasing power, food price instability, and lack of knowledge about quality food.

In 2019, Indonesia established *Badan Riset dan Inovasi Nasional* (BRIN), or the National Research and Innovation Agency, which coordinates all R&D programs across sectors. During the transformation of IAARD into BRIN, streamlining input and communication with the MoA has also become a challenge. More importantly, amid this transformation, farmers should be the center of agricultural R&D activities.

Major gaps in agriculture R&D which need to be addressed are: (1) Inadequate research funding; (2) Disproportionate budget allocation across commodities and thematic areas in responding to emerging challenges; (3) Barriers to the adoption of innovation by small-scale farmers; (4) Gaps in food consumption patterns that hinder the achievement of food security and nutrition fulfillment; (5) Unestablished R&D dissemination mechanism across working units in BRIN; and (6) Tenuous connection and coordination between BRIN and line ministries as partners in formulating agriculture R&D strategies and delivering agricultural R&D results.

To address these gaps, the research team proposed seven major recommendations to strengthen the research ecosystem. ***First***, the Government of Indonesia needs to increase research funding to reach around 0.56% of agriculture GDP in 2030, in order to strengthen agriculture R&D and promote evidence-based policy. Creating enabling ecosystems for researchers is imperative in order to advance agriculture technology and provide information for users (farmers and private sectors/industries). ***Second***, given that the dominant budget source is from the government, there is an urgency to diversify research funding sources from the private sector, philanthropists, and donor agencies. Recommended actions to promote this include: (1) Implementing the levy systems; (2) Developing multi-stakeholder partnerships involving the private sector to generate market-based innovation research; and (3) Enhancing networking with international funding sources. ***Third***, based on the current R&D budget structure, we propose to increase share of budget allocations for public agriculture across strategic thematic areas and commodities. ***Fourth***, the delivery system of public R&D to the farmers needs to be improved, including the mechanism of agricultural technology transfer from BRIN to small-scale farmers. ***Fifth***, it is of strategic importance to strengthen the delivery system of agricultural technology and innovation from its sources (such as BRIN, universities), channeling through ministries/agencies to end users, particularly farmers. ***Sixth***, to improve the research ecosystem, new strategies, coordination, and communication platform inside BRIN have to be developed fully. ***Seventh***, at the current phase of R&D system transformation, finalizing connection and coordination between the BRIN and line ministries/agencies is key to formulating agriculture R&D strategies and utilizing agricultural R&D results. Recommended actions include: (1) Strengthening the governance system by establishing an advisory board of the research organization; (2) Finalizing the research systems transformation from line ministries/agencies to BRIN; (3) Developing a partnership strategy and communication platform to transmit technology and innovation from BRIN to technical units at MoA.

In response to the emerging issues on environment sustainability, climate resilient, nutrition, and agricultural transformation, it is advisable to prioritize future research agendas in the two areas. The first is thematic research on climate resilience, environment, and nutrition. This recommendation is in line with BRIN's current priorities to strengthen research on the green economy, blue economy, and digital technology by utilizing the circular economy approach. The second is commodity research areas to support agricultural transformation on commodities, shifting from food crops to high-value commodities. The selection of prioritized commodities should be based on the foresight analysis providing sound information on the economic prospects of the corresponding commodities.

CHAPTER ONE

INTRODUCTION

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INTRODUCTION

1.1. Background

The agriculture sector is the backbone of economic systems in many countries as it produces food to supply the market demands and provides employment for rural populations. Two indicators of Sustainable Development Goals (SDGs), i.e., ‘no poverty’ and ‘zero hunger’, are also directly linked to food and agriculture. Therefore, optimizing agricultural performance is the key to improving welfare and the economy, which relies heavily on technological change, markets, institutions, climate change, and government policies.

However, the current global trends in agricultural and food systems are heading in the wrong direction. If this continues, the SDGs and the Paris Agreement targets will be out of reach, and the collective actions spanning decades may go to waste. The way food is produced globally threatens climate stability and ecosystem resilience. It remains the single most significant driver of environmental degradation and transgression of planetary boundaries (FOLU, 2019; EAT-Lancet, 2019, as cited in Syngenta Foundation, 2021), with consequences including land degradation, water and soil pollution, biodiversity loss, and deforestation. The current production methods consume non-renewable energies and emit large volumes of greenhouse gases. Despite the high investment, large quantities of good food are wasted along the value chains between farmers’ fields and consumers’ waste bins.

The three problems related to food provision (the triple burden) are hunger, micronutrient deficiency, and overweight and obesity. The Green Revolution has helped feed billions of people in Asia, but micronutrient deficiency remains a challenge. Globally, about two billion people suffer from micronutrient deficiencies (Ritchie and Roser, 2017). On top of this is a problem caused by the degradation of natural resources, such as water, land, and agro-biodiversity.

In Indonesia, food is considered: (1) An essential human need, so its fulfilment is part of human rights; (2) An obligation of the state, so the availability, stability, affordability, and fulfilment of sufficient, safe, balanced nutrition need to be guaranteed; and (3) A demand to be supplied by domestic production. The third concept is termed food self-sufficiency (GoI, 2012; MoA, 2020; BKP, 2020). Indonesia set this policy because the country has a large population and rich and diverse natural resources. The Indonesian national medium-term development plan (RPJMN) states that the first out of seven national programs, called National Program-1 (NP-1), aims to strengthen economic resilience for quality and equitable growth. One of the NP-1 targets aligns with the SDG Priority Program-3 (PP-3), namely increasing availability, access, and quality of food consumption (GoI, 2020).

The sector contributed 13.70% to Indonesia’s Gross Domestic Product (GDP) in 2020[1] (GoI, 2020), with the highest sub-sector attribution from forestry, fishery, and agriculture

[1] The total GDP of Indonesia in 2020 exchange rate (USD1 = IDR14,105) was about IDR16,434.20 trillion or USD1.17 trillion.

services[2] (3.70%), followed by estate crops (3.63%), food crops (3.07%), livestock (1.68%), and horticulture (1.62%). At face value, these numbers seem significant, but in the last three decades, the agriculture sector's contribution to GDP declined from 21.5% in 1990 to 13.70% in 2020. Regarding employment, the food crops sub-sector absorbed 43.34% of the total labor in agriculture, estate crops 33.26%, livestock 12.29%, and horticulture 11.11%. Likewise, the total employment in the sector decreased from 51% in 1990 to 33% in 2020 (Sudaryanto *et al.*, 2021). This observation indicates that the decrease in the agricultural sector's contribution to GDP was faster than the decline in the share of labor absorption.

The role of agriculture in the national economy during the pandemic was significant, providing a cushion to mitigate the impacts. In 2020, the country's economic growth was -2.07% (c-to-c), mostly attributable to the sharp declines in the transportation, tourism, and manufacturing sectors. Meanwhile, the agriculture sector managed to increase by +1.75%. In the rural areas, the sector became social safety net for temporary unemployed workers.

In terms of welfare, GDP per capita in the agricultural sector from 2016 to 2020 increased about 5.12% per year, namely from IDR44.25 million (USD3,137) to IDR53.33 million (USD3,781). The data indicate that farmers' welfare on a national level has been improving (BPS, 2021). Nevertheless, this does not mean that income has been well distributed because 46.30% of the total number of poor households in Indonesia in 2020 came from the agriculture sector (ICADIS, 2020); BPS, 2021). As of 2020, the poverty rate in Indonesia reached 11.2%, which means about 28.6 million out of the 272 million total population.[3] The rate in the agriculture sector is claimed to have declined from 12.7% in 2000-2009 to 8.2% in 2010-2018 (Sudaryanto *et al.*, 2021), but the eradication effort needs to continue, especially in the post-pandemic era because households may have fallen back to the poverty line due to the lower economic growth.

Regarding production, Indonesia has shifted from staple food and low-value agriculture to high-value and commercialized commodities, such as horticulture, estate crops (such as palm oil, cocoa, rubber, coffee, etc.), and livestock. This transformation also changes farmers' orientation from mere subsistence to more commercialized and market-oriented (Sudaryanto *et al.*, 2021).

In terms of food security, progress has also been observable. In the 2015-2019 period, the prevalence of undernourishment (PoU) declined from 10.73% to 7.63%. Likewise, the stunting rate decreased from 37.2% in 2013 to 27.6% in 2019. The prevalence of people with moderate and severe food insecurity as measured by the food insecurity experience scale (FIES) between 2017 and 2019 also decreased from 8.66% to 5.42% (an annual decline of 1.62%). However, this positive trend was disrupted by the COVID-19 pandemic, pushing the PoU to 8.34% in 2020, which is higher than in 2017. Meanwhile, the value of FIES in 2020 was lower than the previous year (5.12%). This positive trend was attributable to the

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[2] Agricultural service businesses are activities carried out by individuals and business entities based on remuneration or contracts, which include land management, irrigation, fertilisation, rental of agrarian equipment with operators, seed distribution, control of plant-disturbing organisms, pruning, harvesting, post-harvest handling, grass-seeking services for fodder, livestock grazing, livestock health services, shearing, stud rental, egg hatching, and maintenance of agricultural equipment (BPS, 2021)

[3] National poverty line in Indonesia is defined as the amount of money required to obtain 2,100 kcal of food per day per person along with small amount for other basic non-food items (BPS, 2022)

government's social safety nets in the form of cash transfers and food distribution to low-income households and those who lost their jobs during the pandemic (Bappenas, 2021).

The government of Indonesia (GoI) has set program priorities, indicators, indicative budgets, locations, ranks of importance, and implementing institutions based on the RPJMN of 2020-2024. The agricultural sector proposes 12 programs, with the highest budget allocation for increasing production, productivity, and quality of food crop products, as well as providing infrastructure and facilities. These programs account for 53% of the total MoA budget. This budget allocation shows that agriculture remains an important sector of the Indonesian economy. It is prioritized to ensure food and nutrition security and farmers' welfare, reduce poverty, and support the manufacturing sector's growth.

In any case, the development of agriculture should follow the sustainability principle. For example, research and development (R&D) can develop technology and innovation adapted to the local context. This is possible if the agricultural research management is sound and the funding sufficient. Currently, the GoI is reforming its research management system towards more integration by, among others, establishing the National Research and Innovation Agency (BRIN). Concerning the R&D budget, according to Stads *et al.* (2003), Indonesia's spending on agriculture declined in the past decade until 2017 (in inflation-adjusted terms), from 0.48% of the total agriculture GDP in 2004 to 0.17% in 2017. This is the lowest percentage of research spending among ASEAN counties, such as Malaysia (0.85%), Thailand (0.94%), and Viet Nam (0.20%). Meanwhile, the share of agriculture R&D spending of the total expenditure of the Indonesian Ministry of Agriculture (MoA) was about 8% per year during 2010-2020.

The RPJMN 2020-2024 also indicates that MoA implements 12 programs according to the directorate general (DG) level organization. The Indonesian Agency for Agricultural Research and Development (IAARD) manages a sustainable agricultural bio-industry and technology innovation program, with a budget allocation of around 6.09% (of the MoA's total budget) (see Table 1.1). In 2021, the MoA simplified the development programs into five categories: 1) availability, access, and quality of food consumption, 2) value-added and industry competitiveness, 3) research and innovation of science and technology, 4) education and vocational training, and 5) management support. The IAARD implements programs under the third category (MoA, 2021).

Table 1.1. Agricultural program and indicative budget[4] in the RPJMN 2020-2024

Program	(%)
Management and implementation support to technical tasks of MoA	2.33
Supervision and enhancement of the accountability of apparatus of MoA	0.39
Increase production productivity and quality of food crop products	34.05
Production and value-added of horticulture production improvement	6.19
Sustainable production development of the estate crops products	7.69
The food supply of animal origin and community livestock agribusiness	8.52

[4] The indicative budget can be updated through Government Work Plan by considering: (1) Readiness and implementation capacity; (2) Availability and budget sources; and (3) Involvement of local government, business entities, and community. Moreover, the paradigm of indicative funding framework in the RPJMN 2020-2024 is prioritized through public-private partnerships. Therefore, it involves the private sector and state/local-owned enterprises (*Badan Usaha Milik Negara/Daerah-BUMN/D*), while total government financing is the last choice.

Table 1.1. Continued…

Program	(%)
Infrastructure and facilities development provisions	19.34
Sustainable agricultural bio-industry and technology innovation creation	6.09
Community food security and diversification improvement	5.41
Agricultural extension and training	3.80
Agricultural quarantine quality and bio-safety control enhancement	2.74
Agricultural education	3.44
Total	**100.00**

Source: GoI, 2020

1.2. Rationale

Sustainable agriculture development must be implemented, and agri-food systems must be transformed to achieve food and nutrition security. This transformation will require innovation, driven by the needs of farmers, consumers, and environmental sustainability. Agriculture R&D has a vital role in creating technologies and innovation. However, investments in agri-food system R&D in Indonesia need support from the public and private sectors. Therefore, new approaches to innovation cooperation between governments, businesses, and agricultural organizations are needed.

At the global level, the current agriculture innovation system is split between the private sector undertaking commercial research in food and agribusiness industries and the public sector comprising the Consultative Group on International Agricultural Research (CGIAR), universities, National Agricultural Research Systems (NARS), and other regional and local research organizations. The private sector focuses more on product research and delivering products to market, while the public concentrates on basic and applied research.

Certain gaps in the agri-food system, such as issues facing poor farmers, people, and communities, are not likely to be a priority for the private sector because of the low-value creation potential. Therefore, the public sector innovation system must address these gaps from a food and nutrition security perspective. The recent call to action to double funding for the CGIAR system seems appealing and perhaps necessary, but this is only one dimension of the problem (TRFN, 2019, as cited in Syngenta Foundation, 2021). Another challenge is to deliver the research impacts and implications to farmers and consumers. This is because promising research results may not reach the relevant stakeholders due to the lack of connections.

Developing countries need more responsible research and innovation. Past attempts within the global food systems seem to have intensified the triple burden instead of reducing it. After all, innovation is a double-edged sword rather than simply beneficial (TRFN, 2019, as cited in Syngenta Foundation, 2021). In other words, countries will benefit from reflections on the recommended direction along with the assessment of the risks and benefits. In the context of innovations in products and services to tackle issues faced by poor farmers and consumers, a more integrated agri-food system is needed. The question remains how public agriculture and food R&D in developing countries should be reoriented and supported. Answering this question should consider the fact the reform of national R&D and food system management in Indonesia is currently underway.

With these strategic environments in the background, this study aims to shed light on the past and current foci of public agriculture and food R&D agenda, significant shifts and trends in both public and private research spending at the national level, and food system management in Indonesia. From those findings, this study seeks to provide policy recommendations on reorienting the future national R&D agenda. The outcome is expected to address the farmers' needs on technologies and innovations and consumers' preferences, handle sustainability and climate resilience needs, and lay down the foundation and actions for making the shift and promoting corresponding investment and policy changes.

Reorienting public food and agriculture development in collaboration with other relevant stakeholders, including the private sector, is imperative to achieve sustainable and climate-resilient food systems. The partnership can be built through the private sector's core businesses, considering inter-sectoral linkages and value chains, using novel techniques and data sources (OECD, 2021).

1.3. Objectives

This study aims to understand public research activities and funding to support innovations that will tackle the gaps in the agri-food system in Indonesia. Specifically, the objectives of this study are as follows:

1. Identifying the current major initiatives, spending levels, and drivers of public and private R&D spending on food and agriculture;
2. Investigating the gaps being faced by poor farmers and consumers that are not supported by the current system; and
3. Delivering recommendations on the priorities to tackle these gaps and direct the shift in the public R&D management to deliver on those priorities.

CHAPTER TWO

METHODOLOGY

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METHODOLOGY

2.1. Conceptual Framework

The conceptual framework of this study consists of four pillars: (1) Laws and regulations that govern activities; (2) Resources such as the natural, human, and capital resources; (3) Infrastructure and facilities that support social change and development; and (4) Institutions and organizations for activity implementation, development, and supervision (Figure 2.1).

Figure 2.1. Conceptual framework of the study

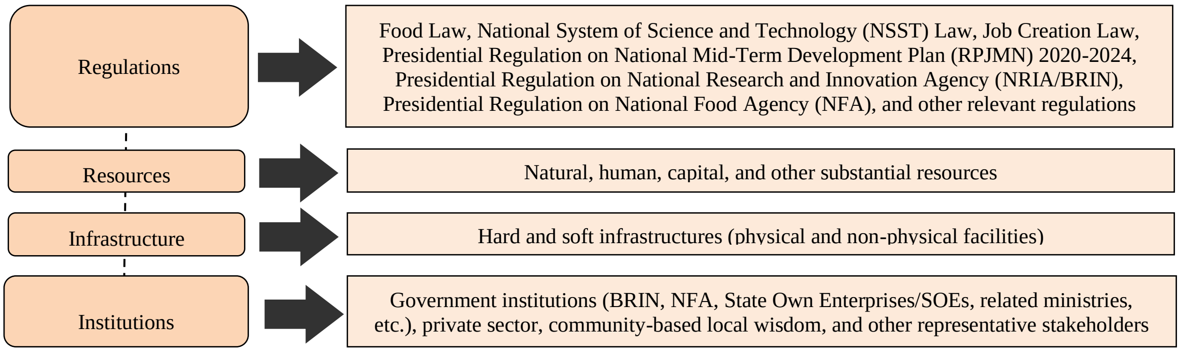
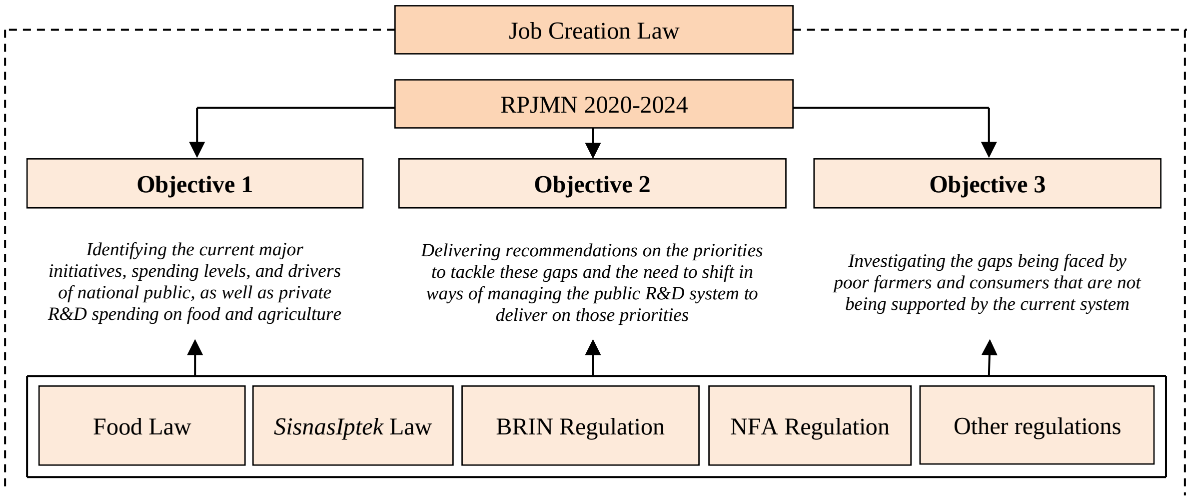


Figure 2.2 illustrates the direct and indirect regulations related to the study's objectives, and Box 2.1 elaborates on the regulations' descriptions. Among these regulations, the role of the National System of Science and Technology (NSST) is the most fundamental element. Its goal is to create relationships that form a planned, directed, measurable, and sustainable linkage between institutional elements and resources so that science and technology become a unified network that forms the basis of national development policies.

Figure 2.2. Direct and indirect regulations related to the objectives of the study



Box 2.1. Relevant Regulations of the Study

Presidential Decree Number 45/1974 on the Establishment of Indonesian Agricultural Research and Development (IAARD)
This decree underpinned the establishment of IAARD on 26 August 1974. The institution managed 12 echelons-two institutions consisting of one secretariat, four centers (program preparation, statistical data processing, biological and agricultural quarantine facilities, and agricultural libraries), two research centers (soil and agro-economic), and five development research centers (food crops, industrial crops, forestry, livestock, and fishery).

Law Number 18/2012 on Food (Food Law)
This law emphasizes the state's obligation to achieve availability and affordability of foods and fulfilment of consumption needs. Aside from sufficient quantity, food consumption must be safe and nutritionally balanced. The food security targets are national and local, covering all individuals equally in all territories at all times, utilizing local resources, institutions, and culture (GoI, 2012).

Law Number 11/2019 on National System of Science and Technology (NSST Law)
This law regulates the national science and technology system to support national development policies, achieve national goals, and increase competitiveness and independence (GoI, 2019).

Law Number 11/2020 on Job Creation
This law supports the creation of job opportunities through the facilitation, protection, and improvement of the investment ecosystem based on equality, legal certainty, ease of doing business, amity, and independence principles in order to accelerate the national strategic projects (GoI, 2020b).

Presidential Regulation Number 18/2020 on the 2020-2024 National Medium-Term Development Plan
This regulation comprises national development strategies, general policies, strategic priority programs/projects of ministries/institutions and cross-ministries/institutions, regional and cross-regional development directions, and development priorities (GoI, 2020a).

Presidential Regulation Number 78/2021 on National Research and Innovation Agency (BRIN)
This regulation governs various research institutes, such as the Indonesian Institute of Science (IIS), National Nuclear Energy Agency (NNEA), Indonesian Aeronautics and Space Agency (IASA), Agency for Assessment and Application of Technology (AAAT), and research agencies in 48 ministries/agencies that have been merged into BRIN. With an IDR26 trillion budget allocated by the government for research per year and a large number of researchers, BRIN is expected to boost national research and innovation and help the country equalize with other countries in Asia, such as Singapore and South Korea (Burhani *et al.*, 2021).

Presidential Regulation Number 66/2021 on National Food Agency (NFA)
This regulation governs NFA in coordinating, formulating, stipulating, and implementing policies on food availability, stabilizing food supply and prices, reducing food and nutrition insecurity, diversifying food consumption, and improving food safety (GoI, 2021).

Indonesia is now restructuring the institutions and reforming the national research and food system management. ***First***, R&D activities that were previously carried out by sectoral ministries and institutions are now merged into a national institution called the National Research and Innovation Agency (BRIN)[5], based on Presidential Regulation Number 78/2021 (GoI, 2021) mandated in Law Number 11/2019 on the National System of Science and Technology (GoI, 2019). ***Second***, for the national food system development, the government established the National Food Agency (NFA) as mandated by Presidential Regulation Number 66/2021 (GoI, 2021a).

[5] BRIN is a government agency under the President's direct supervision. This agency's task is to integrate R&D and promote inventions and innovations. This task was previously handled by the Ministry of Research and Technology, four non-ministerial government agencies (Indonesian Institute of Sciences/IIS, Agency for Assessment and Application of Technology/AAAT, Indonesian Aeronautics and Space Agency/IASA, and National Nuclear Energy Agency/NNEA), and 48 R&D agencies of the ministries/institutions.

BRIN aims to forge a collaborative culture and network and leverage science and technology in the formulation of national development policies. Prior to the establishment of BRIN, ministries and institutions worked in silos, which led to cost ineffectiveness and overlaps in R&D activities. Integration was needed to improve the current situation. Therefore, one of BRIN's main objectives is to increase the intensity and quality of interactions, partnerships, and synergies between stakeholders in science and technology.

Meanwhile, NFA is tasked to coordinate, formulate, determine, and implement policies on food systems development to achieve food resilience, and nutrition security. Its goal is to address issues in food availability, supply and safety, food and nutrition insecurity, consumption diversification, and price stabilization. Previously, Food Security Agency (FSA) handled some of these tasks under the Ministry of Agriculture (MoA). With NFA, all R&D activities in food development are now centralized. Box 2.2 describes the roles of NFA in more detail.

Box 2.2. National Food Agency (NFA)

Formed through Presidential Regulation Number 66/2021, NFA is a government agency carrying out government duties in the food sector under the direct supervision of the President. Strategic food issues that need to be tactically handled immediately are: (1) Stability of food prices at the producer and consumer levels; (2) Maintenance of food availability across time and regions; (3) Formulation of food importation policies; (4) Achievement of food and nutrition security; and (5) Guarantee of the safety of traded or distributed food. The Presidential Regulation determines nine food commodities under NFA, i.e., rice, maize, soybeans, sugar (for direct consumption), shallot, chilly, eggs, meat, and chicken. Through this regulation, the FSA-MoA is transformed into NFA.

To carry out these tasks, in the Presidential Regulation Number 66/2021, some authorization by relevant ministries were transferred to NFA, namely: (1) Policy on food importation by the Ministry of Trade; 2) Policy on the volume of food reserve by the Ministry of Agriculture; and (3) Policy on the supervision of State Logistics Agency (Bulog) in food reserve management by the Ministry of State-Owned Enterprises (SOEs). In addition, authority in food price formulation is also transferred to NFA. Considering these transfers, the first step of NFA in its initial operation should be to consolidate and coordinate with the Ministry of Trade, MoA, Ministry of SOEs, and Bulog. Meanwhile, regarding food safety management, NFA should coordinate with the Agency of Drug and Food Control (ADFC) (Suryana, 2021).

These two new institutions have a ministerial-level status and report directly to the President. They signify strategic changes and reforms of the government institutions related to national R&D and food system management that will significantly influence agricultural R&D management and the achievement of SDGs, especially Goals 1 and 2. Under these circumstances, it is imperative to understand the changes, impacts, and anticipations.

2.2. Scope of the Study

This study focuses on agricultural food systems, comprising strategic commodities, i.e., food crops (rice, maize, soybean), horticulture (pineapple and mango; shallot and chili), estate crops (coffee and cocoa), and livestock (beef and poultry). The coverage of issues and topics to achieve the study objectives can be seen in Table 2.1.

Table 2.1. Objectives, issues, and topics of the study

Objective	Issue/Topic
1. Identifying the current major initiatives, spending levels, and drivers of public and private R&D spending on food and agriculture	▪ Food and agriculture R&D management - Past (up to 2020) food and agriculture R&D management on technology invention and delivery system from the agricultural research system to farmers; and - Prospective food and agricultural R&D management and technology delivery system from the agricultural research system to farmers (integration of national R&D system under BRIN) ▪ Areas and objectives of development policies that have implications on agriculture R&D in Indonesia: - The implication of national policy in the 2020-2024 Medium-Term National Development Plan (RPJMN) on food and agriculture R&D management - The implication of policies and programs from the MoA Strategic Plan on food and agriculture R&D management; and - Priority areas of public food and agriculture R&D. ▪ Public R&D spending on food and agriculture: - Public R&D spending on agriculture in the past five years allocated to the priority areas, e.g., crops that received most public funding, as well as R&D spending based on their thematic and impact areas, and the trends and shifts in R&D fund allocation; - Percentage of spending on programs that address nutrition, sustainability, and climate resilience issues; and - Mechanism and governance of the fund allocation and their evolutions. ▪ Private sector R&D spending in the past five years ▪ Public and private sectors' roles in agriculture spending: - Differences in fund allocation between public and private sectors; - Types of public and private institutions, their roles and responsibilities, and nature of partnerships in agriculture and food R&D, the incentives for goal achievement, the decision-making within entities and partnerships, and the funding allocation; and - The extent to which the public R&D system develops and delivers products and services that farmers and consumers use.
2. Investigating the gaps faced by poor farmers and consumers that are not supported by the current system	▪ The outcomes of past R&D portfolio in agricultural development, poverty reduction, food and nutrition security, and environmental sustainability; ▪ Problems faced by small-scale farmers due to climate change such as changing ecosystems and temperature increase, environmental issues such as degrading water quality and extreme pest outbreaks, and available technology to cope with these problems; ▪ The types of products in the last five years that have been adopted the most and had the greatest impact on yields and income; ▪ The types of products that did not deliver as expected and the causes; ▪ The shifts in food consumption patterns toward more balance nutrition, well-prepared and 'healthy' foods; ▪ The trends in the fulfilment of food demand by domestic supply and imports in the last five years; and ▪ Policy directions in the next five years regarding small-scale farmers' empowerment based on the Medium-Term National Development Plan (RPJMN) and Agriculture Development Strategic Planning; and the responses to the changes in the agriculture ecosystem, including global agricultural market dynamics.

Table 2.1. Continued…

Objective	Issue/Topic
3. Delivering recommendations on the priorities to tackle the gaps and direct the shift in the public R&D management to deliver on those priorities	▪ Identifying priority areas in public R&D systems to tackle the significant gaps; ▪ Improving the delivery system of public R&D outcomes to farmers and consumers, including the mechanism for technology transfer from BRIN to users/small-scale farmers; ▪ Recommending the need for shifts in public R&D system and management; ▪ Supporting arrangements and incentives for the private sector's involvement in public-private R&D partnerships to create innovative technologies for small-scale farmers; ▪ Formulating necessary steps and actions to realize the shift in the R&D system and management, along with the corresponding investment and policy changes; ▪ Sequencing R&D policy and investment; ▪ Recommending improvement in capacities to guide the reprioritization process effectively; and ▪ Optimizing the roles of government and the private sector in supporting the reorientation of agricultural research and innovation.

2.3. Data and Information Sources and Analyses

The first step of this study's data and information collection was reviewing literature such as academic journals, research reports, and policy documents. These secondary data and information were collected from Indonesian government institutions, including MoA, the Central Bureau of Statistics (*Badan Pusat Statistik*/BPS), and other related institutions. Meanwhile, the primary data and information were collected through in-depth interviews (in person or via call and virtual platforms) with stakeholder representatives from the public and private sectors. The list of stakeholders is presented in Appendix 1. In addition, the research team also conducted fieldwork through ocular surveys and discussions with farmers and other relevant key informants/institutions.

The primary data and information were about the agriculture R&D funding and priority areas, including the achievement of the recent and ongoing agriculture R&D activities nationally and the gaps in their research agenda. Other topics include the direction of future innovation and R&D agenda that gear toward achieving SDGs, aim to meet the local needs, improve rural incomes and livelihoods, ensure nutrition and health, increase equity and inclusion, and mitigate climate change.

Data and information were collected using questionnaires, interview guidelines, field notes, and recording devices. The questionnaires and interview guidelines are presented in separate documents from this report. The data and information were subsequently analyzed using a descriptive method based on the key issues in food and agriculture R&D, i.e., budget allocations, trends, themes, and impact areas. The data and information were compiled to identify the shifts in public R&D management in order to achieve sustainable, sufficient, and climate-resilient food systems in Indonesia. The following mechanisms and assumptions are employed to reach the objectives:

1. The IAARD data and information were collected across its research centers and analyzed based on the available time series. The rationale for focusing mainly on

IAARD data is because food and agriculture R&D projects in Indonesia are predominantly (>90%) managed by IAARD. The R&D budget allocations comprise: a) a general overview of R&D spending (2010-2021), b) contribution of R&D spending to GDP, c) detailed R&D spending (2015-2020), d) R&D spending by sources, e) R&D spending by expenditure types, and f) R&D spending by work units.

2. The R&D spending by sources comprises state-owned budget and non-tax state revenue, as well as grants and loans from donors and other related sources. Meanwhile, R&D spending by expenditure types includes personnel, operation, maintenance, research and technical support, infrastructure, and capital.
3. The R&D spending was clustered into impact areas by analyzing the research titles. The thematic areas were adopted from the Indonesian Ministry of Research Technology and Higher Education (MoRTHE, 2017). Meanwhile, impact areas were examined based on the proposal in this study. The thematic and impact areas were discussed with relevant experts and analyzed descriptively. Table 2.2 and Table 2.3 present the descriptions and output summaries of the thematic and impact areas.

Table 2.2. Thematic areas of R&D spending

Thematic	Description	Output
Breeding technology	Modifying crops and livestock genetics to produce the desired characteristics (superior seeds/breeds) such as short growth period (fast yielding), resistance to pests and diseases, and high production rates	Developed and released varieties
Cultivation and sub-optimal land use technologies	Improving land with low fertility to allow for optimal plant growth by managing nutrients and conserving soil and water	Developed and implemented technologies for cultivation and sub-optimal land use improvement
Post-harvest technology	Achieving optimal efficiency by applying various technologies such as engineering principles in processing, maintaining, manipulating, and maximizing crop production and livestock reproduction	Developed and implemented R&D for post-harvest
Technologies to support food security and self-sufficiency	Supporting food sufficiency in quantity and quality and providing safe, equitable, and affordable food sourced from domestic production	Developed and implemented R&D for food security and self-sufficiency

Table 2.3. Impact areas of R&D spending

Impact	Description	Output
Productivity	R&D activities aiming to improve productivity by increasing crops production and livestock reproduction efficiencies through the use of technology, including plant breeding, cultivation techniques, fertilizing, pests/diseases/weeds control, water management (irrigation), harvest and post-harvest (processing), agri-tech, and other related technical aspects	Area, production, productivity (selected commodities)
Nutrition	R&D focusing on improving the nutritional quality of plants and livestock, including the edible matter's nutrient enrichment and contamination prevention	Dietary energy adequacy, desirable dietary patterns, the prevalence of stunting, etc.

Table 2.3. Continued…

Impact	Description	Output
Climate resilience	R&D aiming to anticipate, respond to, and mitigate hazardous events, trends, or disturbances related to climate by assessing how climate change will create new or alter the current risks and then finding solutions to protect crops and livestock from the risks	Anticipation, mitigation, and other related actions
Environmental sustainability	R&D on natural resources management to restore and prevent soil, water, and land degradation, preserve the environment, and enhance the quality of life	Sustainable environment

4. The R&D spending allocation was also influenced by the dissemination process undertaken by five local selected institutes: the Assessment Institute for Agricultural Technology (AIATs) in the provinces of North Sumatra, West Java, Central Kalimantan, West Nusa Tenggara, and Central Sulawesi.
5. Supporting data and information were collected from other related public institutions (mainly universities) and private sectors.
6. All R&D spending was measured in Indonesian currency (IDR) and converted to US dollars (USD) using the official exchange rate in the corresponding years and deflated by the latest consumer price index (2018=100) to counterbalance the inflation and deflation (Table 2.4). The real R&D spending was also computed by the share ratio to determine the percentage of the trend toward policy intervention.

Table 2.4. Exchange rate and consumer price index, 2015-2020

Year	Exchange Rate (IDR/USD)	Consumer Price Index
2015	13,400	90.80
2016	13.309	93.33
2017	13,380	96.90
2018	14,278	100.00
2019	14,138	103.49
2020	14,556	104.91

Source: BPS, 2015-2020

7. Above all, due to the limited availability of comprehensive data and information, this study's compilation and analysis period considered the last six years, namely from 2015 to 2020. Therefore, it includes an analysis of trends and other factors related to the implementation of R&D within these periods.

2.4. Novelty and Limitation of the Study

This study analyses the public agriculture R&D budget over time and disaggregates funding into strategic commodities and priority thematic areas. The novelty of this study is also reflected in the assessment of the relationship between R&D budget allocation and the impact on agriculture development, food and nutrition security, climate resilience, and environmental sustainability. Data related to the above-mentioned subjects were collected from the public sector, i.e., government institutions, research agencies, universities, the private sector, and non-government organizations. Special efforts were made to approach the private sector since companies were unwilling to share financial data and information, they considered confidential. Meanwhile, non-government, food and agriculture R&D organizations in Indonesia are limited. Some private companies were willing to share limited data and information, including PT Syngenta Indonesia, Indonesian Coffee and Cocoa Research Institute (ICCRI), Pupuk Indonesia Holding Company, PT Bisi International Tbk., and PT East West Seed Indonesia.

CHAPTER THREE

CURRENT MAJOR R&D INITIATIVES AND SPENDING TRENDS

CHAPTER THREE

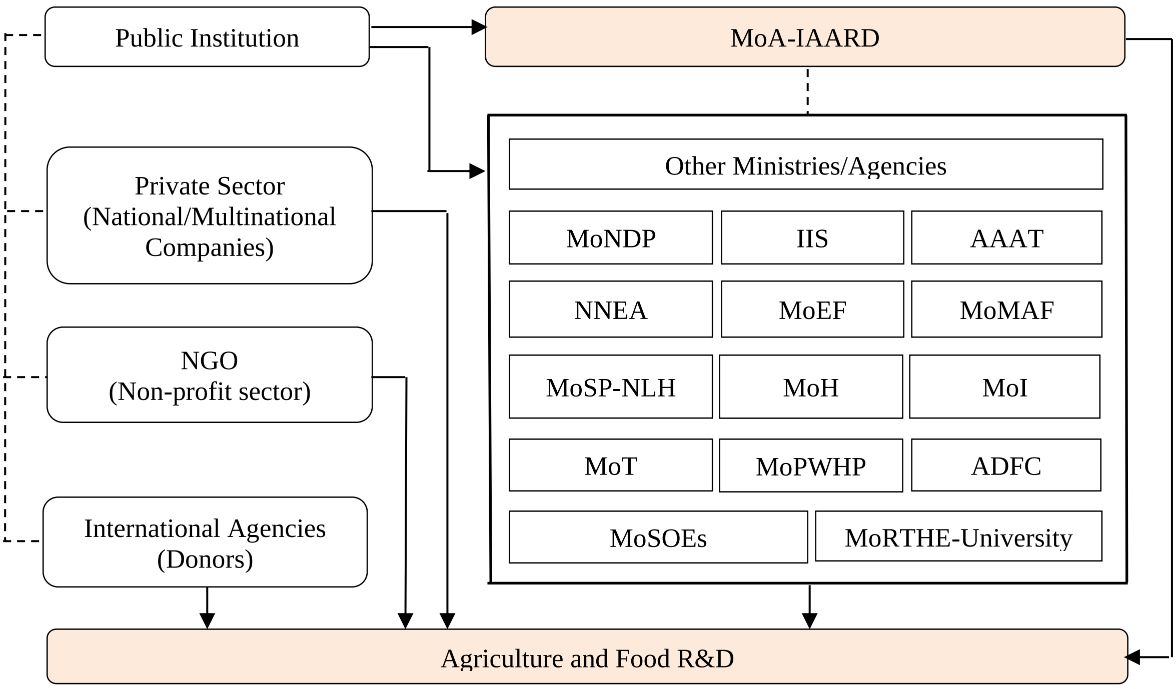
CURRENT MAJOR R&D INITIATIVES AND SPENDING TRENDS

This chapter identifies the current major initiatives and spending trends in agriculture and food R&D in Indonesia. This chapter's organization is as follows: (1) Agriculture and food R&D management; (2) Main objectives and implications of R&D management policies; (3) Public and private R&D roles and spending; and (4) Public R&D management and delivery of products and services to farmers and consumers. Data and information were collected from primary sources, i.e., interviews and focus group discussions with relevant stakeholders, and secondary sources, i.e., documentation such as reports, datasets, and other relevant materials from representative stakeholders and institutions. These sources are supported by fieldwork data, i.e., consultation with experts and discussions with farmers and other relevant informants/institutions about public R&D and product and service delivery to end users.

3.1. Agriculture and Food R&D Management

Agriculture and food R&D in Indonesia are managed by: (1) Public; (2) Private; (3) Non-governmental; and (4) International organizations as shown in Figure 3.1 below.

Figure 3.1 Agriculture and food R&D management in Indonesia before the BRIN



Note: MoA (Ministry of Agriculture); IAARD (Indonesian Agency for Agricultural Research and Development; MoNDP (Ministry of National Development Planning/Bappenas); IIS (Indonesian Institute of Sciences); AAAT (Agency for Assessment and Application of Technology); NNEA (National Nuclear Energy Agency; MoEF (Ministry of Environment and Forestry); MoMAF (Ministry of Marine Affairs and Fisheries); MoSP-NLH (Ministry of Agrarian Affairs and Spatial Planning/National Land Agency); MoH (Ministry of Health); MoI (Ministry of Industry); MoT (Ministry of Trade); MoPWHP (Ministry of Public Works and Housing Profile); ADFC (Agency of Drug and Food Control); MoSOEs (Ministry of State-Owned Enterprises); MoRTHE (Ministry of Research, Technology, and Higher Education); NGO (Non-government Organization)

The public institutions comprise ministries/agencies, with most activities (>90%) conducted by the Ministry of Agriculture (MoA), particularly the Indonesian Agency for Agricultural Research and Development (IAARD). Since its establishment on 26 August 1974, IAARD has undergone several changes and improvements through organizational restructuring and transformation (Box 3.1).

Box 3.1. IAARD Organizational Restructuring and Transformation

1974-1980: IAARD comprised Secretariat, Research Centers for Program Preparation, Statistical Data Center, Agricultural Biology and Libraries, Agricultural Quarantine, Soil, Agroeconomics, Food Crops, Estate Crops, Livestock, Forestry, and Fishery centers.

1981-1986: Following the strategic plans and the demands for agricultural development, the agency reshuffled into Secretariat, Research Centers for Statistical Data, Agricultural Library, Soil and Agro-climate, Agroeconomics, Food Crops, Estate Crops, Horticulture, Livestock, and Fishery units.

1987-1991: IAARD comprised Secretariat and Research Centers for Statistical Data, Agricultural Library and Communication Center, Soil and Agroclimate, Agricultural Social Economics, Food Crops, Estate Crops, Livestock, and Fishery centers. A new center was established: Research Center for Agricultural Equipment and Machinery.

1992-1997: In line with the government's program to streamline and develop the structural and functional positions, IAARD established Assessment Institutes for Agricultural Technology (AIATs) in several provinces of Indonesia.

1998-1999: Research Center for Estate Crops was transferred from IAARD to the Ministry of Forestry and Estate Crops.

2000-2001: Research Center for Fishery was transferred to the Ministry of Marine Affairs and Fishery, and the Center for Agricultural Library and Communication to the MoA's Secretariat General.

2002-2004: Research Center for Agricultural Equipment and Machinery was transformed into the Center for Agricultural Mechanization. The new Center for Biotechnology and Agricultural Genetic Resources and Postharvest, along with two Assessment Institutes for Agricultural Technology in Banten and Bangka Belitung provinces.

2005: Research Center for Soil and Agroclimate was transformed into Research Center for Agricultural Land Resources. Center for Agricultural Social Economics was transformed into the Center for Agricultural Social Economics and Policy Studies. The Research Center for Assessment and Development of Agricultural Technology was also established to coordinate the 28 Assessment Institutes for Agricultural Technology (AIATs) across the country.

2006-2010: Following the changes in the strategic plans, IAARD restructured the organization by increasing some of the centers' echelon status, i.e., Rice, Veterinary, Citrus and Horticultural Sub-tropic, Spices and Industrial Crops, and Environmental Agriculture centers. In 2010, IAARD established two institutions in West Papua province: The Center for Agricultural Technology Transfer Management and AIAT.

2011-2012: IAARD transformed and established Research Units of Palma, Sweeteners, Fibers, Spices and Medicinal Plants, Industrial and Freshener Plants, Center of Cattle and Goat, Center of Tungro Disease, and AIATs in Riau Islands and West Sulawesi.

2013-2014: IAARD comprised Secretariat, Research Centers for Food Crops, Horticulture, Estate Crops, Livestock, Agricultural Social Economics, and Policy Studies, Library and Agricultural Technology Dissemination, Agricultural Mechanization, Agricultural Postharvest, Biotechnology, and Agricultural Genetic Resources, Agricultural Land Resources, Agricultural Technology Assessment, Rice, Veterinary, Agricultural Technology Transfer Management, and AIATs.

Box 3.1. Continued…

2015-2016: The Center for Quality Testing and Agricultural Machinery Tools within the Directorate General of Agricultural Product Processing and Marketing was transferred to Agricultural Mechanization Center under IAARD.

2017-2020: IAARD managed 12 research centers, 15 research institutes, one center for agricultural technology assessment and development, 33 AIATs, and three AIATs.

2021-present: More than 1,000 researchers have been transferred from IAARD to the National Research and Innovation Agency (BRIN). The research centers/units have been transformed into non-research works within the MoA.

As prominent agriculture and food R&D institution, IAARD held a first-echelon structural position in MoA (Appendix 2). The organizational structure of the MoA and IAARD including IAARD's work units can be seen in Appendix 3 and Appendix 4. IAARD supports programs of the other first echelons to achieve the vision and mission of the MoA, especially in providing technological packages and policy recommendations. IAARD also assists in the planning, implementing, and monitoring of various MoA policies and programs, especially the strategic ones. Table 3.1 shows IAARD's vision, missions, objectives, and program goals.

Table 3.1. IAARD's vision, missions, objectives, and program goals

Item	Description
Vision	▪ To become a leading research and development institution that produces technology and innovation supporting advanced, independent, and modern agriculture
Missions	▪ To produce technology and innovation with scientific value and impact recognition that supports advanced, independent, and modern agriculture ▪ To establish a transparent, professional, and accountable institution
Objectives	▪ To provide technology and innovation that support advanced, independent, and modern agriculture ▪ To realize bureaucratic environment reform ▪ To manage an accountable convinced quality budget
Program goals	▪ To utilize agricultural technology and innovation ▪ To implement effective and efficient bureaucracy ▪ To organize an accountable and quality budget

Source: IAARD, 2020

Other activities in agriculture and food R&D are carried out by specific ministries/agencies relevant to the program implementations, namely the Ministry of National Development Planning (MoNDP/Bappenas), Indonesian Institute of Sciences (IIS), Agency for Assessment and Application of Technology (AAAT), National Nuclear Energy Agency (NNEA), Ministry of Environment and Forestry (MoEF), Ministry of Marine Affairs and Fisheries (MoMAF), Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (MoSP-NLA), Ministry of Industry (MoI), Ministry of Trade (MoT), Ministry of Health (MoH), Ministry of Public Works and Housing Profile (MoPWHP), Agency of Drug and Food Control (ADFC), Ministry of State-Owned Enterprises (MoSOEs), and Ministry of Research, Technology, and Higher Education (MoRTHE).

Apart from public institutions, agriculture and food R&D is also conducted by the private sector, i.e., national/multinational companies and supported by non-government organizations (NGOs) comprising the non-profit sector and international donor agencies.

3.1.1. R&D Management from Agricultural Research Systems to Farmers

The R&D activities from agricultural research systems to farmers were primarily managed by IAARD by involving national research centers and regional/local assessment institutes. The agency played an essential role in planning and delivering R&D to farmers and evaluating stakeholders' feedback for improvement and future development. This process is managed using Multi-Channel Dissemination Spectrum (SDMC), according to the characteristics of stakeholders. The SDMC comprises three interrelated components, as summarized in Table 3.2.

Table 3.2. R&D management from agricultural research systems to the farmer

Management	Description
Generating system	Generating R&D centers and disseminating to farmers through assessment institutes using communication channels
Delivery system	Delivering R&D by optimizing stakeholders (assessment institutes, technical directorate general units, extension agencies*], regional apparatus work units, and libraries) and dissemination media (exhibitions, meeting forums, print media, electronic/digital media, and social media). In MoA, the extension system is structurally separated from R&D.
Receiving system	Receiving R&D at farmer groups by involving local governments, state-owned enterprises, national/regional decision-makers, extension workers, entrepreneurs/private sectors/industries, and researchers/scientists through: (1) Designing a model; (2) Increasing farmers' technical production efficiency and market innovation to improve income and welfare; (3) Providing appropriate technology to support agricultural development in the region; (4) Empowering farmers through group participation and institutional development; (5) Improving infrastructure in rural areas to support agricultural/agribusiness innovation; and (6) Increasing farmers' access to agricultural technology and market information.

Note: *] The extension system is under the regional government institutions, separated from R&D
Source: Indraningsih, 2017

Assessment institutions need to be involved in R&D end-to-end management, from agricultural research systems to farmers. The R&D results from research centers can be disseminated through: (1) A communication forum such as 'breakfast briefings or monthly meetings aiming to reach agreements or commitments between assessment institutes and stakeholders; and (2) Open houses and road shows. Extension institutions should also be involved in the R&D end-to-end management because extension workers work closely with farmers in the field meetings and are the primary source for farmers to obtain agricultural information. Therefore, assessment institutions must bridge extension officers and researchers to optimize the dissemination.

3.1.2. The Prospect of Integrated National R&D System

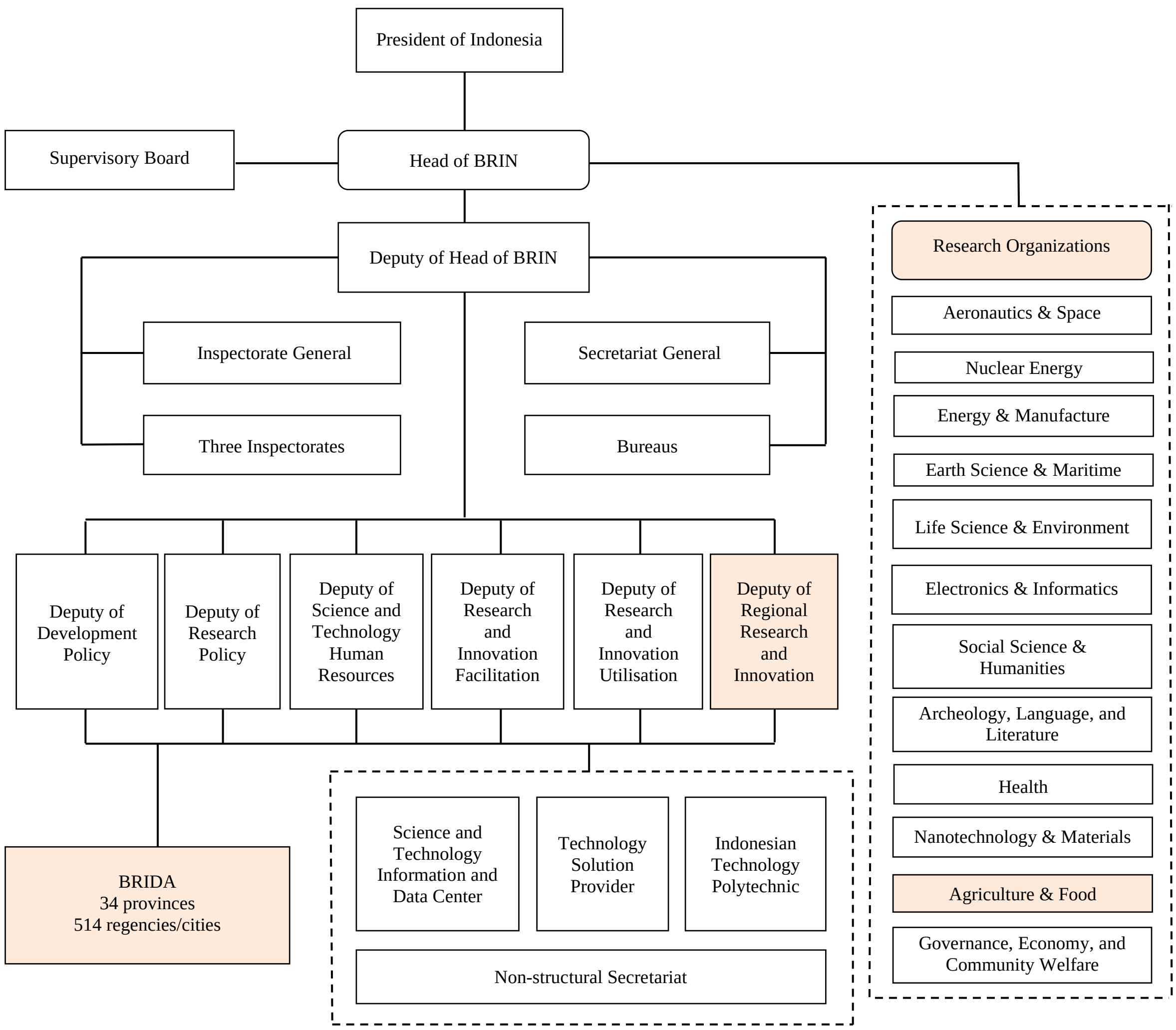
National Research and Innovation Agency or *Badan Riset dan Inovasi Nasional* (BRIN) aims to integrate research and development (R&D) invention and innovation by coordinating all R&D programs in the country. BRIN was built upon President Joko Widodo's commitment to improving research quality and strengthening the national R&D ecosystem. The implementation is regulated by the Government of Indonesia (GoI) Law Number 11/2019 (GoI, 2019) on the National System of Science and Technology and Presidential Regulation Number 78/2021 concerning the BRIN. With the regulations, civil servants in research, development, and application of science and technology in the ministries and institutions are transferred to BRIN (MoSAUBR, 2021; OECD, 2022).

As stated in Presidential Regulation Number 78/2021 (GoI, 2021b), the duties and functions of BRIN are:

1. Consolidating national research and innovation policies, including the master plans and national research priorities
2. Implementing research and innovation activities in non-college government institutions
3. Managing research and innovation funds in the state budget, the yield of research endowment funds, research education, and oil-palm plantation research funds
4. Organizing research officers, engineers, nuclear technology developers, biologists, scientific data analysts, science and technology utilization analysts, scientific publishing managers, plant managers, plant technicians, and other relevant stakeholders.

Based on Regulation Number 16/2022, BRIN is under the direct supervision of the President, and is authorized and responsible for conducting research, development, assessment, and application, invention and innovation, implementation of nuclear power, and integrated space operation. BRIN comprises Regional Research Innovation Agencies (BRIDAs) in 34 provinces and 514 districts/cities (Figure 3.2).

Figure 3.2. The organizational structure of BRIN



Source: BRIN, 2022

The Research Organization in BRIN oversees research operations, development, assessment, applications, inventions, and innovations. Under the Research Organization, each research center conducts studies on specific topics within the area of expertise (Figure 3.3).

Figure 3.3. R&D management process at BRIN

Source: BRIN, 2022

As a result of this transformation, about 73% or 1,100 out of 1,600 researchers in IAARD working in: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Health; and (4) Governance, Economy, and Community Welfare, were transferred to Research Organization in BRIN. In this transformation (integration) process, only researchers from IAARD transferred to BRIN, not accompanied by a transfer of institutions, infrastructures and assets.

3.2. Main Objectives and Implications of the R&D Transformation

The IAARD's research priority is science and technology, with three areas: (1) Plant, livestock, and veterinary; (2) Agricultural resource systems; and (3) Agricultural technology development. The agency also assists in the provisions of technology packages, policy recommendations, planning, implementation, and monitoring of strategic program policies of MoA.

The IAARD's key performance indicators include: (1) Research impacts; 2) The extent to which bureaucratic reform is implemented; and (3) The feasibility of performance-based budgeting (IAARD, 2020). These indicators were met by, among others, the release of high-yielding crop and animal varieties and the protection and availability of genetic plant and animal resources.

The IAARD technical units carry out their duties and functions economically, effectively, efficiently, in an orderly manner, and compliant with the laws and regulations. This success is also dependent on holistic and reliable internal control. Therefore, efforts have also been made to improve the performance, transparency, and accountability of financial management of the Internal Control Unit (SPI), which oversees the environment and risk assessment, activity mechanism, information, and communication, as well as monitoring and evaluation.

3.2.1. Strategic Agricultural Policies and Programs

The national agricultural and food R&D policies are part of the MoA 2020-2024 strategic plan issued through the Decree of the Minister of Agriculture Number 259/2020 (MoA, 2020a). This strategic plan emphasizes the national strategic role of IAARD to create agricultural technology and innovation, as postulated in Presidential Regulation Number 45/2015 concerning the MoA and MoA Regulation Number 43/2015 concerning the organization and governance of MoA's work. IAARD, together with universities and other research institutions, produce technology packages suitable for the optimization of agricultural resources to increase productivity, quality, and production capacity.

IAARD achieves its goals by: (1) Formulating technical policies, plans, and programs for research, development, and innovation in agriculture; (2) Implementing the programs; (3) Disseminating the results; (4) Monitoring, evaluating and reporting on the implementation of programs; (5) Improving the IAARD administration; and (6) Delivering other functions assigned by MoA.

IAARD has produced various technologies and innovations, and contributed to the development of the agricultural sector in Indonesia, especially in terms of technical efficiency, productivity, and agricultural product quality. In productivity, for example, IAARD's contribution can be seen in the creation and application of varieties, lines, clones, and superior seeds through conventional breeding techniques and biotechnology.

The programs, directions, and targets have also been reoriented. Collaborative research is supported by the development, assessment, and implementation of priorities. The policy focuses on thematic, strategic, innovative, and integrated agriculture and food research and development. A model called Collaborative Innovative Development Research (CIDR) guides the dissemination of technological innovation and connects work units within IAARD, as well as beneficiaries such as national and international research institutions, universities, prospective private sector, and local governments. CIDR issues seven activity titles: (1) Food crops; (2) The development of innovation-based adaptive agriculture in different agroecosystems; (3) The development of phytopharmacology, i.e., traditional spices and medicinal plants; (4) The development of modern and sustainable agriculture; (5) Added value and competitiveness; (6) Food security based on local resources; and (7) Development of innovative local-based agroindustry models to support food security, as well as increase added value. These programs were implemented in 24 locations with main commodities, i.e., rice, soybeans, sugar cane, garlic, and cattle.

One of the prioritized agricultural policies and programs is increasing the production of staple foods, such as rice, maize, and soybeans. This was done by cultivating stress-resistant high-yielding varieties backed by research in potential sub-optimal lands. The untapped potential of sub-optimal land accounts for 30.67 million hectares, so food production in this area could help anticipate the increase in demand due to the increase in population, which is estimated to reach 275.77 million people in 2022 (BPS, 2017).

Another priority is the development of regional areas to reduce the gap between urban and rural areas, which is caused by the centralized distribution of fund. The agency seeks to shift this to the, outermost, frontiers, and underdeveloped areas[6]. Agricultural activities and innovations aim to increase productivity and quality and reduce production, distribution, and marketing (logistics) costs. The MoA 2020-2024 strategic plan suggests the need to achieve food security, which means a stable food supply, easy and cheap food access, and reliable food distribution (MoA, 2020b). The formulated policies are as follows:

1. Increasing the agricultural sector's production and productivity by delivering MoA functions and tasks optimally.
2. Empowering small-scale food businesses, which has been implemented since 2018 based on MoA Regulation Number 18/2018 on Agricultural Area Development Guidelines Based on Farmers Corporation.
3. Increasing food affordability and utilization, which have been implemented since 2008 based on Presidential Regulation Number 1/2008 concerning Rice Policy for Poor Households (*Raskin*).
4. Supporting the distribution of food aid or by delivering MoA functions and tasks optimally.
5. Promoting diversification of food consumption through the delivery of MoA functions and tasks.

The development of science, technology, and innovation (STI) and the higher education system can contribute to growth generation. The STI Scoreboard and Outlook developed by OECD in 2011-2012 highlight the current trends and indicators to assess a country's progress in utilizing innovations (Olsson and Meek, 2013), including:

1. Knowledge economies: STI contribution to economic growth, e.g., gross national product (GNP); new indicators of growth, such as intangible assets, foreign direct investment, changing innovation landscape (high-impact universities and national research agencies, e.g., BRIN), green science innovation, and international collaboration; and major global issues shaping society, such as environment, aging populations, and women participation in education and the workforce (including R&D).
2. Building knowledge: Science and technology occupations, research communities, international mobility, R&D expenditure (including STI business creation), new doctorates and career paths, and investment in ICT.
3. Connecting knowledge: Public, private, and international R&D funding; science/technology linkages; labor mobility; innovation, technology, and knowledge transfer; and national and international collaboration for innovation.
4. Targeting new growth areas: Government R&D funding; health and environment technologies, including biotechnology R&D; and ICT access, services, and costs.
5. Encouraging innovation in firms: Providing mixed modes of innovation; supporting trademarks, tax incentives, and access to capital; creating facilitating environments and policies; and nurturing talents and entrepreneurial culture, especially in tertiary/higher education.

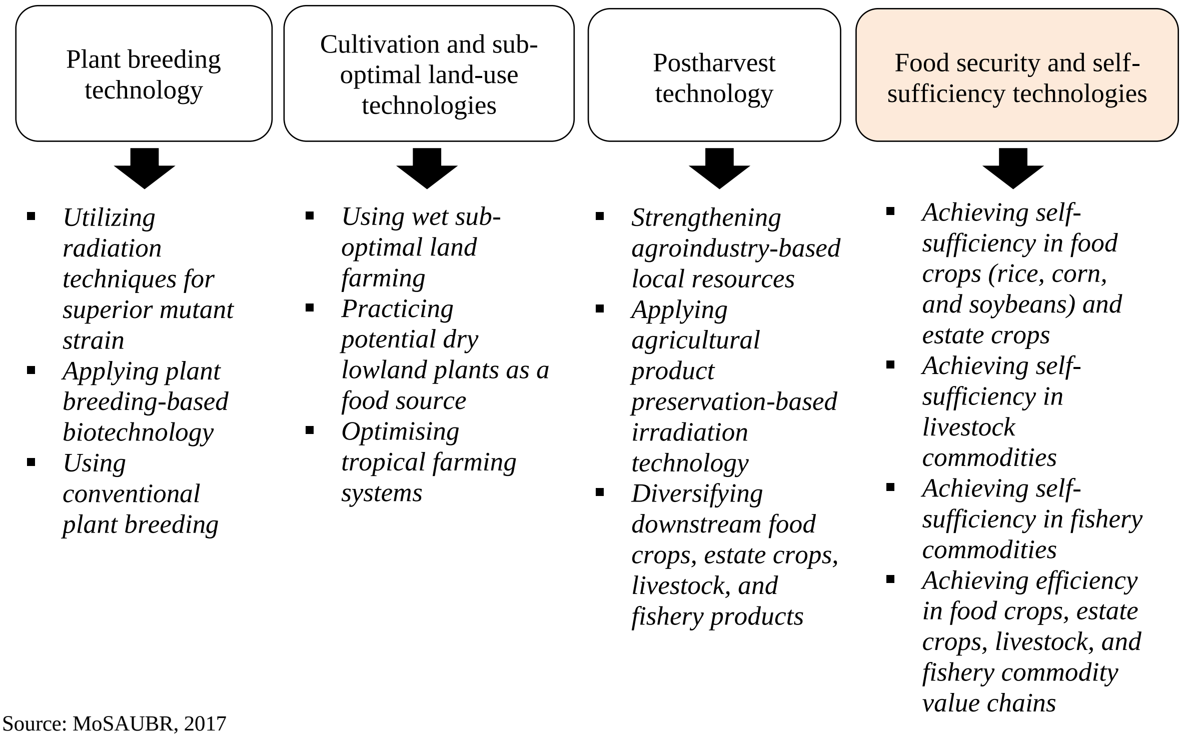
[6] Based on Presidential Regulation Number 78/2005, Indonesia has border areas in 187 sub-districts in 41 districts/municipalities in 13 provinces and there are 10 districts/municipalities that have 92 frontier islands (GoI, 2005). Moreover, according to Presidential Regulation Number 63/2020, there are 62 districts were categorized the disadvantaged, frontline, and outermost regions (GoI, 2020).

6. Competing in the global economy: Balanced employment in service and manufacturing industries, firm sizes and dynamics, trade openness, R&D and technology specialization, e-commerce, patenting advances, innovative sectors (including education and training), and technological performance quality and impacts.

3.2.2. Major Priority Areas of Public R&D in Agriculture

The four major priority areas of public agriculture R&D are: (1) Plant breeding technology; (2) Cultivation and sub-optimal land-use technologies; (3) Postharvest technology; and (4) Food security and self-sufficiency technologies. More specifically, technologies to support food security and self-sufficiency are geared towards sufficiency in: (1) Food crops (rice, maize, and soybeans) and estate crops; (2) Livestock; (3) Fishery, and towards (4) Value chain efficiency in all the above (Figure 3.4).

Figure 3.4. Focused R&D on food and agriculture



Source: MoSAUBR, 2017

The implementation of public R&D in agriculture involves an integration and support from relevant institutions, including ministries/agencies and universities. This involvement can be organized by theme, topic, and budget (Table 3.3). However, the implementation of this agriculture R&D will be transformed by BRIN, except for universities, which are still under the Ministry of Education and Culture.

Table 3.3. Integrated research foci on food and agriculture in Indonesia

Research		Supporting Budget	Institution
Thematic	Topic		
Plant seed breeding technology	▪ Utilizing radiation techniques for superior mutant strain	▪ NNEA	▪ MoA (IAARD), NNEA
	▪ Applying plant breeding-based biotechnology	▪ MoA (IAARD), NNEA	▪ MoA (IAARD), NNEA
	▪ Using conventional plant breeding	▪ MoA (IAARD)	▪ MoA (IAARD), MoEF, IIS

Table 3.3. Continued…

Research		Supporting Budget	Institution
Thematic	Thematic		
Cultivation and sub-optimal land use technologies	▪ Using wet sub-optimal land farming	▪ MoA (IAARD), MoEF, AAAT	▪ MoA (IAARD), MoEF, IIS, AAAT, Universities
	▪ Practicing potential dry lowland plants as a food source	▪ IIS	▪ MoA (IAARD), MoEF, IIS, Universities
	▪ Optimizing tropical farming systems	▪ MoA (IAARD), IIS, AAAT	▪ MoA (IAARD), MoEF, IIS, Universities
Postharvest technology	▪ Strengthening agroindustry-based local resources	▪ MoA (IAARD), IIS, AAAT	▪ MoA (IAARD), MoI, MoEF, MoSP-NLH, IIS, AAAT, Universities
	▪ Applying agricultural product preservation-based irradiation technology	▪ NNEA	▪ MoA (IAARD), NNEA, Universities
	▪ Diversifying and down streaming food crops, estate crops, livestock, and fishery	▪ MoA (IAARD), MoEF, MoMAF, MoI, IIS, AAAT	▪ MoA (IAARD), MoEF, MoMAF, MoI, IIS, AAAT, Universities
Food security and self-sufficiency technologies	▪ Supporting self-sufficiency for food crops (rice, maize, and soybeans) and estate crops	▪ MoA (IAARD), MoEF, IIS, AAAT	▪ MoA (IAARD), MoEF, MoSP-NLH, IIS, AAAT, ADFC, Universities
	▪ Accomplishing food independence of ruminant commodities	▪ MoA (IAARD), NNEA, IIS, AAAT,	▪ MoA (IAARD), NNEA, IIS, AAAT, ADFC, Universities
	▪ Achieving food independence for aquatic commodities	▪ MoMAF, MoEF, MoI, IIS, AAAT	▪ MoMAF, MoEF, MoI, IIS, AAAT, ADFC
	▪ Generating efficiency of food crops, estate crops, livestock and fishery commodity value	▪ MoA (IAARD), MoMAF, IIS	▪ MoA (IAARD), MoMAF, AAAT, ADFC, MoI, MoT, Universities

Note: MoA (Ministry of Agriculture); IAARD (Indonesian Agency for Agricultural Research and Development); NNEA (National Nuclear Energy Agency); IIS (Indonesian Institute of Sciences); AAAT (Agency for Assessment and Application of Technology); MoEF (Ministry of Environment and Forestry); MoMAF (Ministry of Marine Affairs and Fisheries); MoSP-NLH (Ministry of Agrarian Affairs and Spatial Planning/National Land Agency); MoI (Ministry of Industry); MoT (Ministry of Trade); ADFC (Agency of Drug and Food Control)

Source: MoRTHE, 2017

3.3. Public R&D Spending on Food and Agriculture

This subsection focuses on analyzing: (1) The changes in public R&D spending on agriculture and food; (2) The changes in mechanism and governance of R&D spending; and (3) The distribution of R&D spending by thematic and impact areas. The description begins with a general overview of R&D, followed by the contribution of R&D to national and agricultural Gross Domestic Product (GDP), the R&D fund sources, the expenditure types, the work unit management, and the spending based on thematic and impact areas covering selected commodities, namely rice, maize, soybean, mango, pineapple, shallot, chili, coffee, cocoa, beef, and poultry. The final part outlines the R&D spending by selected dissemination and public institutions, i.e., the Assessment Institutes for Agricultural Technology (AIATs) and selected universities, respectively.

3.3.1. Changes in Public R&D Spending on Food and Agriculture

3.3.1.1. General Overview of R&D in Food and Agriculture

In the last 12 years (2010-2021), Indonesia's average public R&D spending on food and agriculture was about USD148.17 million per year. During these periods, the trend of R&D spending slightly decreased by about 3.66% annually (Table 3.4).

The public R&D spending on food and agriculture changed each year depending on the priority programs and the activity requirement. A notable change is the spending in 2020, which decreased by almost half (46.62%) compared to 2019 because the government of Indonesia (GoI) spent more on the COVID-19 control measures during the Large-scale Social Restriction.

Table 3.4. R&D spending on food and agriculture in Indonesia, 2010-2021 (2018=100)

Year	Budget (million USD)	Growth (%)
2010	171.59	
2011	196.95	14.78
2012	182.51	-7.33
2013	194.77	6.71
2014	155.07	-20.38
2015	152.99	-1.34
2016	152.62	-0.24
2017	130.70	-14.36
2018	148.74	13.80
2019	132.64	-10.82
2020	71.38	-46.19
2021	89.30	25.10
Average	148.17	-3.66

Source: IAARD, 2021

Even though the number of COVID-19 cases has decreased since 2021, the R&D spending has not rebounded as the GoI is focusing on the recovery efforts post the pandemic[7]. The total R&D spending in 2021 slowly increased by about 23.76% from USD71.38 million in 2020 to USD89.30 million in 2021.

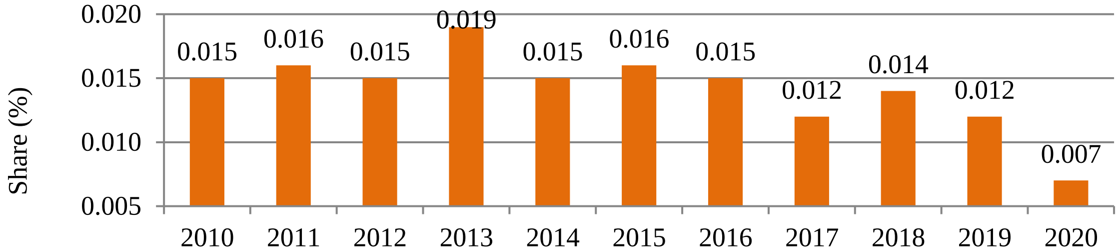
3.3.1.2. The GDP spending on R&D

The GDP spending on food and agriculture R&D between 2010 and 2020 was minor (less than 1%), namely 0.014% per year, with an annual growth of about -5.28% (Figure 3.5). Meanwhile, the agricultural GDP spending on food and agriculture R&D was also relatively small (0.135%) with an average annual growth of about -3.25% (Figure 3.6).

In general, the national GDP spending on the national R&D in Indonesia is lower than in other countries. The country ranked sixth among ASEAN countries and was generally lower than other Asian countries, particularly the Republic of Korea, Japan, China, and India.

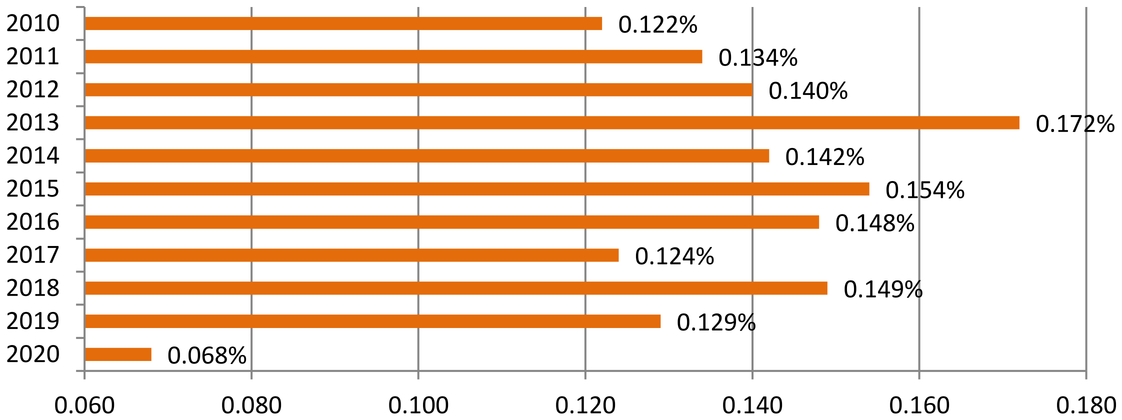
[7] The 2021 state budget was deficit at 5.70% of GDP, expecting a momentum of economic recovery and acceleration from the COVID-19 pandemic control and vaccine availability. The government focused the national development on health, education, information and communication technology, food security, social protection, infrastructure, and tourism, while implementing sound and sustainable fiscal management (MoF, 2021).

Figure 3.5. Share of R&D spending on food and agriculture in national GDP, 2010-2020 (%)



Source: IAARD, 2021

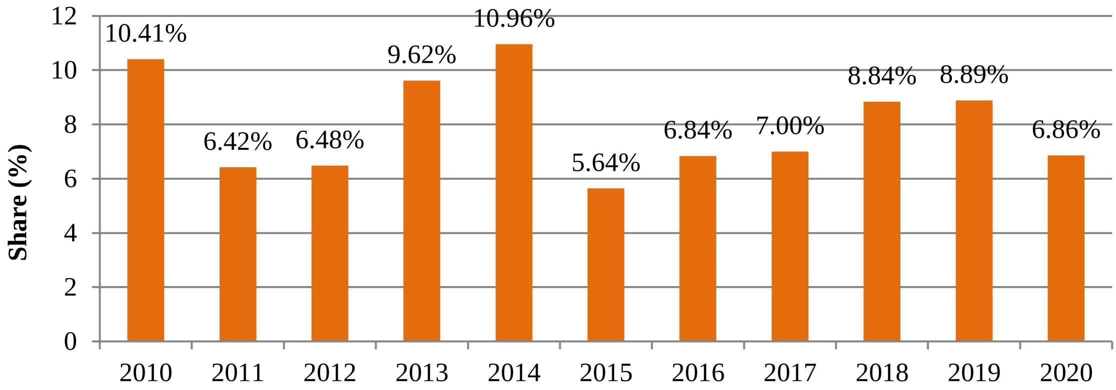
Figure 3.6. Share of R&D spending on food and agriculture to agricultural GDP, 2010-2020 (%)



Source: IAARD, 2021

The proportion of R&D spending in the MoA expenditure was about 8% per year (Figure 3.7). The amounts depend on implemented programs. For instance, the spending in 2020 and 2014 was higher than in other years due to agricultural tools and machinery procurement.

Figure 3.7. Share of R&D spending on food and agriculture to MoA expenditure, 2010-2020 (%)



Source: MoA, 2020b, 2021

The gross expenditure research and development budget was sourced primarily from the national government budget (81.60%), followed by the manufacturing industry and universities. Less than 5% was sourced from the private sector and local government. The government budget allocation on R&D was about 0.23% of GDP, while the gross expenditure of the R&D budget was 0.28% of GDP (Table 3.5).

Table 3.5. Gross Expenditure on Research and Development in Indonesia, 2018

Item	R&D Budget (million) IDR	R&D Budget (million) USD	Share (%)	Formula
GDP	14,837,000	1,039.15	-	A
R&D source:				$B = B_1+B_2+B_3+B_4+B_5$
National government	33,800	2.37	81.60	B_1
Local government	890	0.06	2.15	B_2
University	2,160	0.15	5.21	B_3
Manufacturing industry	3,200	0.22	7.73	B_4
Private sector	1,370	0.10	3.31	B_5
Government budget allocation on R&D	36,690	2.57	0.23[*]	C = (B1/A)*100
Gross expenditure R&D budget[*]	41,430	2.90	0.28[*]	D = (B/A)*100

Note: [*] share to GDP
Source: Subagio, 2022

3.3.2. Mechanism and Governance of R&D Fund Allocation

3.3.2.1. R&D Fund Sources

The majority of public agriculture and food R&D (90.71%) in Indonesia originates from the state-owned budget (APBN) and non-tax state revenue (PNBP)[8], with small proportions coming from grants and loans (8.75% and 0.54%, respectively). Table 3.6 shows that in the last six years (2015-2021), the total R&D spending was USD789.07 million (USD131.51 million/year), with the trend decreasing by about 11.56% annually.

Due to the COVID-19 cases, the R&D spending had decreased by about 45.61% and 43.90% from APBN-PNBP and loans. Meanwhile, grants were halted since many donor agencies redirected their sources to deal with the global pandemic.

Table 3.6. R&D spending by budget sources from 2015- to 2020 (2018=100)

Item	2015	2016	2017	2018	2019	2020
APBN-PNBP:						
Budget (million USD)	140.97	129.95	113.61	130.53	129.98	70.69
Share (%)	92.15	85.15	86.92	87.76	98.00	99.04
Grant:						
Budget (million USD)	11.66	22.17	16.43	17.39	1.42	0
Share (%)	7.62	14.52	12.57	11.69	1.07	0
Loan:						
Budget (million USD)	0.35	0.50	0.67	0.82	1.23	0.69
Share (%)	0.23	0.33	0.51	0.55	0.93	0.96
Total:						
Budget (million USD)	152.99	152.62	130.70	148.74	132.64	71.38
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00

Source: IAARD, 2015, 2016, 2017, 2018, 2019, 2020a

8 The Non-Tax State Revenue (PNBP) disbursable to MoA includes: (1) Revenues from agricultural products; (2) Library services, data processing, and map reproduction; (3) Dissemination and technology development services; (4) Rights and licensing services; (5) Animal and plant quarantine action services; (6) Testing, analysis, and certification services; (7) Services for the use of facilities and infrastructure; (8) Agricultural human resources education and training services; (9) Research and development services, and agricultural education and training based on cooperation contracts with other parties; and (10) Royalties for technology transfer services resulting from agricultural research and development based on cooperation contracts with other parties (GoI, 2016).

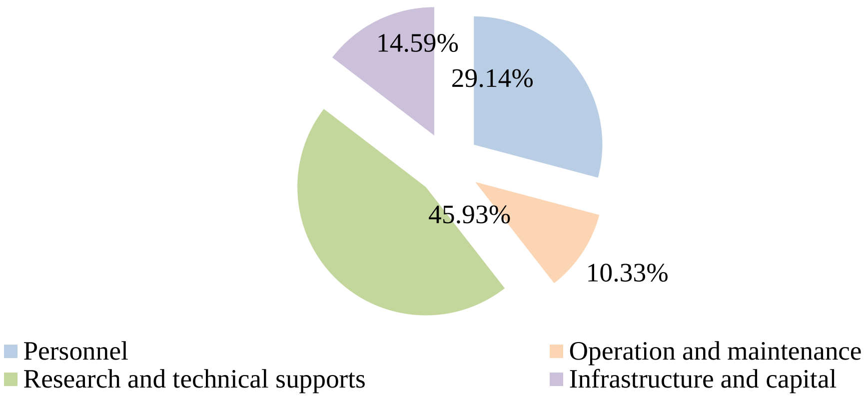
3.3.2.2. R&D Spending by Expenditure Type

The R&D spending by expenditure type encompasses four components:

1. Personnel salaries and other substantial allowances
2. Operation and maintenance, including daily necessities, electricity, water, telephone, Internet, building, and equipment
3. Research and technical support comprising research and program planning, monitoring and evaluation, research cooperation, utilization of dissemination results, human resources management, and financial management.
4. Infrastructure and capital involving building, vehicle, machinery, and equipment procurements.

In the last six years (2015-2020), the largest R&D spending by expenditure type was aggregately allocated to research and technical support. Meanwhile, the lowest was to operation and maintenance (Figure 3.8).

Figure 3.8. R&D spending by expenditure type from 2015 to 2020



Source: IAARD, 2020a

Table 3.7 shows detailed R&D spending by expenditure type. From 2015 to 2020, the trend of R&D spending decreased, except for operation and maintenance, increased by about 5.92% per year (on average).

During the COVID-19 pandemic, the R&D spending on office operations, electricity, water, telephone, Internet, building, and equipment in 2020 increased by about 29.73% from 2019. By contrast, the R&D spending for infrastructure and capital, research, and technical support, and personnel decreased by approximately 27.67%, 10.82%, and 3.75% per year (on average).

Table 3.7. R&D spending by expenditure type from 2015 to 2020

R&D Spending	2015	2016	2017	2018	2019	2020
Personnel:						
Amount (million USD)	43.86	43.76	41.50	35.95	33.62	31.22
Share (%)	28.67	28.67	31.75	24.17	25.35	43.74
Operation and maintenance:						
Amount (million USD)	12.74	13.47	13.50	12.72	12.67	16.44
Share (%)	8.32	8.83	10.33	8.55	9.55	23.03
Research and technical support:						
Amount (million USD)	68.62	67.61	53.58	78.53	73.66	20.46
Share (%)	44.85	44.30	40.99	52.80	55.53	28.67

Table 3.7. Continued…

R&D Spending	2015	2016	2017	2018	2019	2020
Infrastructure and capital:						
Amount (million USD)	27.77	27.78	22.12	21.54	12.69	3.26
Share (%)	18.15	18.20	16.92	14.48	9.57	4.57
Total:						
Amount (million USD)	152.99	152.62	130.7	148.74	132.64	71.38
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00

Source: IAARD, 2015, 2016, 2017, 2018, 2017, 2020a

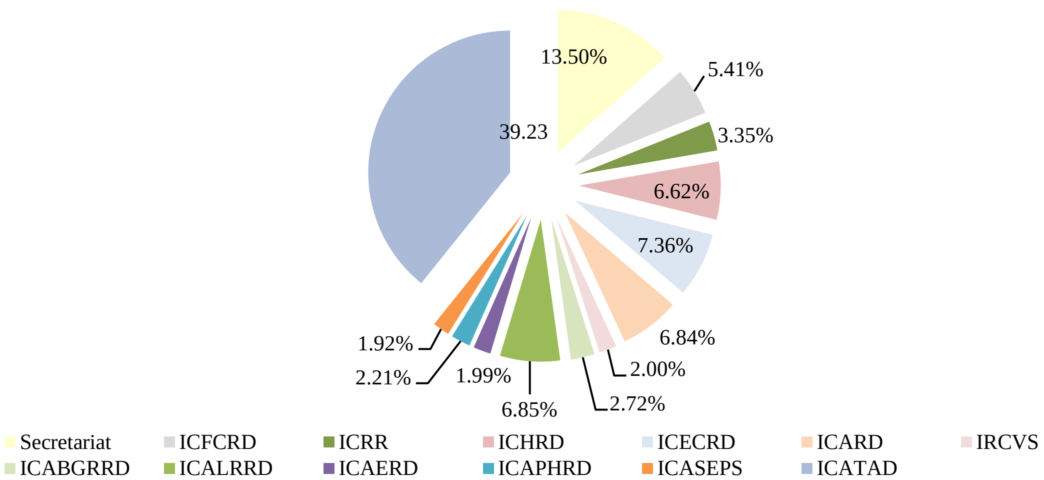
3.3.2.3. R&D Spending by Work Units

Institutionally, IAARD is organized based on budgeting and planning accountability, i.e., commodities, scientific fields, specific locations, and upstream and downstream approaches. In terms of work units, IAARD comprises: (1) A secretariat; (2) Four research and development centers handling R&D commodities; (3) Two centers co-coordinated with the MoA secretariat general; (4) Seven research centers handling R&D for commodities/ scientific fields; (5) 15 research institutes for commodities/scientific fields; (6) 33 Assessment Institutes for Agricultural Technology (AIATs) and one Assessment Center for Agricultural Technology that carry out assessment and dissemination of site-specific technologies; (7) three research stations for commodities/scientific fields; and (8) A research institute under the MoA secretariat general to handle technology transfer and utilization.

The R&D spending by work unit is managed by the secretariat and allocated to research centers and institutes throughout the country. The details of these work units can be seen in Appendix 4.

Over the last six years (2015-2020), most R&D spending (at about 52.73% per year) was allocated to a) the center for agricultural technology assessment and development (ICATAD) for R&D dissemination, and b) the secretariat for R&D management (Figure 3.9). In terms of commodities, the food crops and rice (ICFCRD and ICRR) absorbed most of the spending, followed by estate crops (ICECRD), land resources (ICALRRD), livestock (ICARD), and horticulture (ICHRD). Although rice is part of food crops, it receives special attention because it is a strategic commodity that could raise political and socioeconomic concerns.

Figure 3.9. Annual shares of R&D spending by work units of IAARD from 2015 to 2020



Source: IAARD, 2020a

Detailed R&D spending by work units is presented in Table 3.8. Over the six-year period (2015-2020), the range of annual R&D spending decline is between 3.30% and 20.02%. Nevertheless, some trends were upward, i.e., R&D spending for post-harvest (ICAPHRD), biotechnology and genetic resources (ICABGRRD), and livestock (ICARD), with an increase ranging between 2.83% and 16.38% per year. These include the implementation of special effort (*Upsus*) R&D and poverty alleviation programs, particularly in 2016, 2018, and 2019. Subsequently, the R&D spending by work units decreased due to COVID-19. The biggest decrease of up to 70% was the spending on livestock (ICALRD), biotechnology and genetic resources ICBGRRD), and post-harvest (ICAPHRD). This means that R&D spending related to these work units tends to be lower in case of a health crisis like the COVID-19 pandemic.

Table 3.8. R&D spending by work units from 2015 to 2020 (million USD)

Work Unit	2015	2016	2017	2018	2019	2020
Secretariat	25.88	19.91	19.16	20.41	13.94	7.24
ICFCRD	9.39	8.37	6.52	7.21	6.30	4.88
ICRR	4.29	4.81	3.39	7.61	4.17	2.17
ICHRD	8.83	9.55	10.71	9.91	7.55	5.67
ICECRD	9.81	11.60	11.46	10.42	8.51	6.25
ICARD	6.77	6.38	5.85	14.27	16.50	4.22
IRCVS	2.84	3.33	2.65	2.75	2.33	1.89
ICABGRRD	3.32	5.10	2.57	2.52	6.23	1.72
ICALRRD	12.18	13.22	7.29	7.94	8.42	4.98
ICAERD	2.80	3.28	2.43	3.40	1.95	1.85
ICAPHRD	2.68	3.10	1.83	2.32	5.85	1.65
ICASEPS	2.75	3.13	2.83	2.23	2.29	1.94
ICATAD	61.45	60.85	54.02	57.74	48.58	26.90
Total	152.99	152.62	130.70	148.74	132.64	71.38

Note: ICFCRD (Indonesian Center for Food Crops Research and Development); ICRR (Indonesian Center for Rice Research); ICHRD (Indonesian Center for Horticulture Research and Development); ICECRD (Indonesian Center for Estate Crops Research and Development); ICARD (Indonesian Center for Animal Research and Development); IRCVS (Indonesian Research Center for Veterinary Sciences); ICABGRRD (Indonesian Center for Agricultural Biotechnology and Genetic Resource Research and Development); ICALRRD (Indonesian Center for Agricultural Land Resources Research and Development); ICAERD (Indonesian Center for Agricultural Engineering Research and Development); ICAPHRD (Indonesian Center for Agricultural Post Harvest Research and Development); ICASEPS (Indonesian Center for Agricultural Socio-Economic and Policy Studies); ICATAD (Indonesian Center for Agricultural Technology Assessment and Development)

Source: IAARD, 2020a

3.3.3. R&D Spending by Thematic and Impact Areas

The organization by thematic and impact areas is based on the selected commodities' activities from 2015 to 2020, namely rice (Appendix 5), maize (Appendix 6), soybean (Appendix 7), mango (Appendix 8), pineapple (Appendix 9), shallot (Appendix 10), chili (Appendix 11), coffee (Appendix 12), cocoa (Appendix 13), beef (Appendix 14), and poultry (Appendix 15). Detailed data and information are presented in separate documents. In addition, the outputs of thematic and impact areas of R&D spending are discussed in Chapter Four.

3.3.3.1. R&D Spending by Thematic Areas

Rice

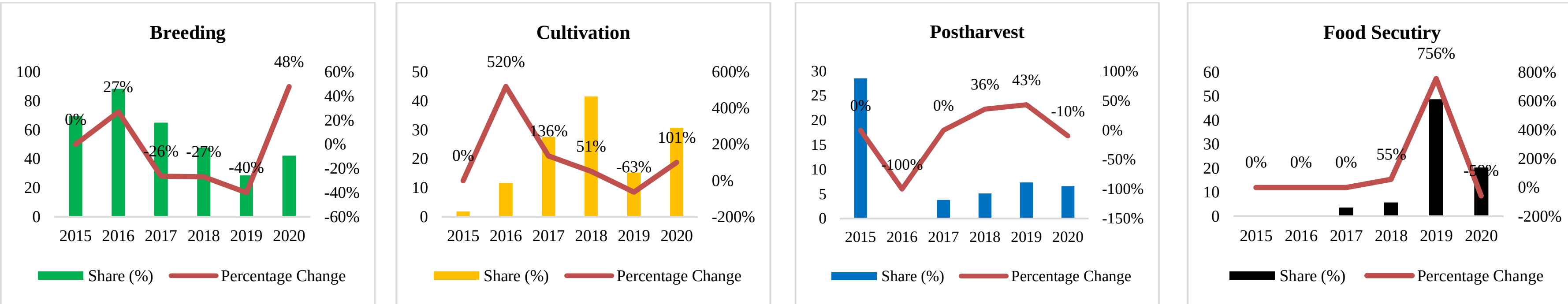
Box 3.2. Rice – R&D spending by thematic areas, 2015-2020

Table 3.9. The amounts and shares of R&D spending on rice by thematic areas, 2015-2020

Thematic area	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	541	69.56	941	88.34	545	65.03	358	47.63	442	28.62	126	42.32	492	55.98
Cultivation	15	1.88	124	11.66	231	27.53	313	41.56	236	15.32	91	30.79	168	19.15
Post-harvest	222	28.56	0	0.00	32	3.78	39	5.12	113	7.32	20	6.61	71	8.06
Food security	0	0.00	0	0.00	31	3.66	43	5.69	752	48.74	60	20.28	148	16.81
Total	777	100.00	1065	100.00	837	100.00	752	100.00	1544	100.00	297	100.00	879	100.00

Source: IAARD, ICFCRD, ICRR, TDRS, IRICC, ICAPOSTRD, ICASEPS, 2015-2020

Figure 3.10. Trends of R&D spending on rice by thematic areas, 2015-2020



Source: IAARD, ICFCRD, ICRR, TDRS, IRICC, ICAPOSTRD, ICASEPS, 2015-2020

The R&D spending on rice by thematic areas from 2015 to 2020 was mainly directed to breeding technology development, indicated by its share of about 56%. This was followed by technological developments in cultivation and sub-optimal land use (19%), food security and self-sufficiency (17%), and post-harvest (8%). The R&D spending on technology development was geared toward food security and self-sufficiency, which has a positive trend with an average increase of 1.5 times.

Maize

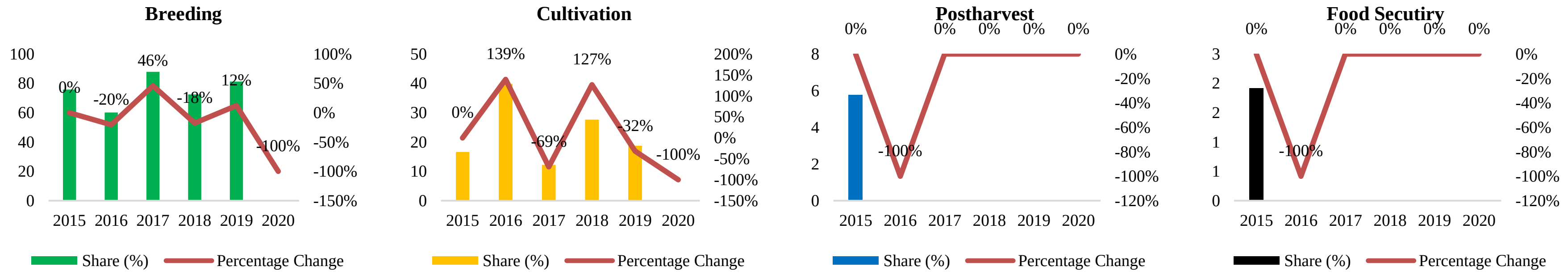
Box 3.3. Maize – R&D spending by thematic areas, 2015-2020

Table 3.10. The amounts and shares of R&D spending on maize by thematic areas, 2015-2020

Thematic area	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	309	75.68	162	60.21	285	87.82	146	72.39	280	81.22	0	0.00	197	76.34
Cultivation	68	16.62	107	39.79	40	12.18	56	27.61	65	18.78	0	0.00	56	21.63
Post-harvest	24	5.78	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	4	1.53
Food security	8	1.91	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	0.50
Total	408	100.00	269	100.00	325	100.00	201	100.00	344	100.00	0	0.00	258	100.00

Source: IAARD, ICFCRD, ICRI, 2015-2020

Figure 3.11. Trends of R&D spending on maize by thematic areas, 2015-2020



Source: IAARD, ICFCRD, ICRI, 2015-2020

The R&D spending on maize by thematic areas from 2015 to 2020 was directed to breeding technology development, indicated by its share of about 76.34% (Table 3.11). The second largest, at 21.63%, was spent on corn cultivation development. The budget allocation for the development of corn cultivation saw a positive trend (while the trends of other themes were negative), with an increase of 12.93% per year.

Soybean

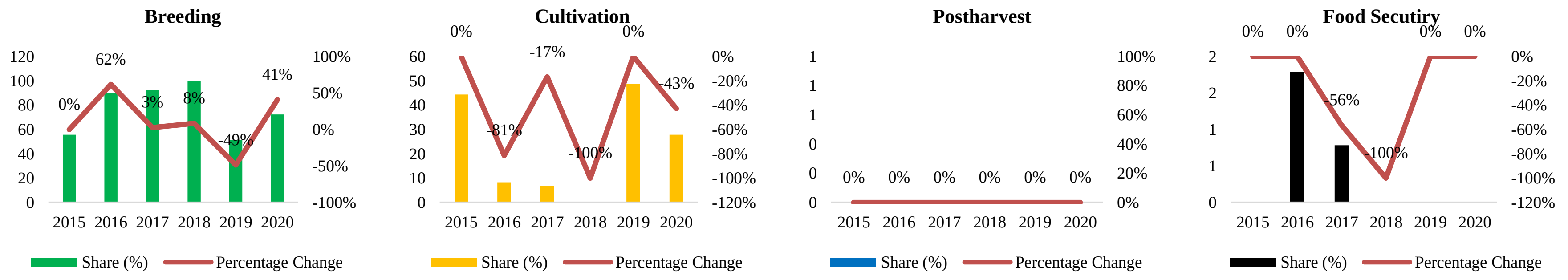
Box 3.4. Soybean – R&D spending by thematic areas, 2015-2020

Table 3.11. The amounts and shares of R&D spending on soybean by thematic areas, 2015-2020

Thematic area	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	155	55.63	445	89.93	364	92.33	77	100.00	147	51.35	76	72.19	211	77.24
Cultivation	123	44.37	41	8.28	27	6.89	0	0.00	140	48.65	29	27.81	60	22.03
Post-harvest	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Food security	0	0.00	9	1.79	3	0.78	0	0.00	0	0.00	0	0.00	2	0.73
Total	278	100.00	494	100.00	394	100.00	77	100.00	287	100.00	105	100.00	273	100.00

Source: IAARD, ICFCRD, ILTCRI, 2015-2020

Figure 3.12. Trends of R&D spending on soybean by thematic areas, 2015-2020



Source: IAARD, ICFCRD, ILTCRI, 2015-2020

The research budget allocation for the 2015-2020 period for soybeans focused on breeding development, amounting to 77.24% (Table 3.12). Breeding is the only R&D theme with a positive trend (Figure 3.11). Other R&D themes were only allocated no more than 25%. In fact, the post-harvest theme received no budget during the analysis period.

Mango

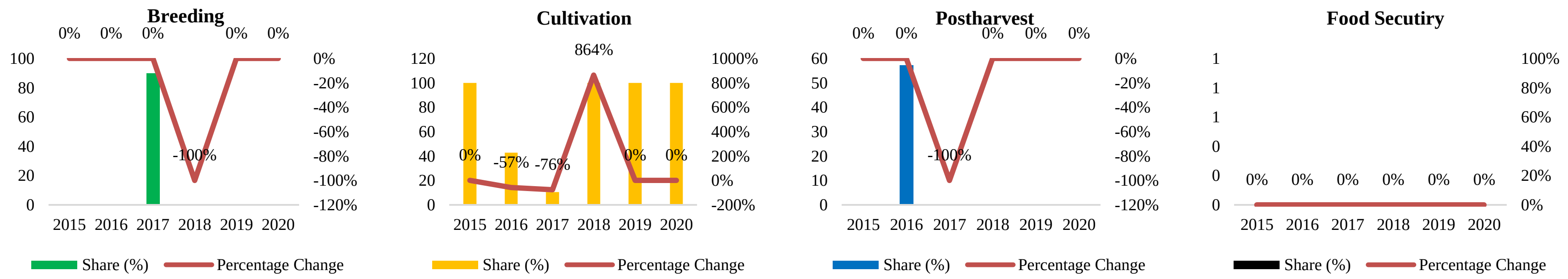
Box 3.5. Mango – R&D spending by thematic areas, 2015-2020

Table 3.12. The amounts and shares of R&D spending on mango by thematic areas, 2015-2020

Thematic	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	0	0.00	0	0.00	127	89.62	0	0.00	0	0.00	0	0.00	21	52.82
Cultivation	15	100.00	20	42.86	15	10.38	16	100.00	15	100.00	7	100.00	15	36.34
Post-harvest	0	0.00	26	57.14	0	0.00	0	0.00	0	0.00	0	0.00	4	10.84
Food security	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	15	100.00	46	100.00	142	100.00	16	100.00	15	100.00	7	100.00	40	100.00

Source: IAARD, ICHORD, ITFRI, 2015-2020

Figure 3.13. Trends of R&D spending on mango by thematic areas, 2015-2020



Source: IAARD, ICHORD, ITFRI, 2015-2020

The R&D spending on mango development was split into four thematic areas, as seen in Table 3.13. The biggest expenditure at 53%was allocated for the development of technology breeding, followed by cultivation and sub-optimal land use technologies at 36%, and post-harvest technology at 10%. Meanwhile, food security received no budget allocation in 2015-2020. In general, the distribution of budgets for all themes followed no specific patterns during the analysis period.

Shallot

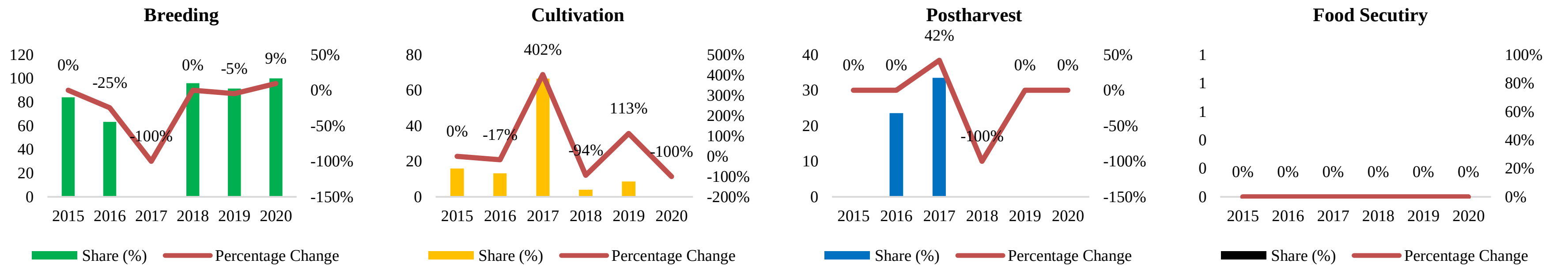
Box 3.6. Shallot – R&D spending by thematic areas, 2015-2020

Table 3.13. The amounts and shares of R&D spending on shallot by thematic areas, 2015-2020

Thematic	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	119	84.02	116	63.18	0	0.00	482	95.97	252	91.43	34	100.00	167	81.61
Cultivation	23	15.98	24	13.25	61	66.52	20	4.03	24	8.57	0	0.00	25	12.36
Post-harvest	0	0.00	43	23.57	31	33.48	0	0.00	0	0.00	0	0.00	12	6.03
Food security	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	142	100.00	184	100.00	92	100.00	502	100.00	276	100.00	34	100.00	205	100.00

Source: IAARD, ICHORD, IVRS, 2015-2020

Figure 3.14. Trends of R&D spending on shallot by thematic areas, 2015-2020



Source: IAARD, ICHORD, ITFRI, 2015-2020

The majority of the R&D budget (82%) for shallot was spent on breeding technology development, followed by cultivation and sub-optimal land use technologies at 12% and post-harvest technology at 6%. Like other commodities, shallot did not receive budget for food security in 2015-2020.

Chili

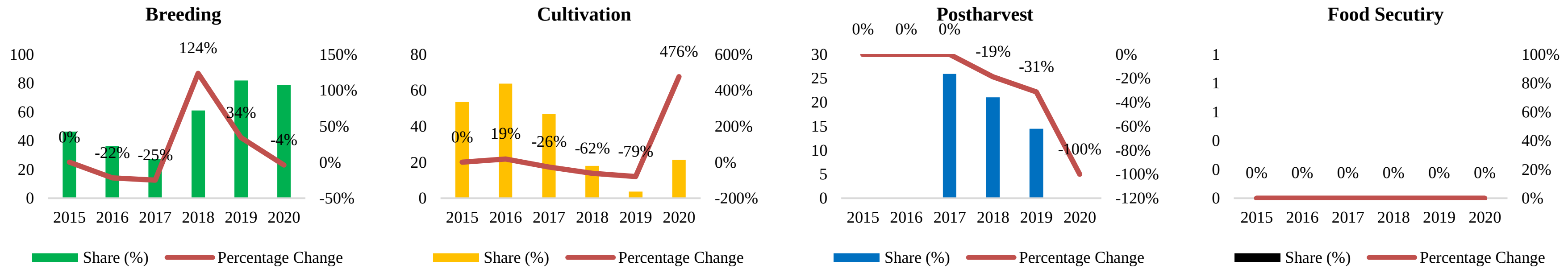
Box 3.7. Chili – R&D spending by thematic areas, 2015-2020

Table 3.14. The amounts and shares of R&D spending on chili by thematic areas, 2015-2020

Thematic	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	28	46.37	35	36.31	15	27.27	81	61.00	151	81.81	53	78.74	61	60.74
Cultivation	33	53.63	62	63.69	26	46.81	24	17.93	7	3.69	14	21.26	28	27.68
Post-harvest	0	0.00	0	0.00	15	25.92	28	21.07	27	14.50	0	0.00	12	11.59
Food security	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	61	100.00	97	100.00	57	100.00	133	100.00	185	100.00	67	100.00	100	100.00

Source: IAARD, ICHORD, IVRS, 2015-2020

Figure 3.15. Trends of R&D spending on chili by thematic areas, 2015-2020



Source: IAARD, ICHORD, ITFRI, 2015-2020

R&D spending on chili was mostly (61%) allocated for research on the development of breeding technology, followed by cultivation and sub-optimal land use technologies and post-harvest technology, at 28% and 12%, respectively. The budget allocations for breeding technology and cultivation and sub-optimal land use have been consistent from 2020-2015, although there was not much increase. Meanwhile, R&D activities for food security activities did not receive a budget.

Coffee

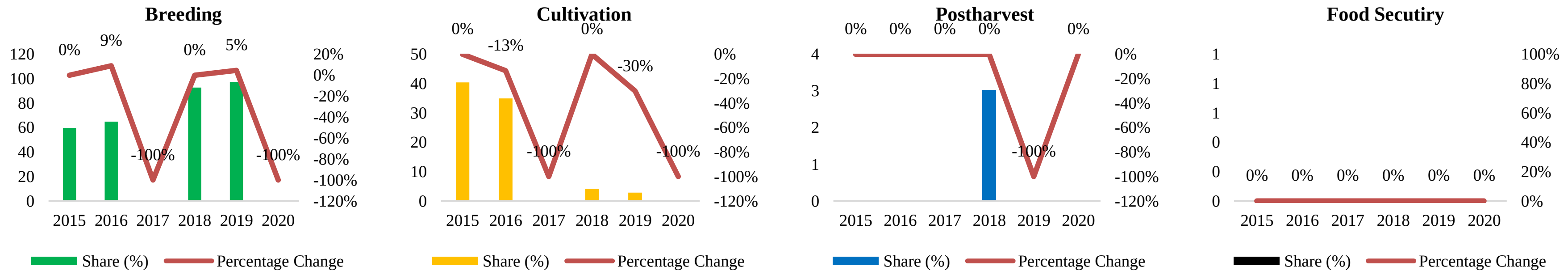
Box 3.8. Coffee – R&D spending by thematic areas, 2015-2020

Table 3.15. The amounts and shares of R&D spending on coffee by thematic areas, 2015-2020

Thematic	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	31	59.64	48	65.01	0	0.00	172	92.86	254	97.12	0	0.00	84	88.19
Cultivation	21	40.36	26	34.99	0	0.00	8	4.12	8	2.88	0	0.00	10	10.84
Post-harvest	0	0.00	0	0.00	0	0.00	6	3.02	0	0.00	0	0.00	1	0.98
Food security	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	52	100.00	74	100.00	0	0.00	185	100.00	261	100.00	0	0.00	95	100.00

Source: IAARD, ICECRD, 2015-2020

Figure 3.16. Trends of R&D spending on coffee by thematic areas, 2015-2020



Source: IAARD, ICECRD, 2015-2020

During the 2015-2020 period, R&D spending on coffee was predominantly absorbed by breeding technology development, at 88% on average. Meanwhile, cultivation technology and suboptimal land use received 11%, and post-harvest only 0.98% of the total spending. Food security did not receive a budget throughout the period. In 2020, three thematic areas did not receive a budget due to budgetary priorities for COVID-19 response.

Cocoa

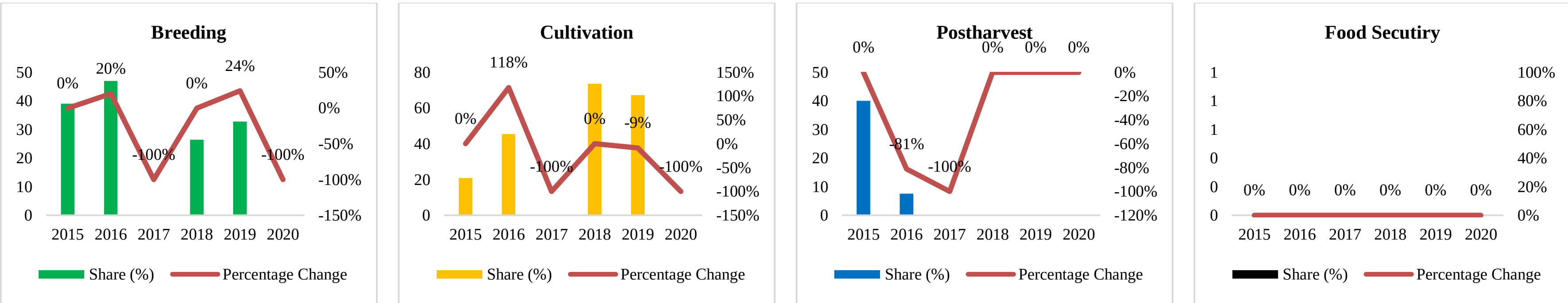
Box 3.9. Cocoa – R&D spending by thematic areas, 2015-2020

Table 3.16. The amounts and shares of R&D spending on cocoa by thematic areas, 2015-2020

Thematic	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	69	39.07	40	46.97	0	0.00	37	26.44	13	32.82	0	0.00	27	36.01
Cultivation	37	20.83	39	45.44	0	0.00	103	73.56	27	67.18	0	0.00	34	46.48
Post-harvest	71	40.09	6	7.59	0	0.00	0	0.00	0	0.00	0	0.00	13	17.50
Food security	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	178	100.00	85	100.00	0	0.00	140	100.00	41	100.00	0	0.00	74	100.00

Source: IAARD, ICECRD, 2015-2020

Figure 3.17. Trends of R&D spending on cocoa by thematic areas, 2015-2020



Source: IAARD, ICECRD, 2015-2020

As much as 47% of the R&D spending on cocoa commodities was allocated for the development of cultivation and sub-optimal land use technologies, followed by research on breeding technology at 36% and post-harvest at 17% (Table 3.18). In general, the distribution of the R&D budget for the development of breeding and cultivation technologies fluctuates during the analysis period. Looking into the average budget more closely, breeding and cultivation received the same value: USD0.03 million. Similar to other commodities, food security did not receive a budget.

Beef

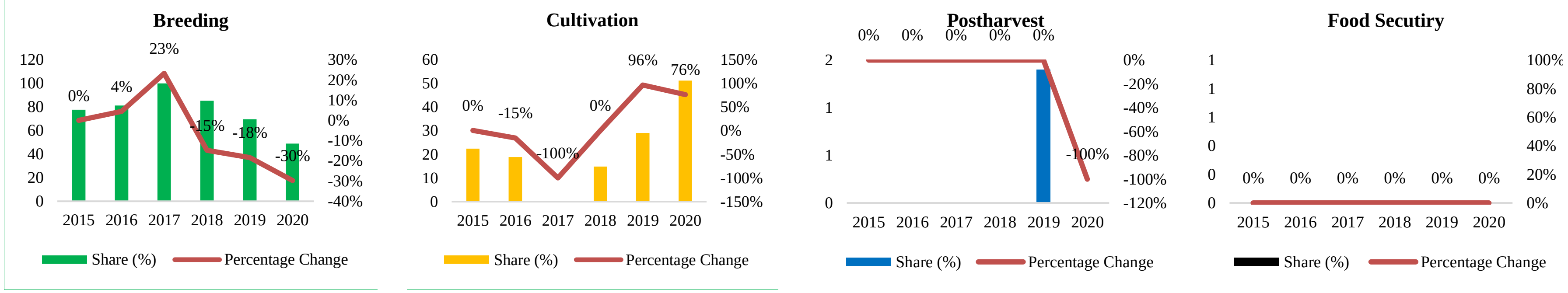
Box 3.10. Beef – R&D spending by thematic areas, 2015-2020

Table 3.17. The amounts and shares of R&D spending on beef by thematic areas, 2015-2020

Thematic	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	355	77.67	405	81.13	169	100.00	207	85.20	537	69.58	171	48.90	307	74.07
Cultivation	102	22.33	94	18.87	0	0.00	36	14.80	224	29.03	179	51.10	106	25.50
Post-harvest	0	0.00	0	0.00	0	0.00	0	0.00	11	1.40	0	0.00	2	0.43
Food security	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	457	100.00	499	100.00	169	100.00	243	100.00	771	100.00	350	100.00	415	100.00

Source: IAARD, ICARD, IRIAP, IRCVS, BCRS, 2015-2020

Figure 3.18. Trends of R&D spending on beef by thematic areas, 2015-2020



Source: IAARD, ICARD, IRIAP, IRCVS, BCRS, 2015-2020

Despite the sharp decline since 2017, overall, breeding technology development received the highest R&D spending during the analysis period. The second priority was allocated for forages and feed technology development, including sub-optimal land use technology. Meanwhile, R&D spending for post-harvest was limited at only 1.4% of the total budget in 2019.

Poultry

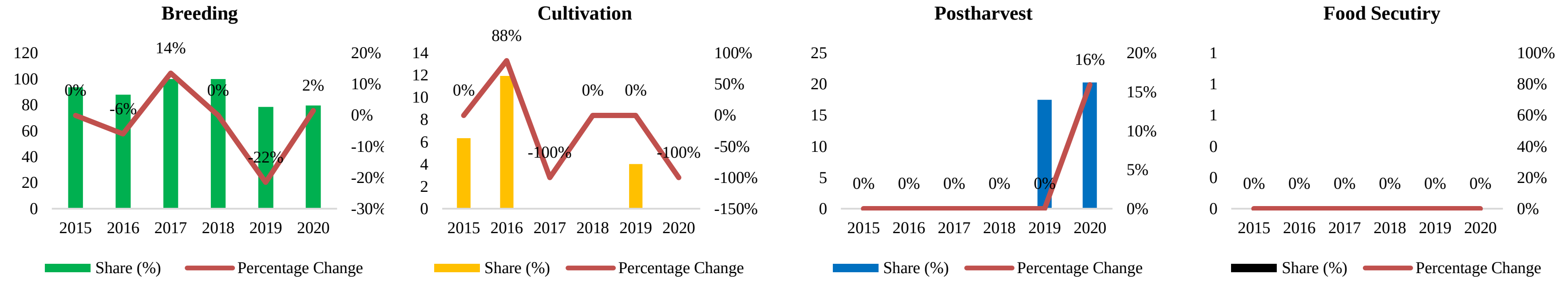
Box 3.11. Poultry – R&D spending by thematic areas, 2015-2020

Table 3.18. The amounts and shares of R&D spending on poultry by thematic areas, 2015-2020

Thematic	2015		2016		2017		2018		2019		2020		Average	
	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%	Thousand USD	%
Breeding	153	93.64	174	88.05	157	100.00	65	100.00	154	78.48	180	51.44	147	87.85
Cultivation	10	6.36	24	11.95	0	0.00	0	0.00	8	4.01	0	0.00	7	4.17
Post-harvest	0	0.00	0	0.00	0	0.00	0	0.00	34	17.52	46	13.11	13	7.98
Food security	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	163	100.00	198	100.00	157	100.00	65	100.00	196	100.00	226	64.55	167	100.00

Source: IAARD, IAARD, ICARD, IRIAP, IRCVS, 2015-2020

Figure 3.19. Trends of R&D spending on poultry by thematic areas, 2015-2020



Source: IAARD, IAARD, ICARD, IRIAP, IRCVS, 2015-2020

The R&D spending on poultry from 2015 to 2020 was prioritized for breeding technology activities. The trends fluctuated throughout the years, with a peak in 2017. Other thematic areas received budget only in certain periods, and it's reflected in the figures. For example, R&D spending on efficiency in production and cultivation was allocated in 2015-2016, and significant spending on post-harvest was disbursed in 2019.

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3.3.3.2. R&D Spending by Impact Areas

Rice

Examined from the impact areas, R&D spending on rice commodities was allocated mostly for productivity. Table 3.19 shows that, over the six-year period (2015-2020), the total amount of R&D spending to improve productivity was about USD4.47 million (average USD0.75 million per year), which amounted to 86.26% of the total R&D spending. Meanwhile, other impact areas received much lower funding: nutrition at 11.20%, environmental sustainability at 3.82%, and climate change at 2.23%. The productivity improvement includes research in high-yielding varieties, pest and disease control, reduction of potential loss of crop yields, land fertility and water management, and cropping patterns.

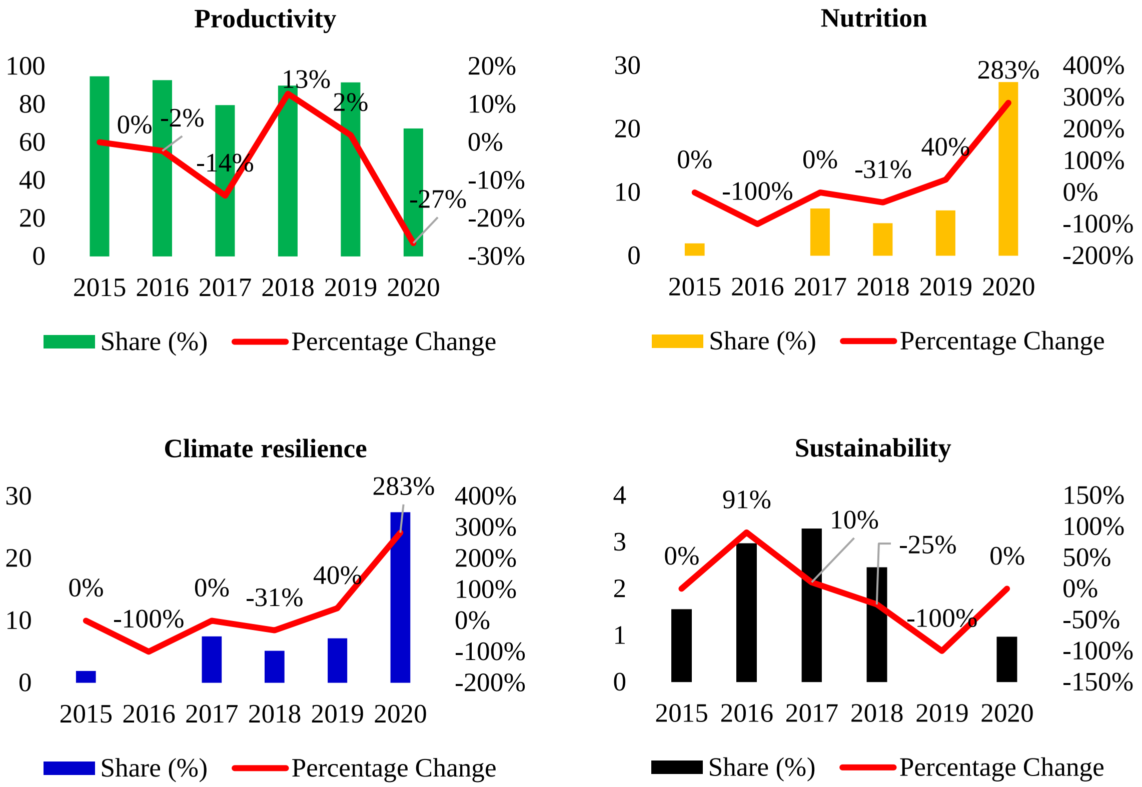
Table 3.19. The amounts and shares of R&D spending on rice by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	810	960	670	510	1350	170	750
Share (%)	95.29	93.2	79.76	89.47	91.84	68	86.26
Nutrition:							
Amount (thousand USD)	20	0	60	40	110	80	60
Share (%)	2.35	0	7.14	7.02	7.48	32	11.2
Climate resilience:							
Amount (thousand USD)	10	30	30	20	0	0	20
Share (%)	1.18	2.91	3.57	3.51	0	0	2.23
Sustainability:							
Amount (thousand USD)	10	40	80	0	10	0	40
Share (%)	1.18	3.88	9.52	0	0.68	0	3.82
Total:							
Amount (thousand USD)	850	1030	840	570	1470	250	840
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: IAARD, ICFCRD, ICRR, TDRS, IRICC, ICAPOSTRD, ICASEPS, 2015-2020

Figure 3.20 shows the trend of R&D spending on rice in the last six years (2015-2020). The trend of R&D spending on nutrition, climate resilience, and sustainability saw a positive trend, i.e., 58.17%, 16.90%, and 43.54%, respectively. The budget allocations for nutrition research increased most significantly although, in some years, there was none. This indicates that the R&D in rice commodities will be directed at improving nutrition, for example zinc nutritional rice seeds or biofortification.

Figure 3.20. The trend of R&D spending on rice by impact areas from 2015 to 2020



Source: IAARD, ICFCRD, ICRR, TDRS, IRICC, ICAPOSTRD, ICASEPS, 2015-2020

Maize

Similar to rice, almost all R&D spending (96.12%) on maize was directed to increasing productivity (Table 3.20). Nutrition development only received the budget in 2015 and sustainability in 2016 and 2017, with a share of less than 5%. Meanwhile, climate resilience received no budget allocation in the period. Increasing maize productivity includes the development of superior seeds, adaptive seeds for sub-optimal land, control of aflatoxin contamination, and technology development for the cultivation, harvest, and post-harvest activities.

Table 3.20. The amounts and shares of R&D spending on maize by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	352	228	316	180	344	0	237
Share (%)	97.83	84.81	97.32	100.00	100.00	0.00	96.12
Nutrition:							
Amount (thousand USD)	8	0	0	0	0	0	1
Share (%)	2.17	0.00	0.00	0.00	0.00	0.00	0.53
Climate resilience:							
Amount (thousand USD)	0	0	0	0	0	0	0
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainability:							
Amount (thousand USD)	0	41	9	0	0	0	8
Share (%)	0.00	15.19	2.68	0.00	0.00	0.00	3.35

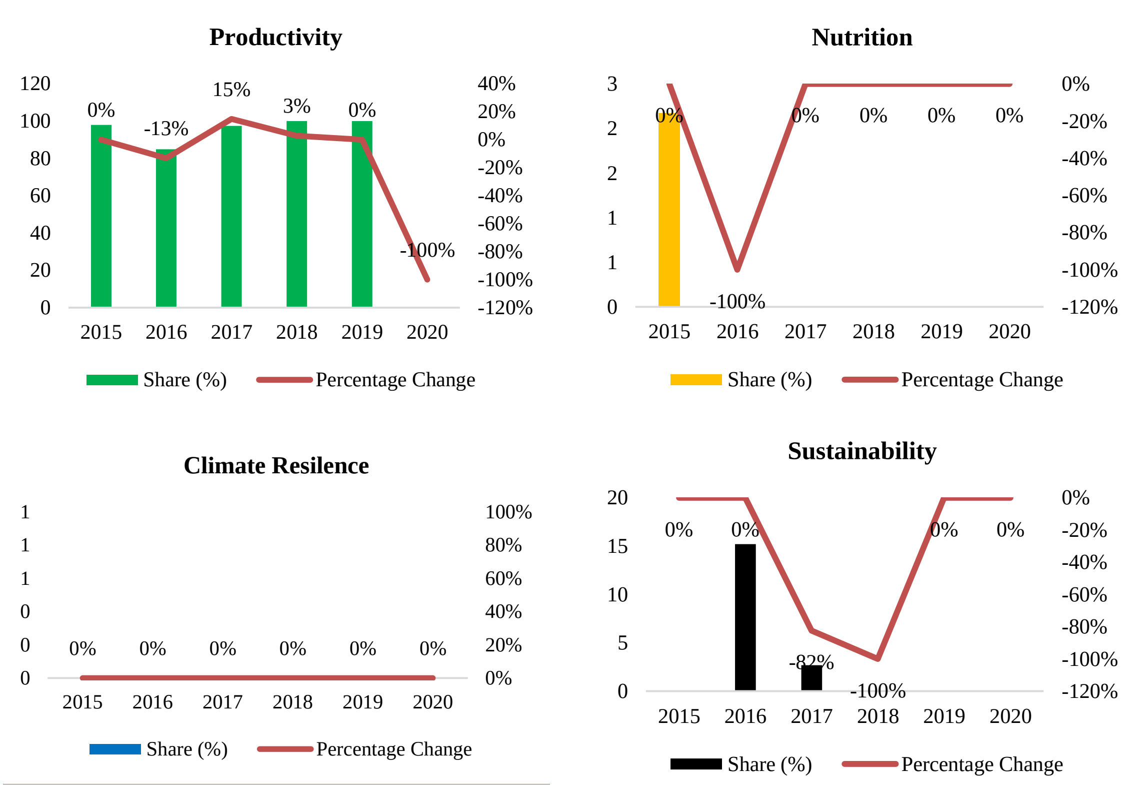
Table 3.20. Continued…

Item	2015	2016	2017	2018	2019	2020	Average
Total:							
Amount (thousand USD)	360	269	325	180	344	0	246
Share (%)	100.00	100.00	100.00	100.00	100.00	0.00	100.00

Source: IAARD, ICFCRD, ICRI, 2015-2020

In general, R&D budget allocation for maize saw a negative trend from 2015 to 2020 (Figure 3.21). The R&D budget stopped in 2020 when the COVID-19 pandemic hit. Nevertheless, considering the large proportion and the steady increase at 1.05% per year, it is predicted that R&D spending on maize in the future will continue to focus on increasing productivity. This may correspond to the fact that maize is not only a food commodity but is also used for feed and energy.

Figure 3.21. The trend of R&D spending on maize by impact areas from 2015 to 2020



Source: IAARD, ICFCRD, ICRI, 2015-2020

Soybean

Similar to rice and maize, almost the entire soybean R&D budget (95.43%) is allocated for productivity from 2015 to 2020 (Table 3.21). Climate resilience received a budget only in 2016 and sustainability in 2016-2018, with a much lower proportion, at 0.94% and 3.63%, respectively. Meanwhile, nutrition received no budget allocation. The productivity improvement includes the development of superior seeds, adaptive seeds for sub-optimal land, biotic and abiotic stress resistance, the improvement of cultivation technology, pest and disease control, the reduction of potential yield loss at harvest, and the development of seed storage technology.

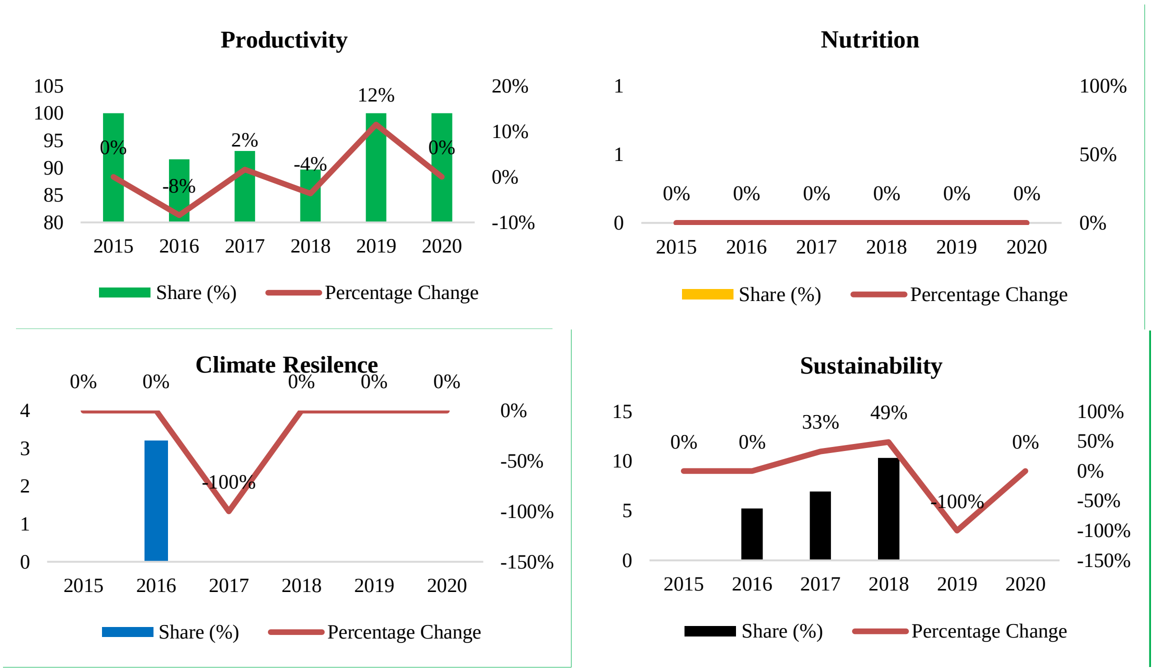
Table 3.21. The amounts and shares of R&D spending on soybean by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	318	445	364	69	287	105	265
Share (%)	100.00	91.57	93.06	89.67	100.00	100.00	95.43
Nutrition:							
Amount (thousand USD)	0	0	0	0	0	0	0
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Climate resilience:							
Amount (thousand USD)	0	16	0	0	0	0	3
Share (%)	0.00	3.21	0.00	0.00	0.00	0.00	0.94
Sustainability:							
Amount (thousand USD)	0	25	27	8	0	0	10
Share (%)	0.00	5.22	6.94	10.33	0.00	0.00	3.63
Total:							
Amount (thousand USD)	318	485	391	77	287	105	277
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: IAARD, ICFCRD, ILTCRI, 2015-2020

In general, soybean R&D budget decreased over the 2015-2020 period (Figure 3.22). Since the productivity budget remained positive at an average of 0.21% per year, it is predicted that the budget allocation will still be allocated for increasing productivity in the future. Indonesia imports soybean in a relatively large volume, so increasing production is considered a priority.

Figure 3.22. The trend of R&D spending on soybean by impact areas from 2015 to 2020



Source: IAARD, ICFCRD, ILTCRI, 2015-2020

Mango

Likewise, R&D spending on mango is prioritized for productivity, with the share of 81% from 2015-2020 (Table 3.22). The budget allocation for productivity in 2017-2020 was relatively stable. The sustainability impact area received only 19.26%, while nutrition and climate resilience did not receive any budgets.

Table 3.22. The amounts and shares of R&D spending on mango by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	0	0	136	16	15	9	29
Share (%)	0.00	0.00	100.00	100.00	100.00	56.95	80.74
Nutrition:							
Amount (thousand USD)	0	0	0	0	0	0	0
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Climate resilience:							
Amount (thousand USD)	0	0	0	0	0	0	0
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainability:							
Amount (thousand USD)	15	20	0	0	0	7	7
Share (%)	100.00	100.00	0.00	0.00	0.00	43.05	19.26
Total:							
Amount (thousand USD)	15	20	136	16	15	16	36
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: IAARD, ICHORD, ITFRI, 2015-2020

However, in 2020, the amount spent on productivity declined from USD136 thousand in 2017 to USD9 thousand in 2020. Likewise, the spending on sustainability decreased form USD15 thousand in 2015 to USD7 thousand in 2020.

Pineapple

Pineapple has not been a priority, as seen in the R&D budget of USD5.7 thousand in total, which is substantially lower than the previous commodities. This budget was disbursed in 2018 and 2019 to increase productivity only (Table 3.23).

Table 3.23. The amounts and shares of R&D spending on pineapple by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	0.00	0.00	0.00	17.47	16.74	0.00	5.70
Share (%)	0.00	0.00	0.00	100.00	100.00	0.00	100.00
Nutrition:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Climate resilience:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainability:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total:							
Amount (thousand USD)	0.00	0.00	0.00	17.47	16.74	0.00	5.70
Share (%)	0.00	0.00	0.00	100.00	100.00	0.00	100.00

Source: IAARD, ICHORD, ITFRI, 2015-2020

The table shows that the spending decreased by about 4.18% from USD17.47 thousand in 2018 to USD16.74 thousand in 2019.

Shallot

Shallot is a valuable commodity in Indonesia, with R&D spending being consistently allocated for productivity throughout 2015 to 2020. On average, the impact of R&D spending has succeeded in increasing productivity by USD0.17 million per year (Table 3.24). There was a significant decrease from USD0.46 million in 2018 to USD0.24 million in 2019. In 2020, the budget decreased substantially to only USD34.42 thousand.

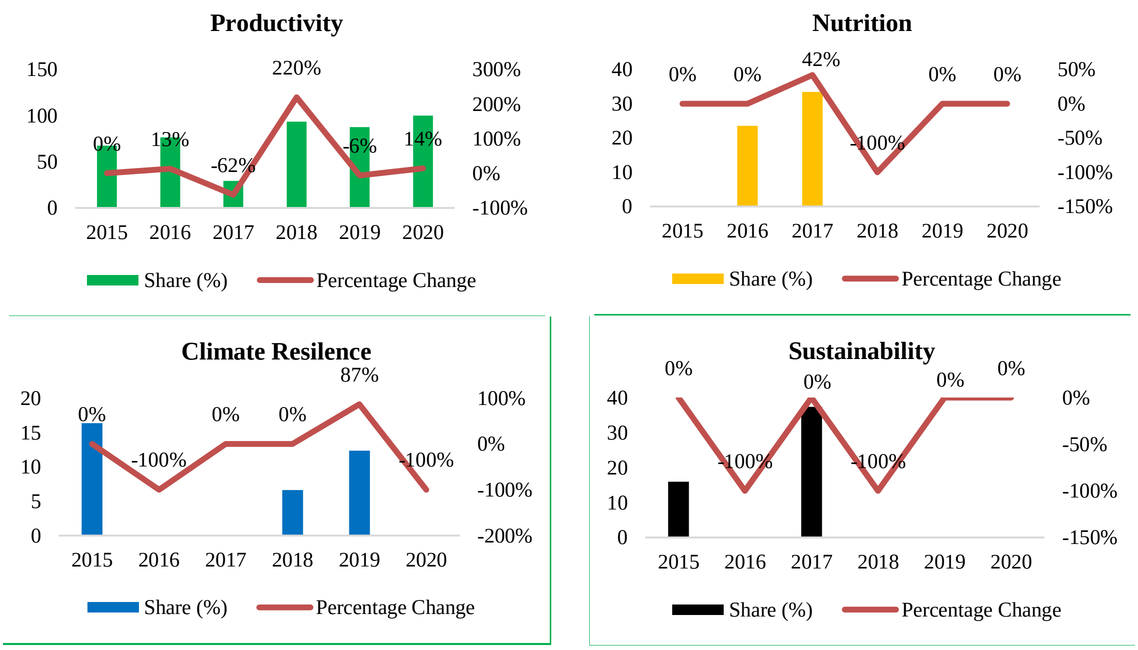
Table 3.24. The amounts and shares of R&D spending on shallot by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	95.95	140.89	26.83	469.09	241.64	34.42	168.14
Share (%)	67.65	76.43	29.19	93.39	87.66	100.00	81.99
Nutrition:							
Amount (thousand USD)	0.00	43.44	30.77	0.00	0.00	0.00	12.37
Share (%)	0.00	23.57	33.48	0.00	0.00	0.00	6.03
Climate resilience:							
Amount (thousand USD)	23.23	0.00	0.00	33.22	34.02	0.00	15.08
Share (%)	16.38	0.00	0.00	6.61	12.34	0.00	7.35
Sustainability:							
Amount (thousand USD)	22.66	0.00	34.32	0.00	0.00	0.00	9.50
Share (%)	15.98	0.00	37.33	0.00	0.00	0.00	4.63
Total:							
Amount (thousand USD)	141.84	184.33	91.92	502.31	275.67	34.42	205.08
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: IAARD, ICHORD, IVRS, 2015-2020

The R&D spending on nutrition, climate resilience, and sustainability fluctuated throughout the year (Figure 3.23). It was because the budget allocation was inconsistent throughout 2015-2020. Based on the allocated budget value, the amount was relatively stable for these three aspects.

Figure 3.23. The trend of R&D spending by impact areas of shallot commodity, 2015-2020



Source: IAARD, ICHORD, IVRS, 2015-2020

Chili

Chili is another strategic commodity in Indonesia. Similar to shallot, chili can also affect inflation. Therefore, it receives more R&D budget than other commodities. Over the six-year period, R&D spending on chili R&D was directed to productivity, with an average of 75% (Table 3.25). Research on climate resilience and nutrition received 10.35%, and 10.27%, respectively.

Only the budget to increase productivity was distributed consistently from 2016 to 2020, with the amount ranging from USD0.07 to 0.12 million. The other impact areas' budgeting was relatively more sporadic.

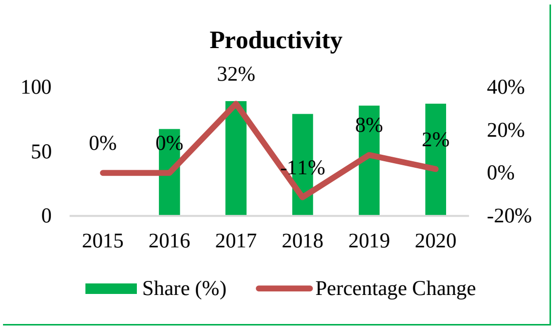
Table 3.25. The amounts and shares of R&D spending on chili by impact areas from 2015 to 2020

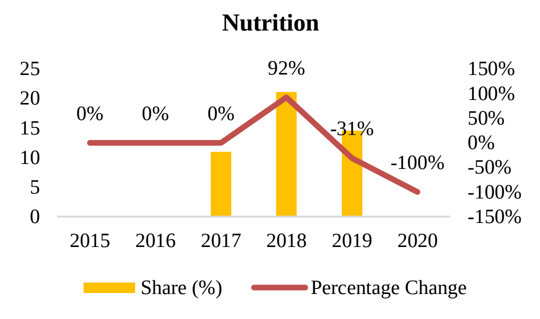
Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	0.00	65.17	118.91	104.93	157.88	58.50	84.23
Share (%)	0.00	67.38	89.03	78.93	85.50	87.04	74.72
Nutrition:							
Amount (thousand USD)	0.00	0.00	14.65	28.02	26.78	0.00	11.58
Share (%)	0.00	0.00	10.97	21.07	14.50	0.00	10.27
Climate resilience:							
Amount (thousand USD)	61.29	0.00	0.00	0.00	0.00	8.71	11.67
Share (%)	100.00	0.00	0.00	0.00	0.00	12.96	10.35
Sustainability:							
Amount (thousand USD)	0.00	31.55	0.00	0.00	0.00	0.00	5.26
Share (%)	0.00	32.62	0.00	0.00	0.00	0.00	4.66
Total:							
Amount (thousand USD)	61.29	96.72	133.56	132.94	184.66	67.22	112.73
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

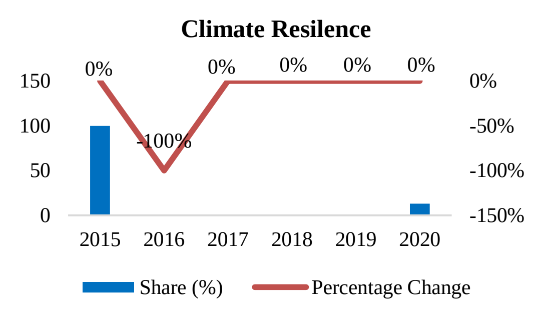
Source: IAARD, ICHORD, IVRS, 2015-2020

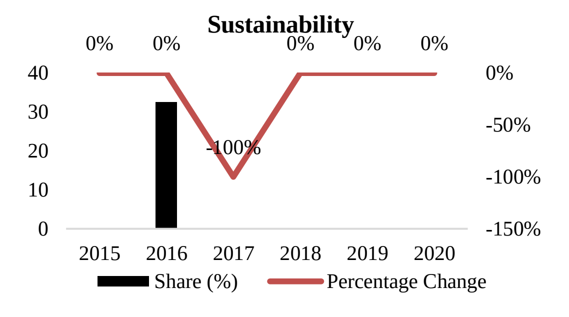
In 2017, R&D spending on chili commodities (89%) was allocated to increase productivity (Figure 3.24). Climate resilience and sustainability only received a budget for a year, while nutrition received allocations in 2017, 2018, and 2019 with a relatively stable amount.

Figure 3.24. The trend of R&D spending by impact areas of chili commodity, 2015-2020









Source: IAARD, ICHORD, IVRS, 2015-2020

Coffee

Over the six-year period, R&D spending on coffee commodities was prioritized for productivity improvement. The 97% of the total budget directed to this impact area is expected to drive significant growth (Table 3.26).

MoA noted that coffee productivity in Indonesia increased by 2.7% annually in 2015-2020. A detailed discussion related to the development of coffee productivity is presented in Chapter IV. Meanwhile, the R&D activities in the coffee industries that are estimated to have an impact on the sustainability area contribute only 3.38%. Meanwhile, nutrition and climate-resilience impact areas did not receive any budget over the six-year period. Moreover, in 2018, 100% of the R&D budget was directed to activities that focused on increasing productivity, amounting to USD0.19 million. This result is in line with the finding from an interview with stakeholders in coffee and cocoa research center in Jember.

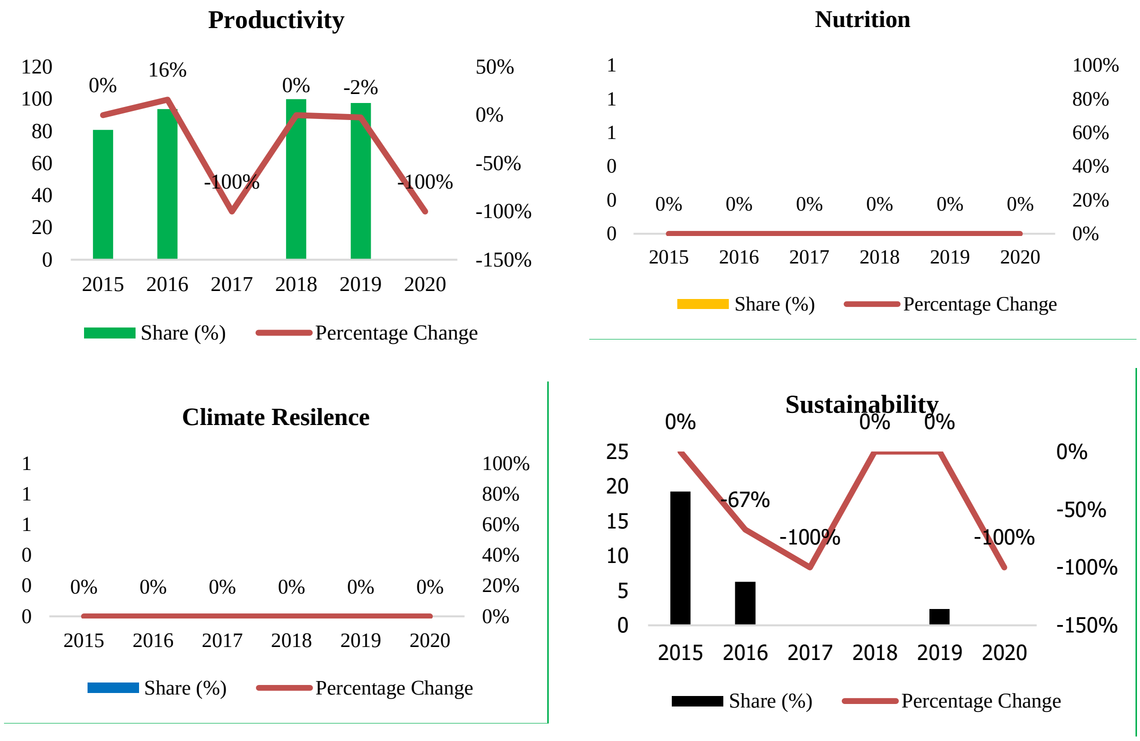
Table 3.26. The amounts and shares of R&D spending on coffee by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	34.62	68.99	0.00	185.35	255.00	0.00	90.66
Share (%)	80.74	93.71	0.00	100.00	97.64	0.00	96.62
Nutrition:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Climate resilience:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainability:							
Amount (thousand USD)	8.26	4.63	0.00	0.00	6.15	0.00	3.17
Share (%)	19.26	6.29	0.00	0.00	2.36	0.00	3.38
Total:							
Amount (thousand USD)	42.88	73.62	0.00	185.35	261.16	0.00	93.84
Share (%)	100.00	100.00	0.00	100.00	100.00	0.00	100.00

Source: IAARD, ICECRD, 2015-2020

Figure 3.25 shows that R&D expenditure focusing on improving productivity and production fluctuated throughout the years. The budget for this impact area increased in 2015 and 2016. In 2017, the budget allocation stopped. In 2018, 100% of the total budget was allocated for activities that aim to increase coffee productivity. In 2020, the budget for this impact area was stopped again. Meanwhile, the budget allocation for impact areas related to environmental sustainability remained small and inconsistent throughout the analysis period.

Figure 3.25. The trend of R&D spending by impact areas of coffee commodity, 2015-2020



Source: IAARD, ICECRD, 2015-2020

Cocoa

Similar to other commodities, activities dominating R&D spending on cocoa aimed to increase productivity (Table 3.27). On average, 86% of the budget was spent on increasing productivity, amounting to USD0.06 million. The second prioritized impact area is the nutritional quality improvement at 10.05%, although the budget was only allocated for two years in 2015 and 2016.

The R&D budget spent on sustainability was relatively small, at 4.32%, and only allocated in 2015 and 2019. Meanwhile, climate resilience impact area received no funding at all (Figure 3.26). Cocoa was a strategic commodity in 2015-2019 and the production was boosted through various programs. It is also included in the triple export increase program (*GratiEks*) in the 2010-2024 periods. However, research budgets for productivity are not consistently allocated in 2015-2020.

Table 3.27. The amounts and shares of R&D spending on cocoa by impact areas from 2015 to 2020

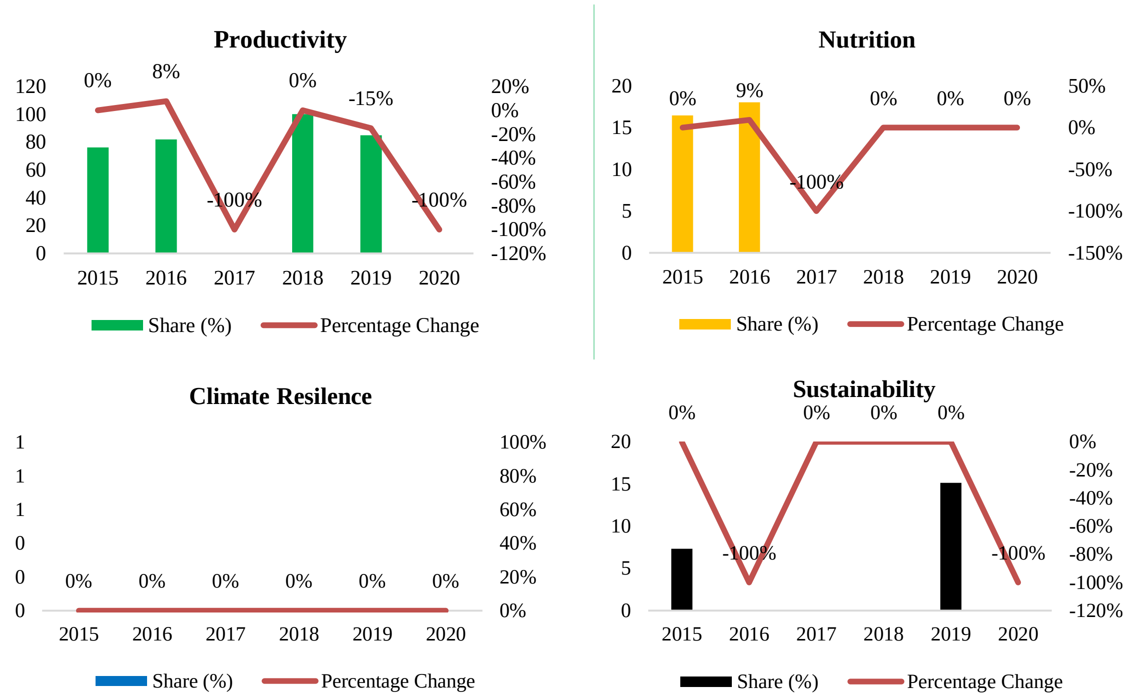
Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	135.28	69.57	0.00	140.42	34.46	0.00	63.29
Share (%)	76.20	81.98	0.00	100.00	84.85	0.00	85.63
Nutrition:							
Amount (thousand USD)	29.27	15.30	0.00	0.00	0.00	0.00	7.43
Share (%)	16.49	18.02	0.00	0.00	0.00	0.00	10.05
Climate resilience:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainability:							
Amount (thousand USD)	12.99	0.00	0.00	0.00	6.15	0.00	3.19
Share (%)	7.31	0.00	0.00	0.00	15.15	0.00	4.32

Table 3.27. Continued…

Item	2015	2016	2017	2018	2019	2020	Average
Total:							
Amount (thousand USD)	177.53	84.87	0.00	140.42	40.61	0.00	73.90
Share (%)	100.00	100.00	0.00	100.00	100.00	0.00	100.00

Source: IAARD, ICECRD, 2015-2020

Figure 3.26. The trend of R&D spending by impact areas of cocoa commodity from 2015 to 2020



Source: IAARD, ICECRD, 2015-2020

Beef

Similar to other commodities, most of the R&D spending on beef from 2015 to 2020 aimed at increasing productivity, with an average of USD0.39 million. The highest spending was in 2019, reaching USD0.66 million USD (Table 3.28). During the COVID-19 outbreak in 2020, R&D spending for improving productivity decreased by almost 50% from the 2019 budget allocation. Although the budget allocation for improving productivity fluctuated, the cattle breeding sector remains a priority because it supplies the demand for protein in Indonesia. Concerns about climate seemed to have grown, as indicated by the positive growth in the budget although the allocation was less than 10%. R&D spending for climate resilience was earmarked to provide a new climate-sensitive production method.

Beef production contributes 2-9 times the greenhouse gases (GHGs) of other animal products, among others (Cusack *et al.*, 2021) listed source of GHGs emissions such as nitrous oxide from soils in fertilized freed production, methane or CH_4 from manure management and CO_2 from land-use/land over change. Thus, many experts suggest the farmers to: (1) Increased efficiency to produce more beef per unit of GHG emitted; and (2) Enhanced land-based-sequestration to offset GHG emissions and improve feed quality to improve the digestion process. Having this illustration, there is a strong need to improve beef management at farm level and improve the feed variety to support the plant-based feed for beef cattle production.

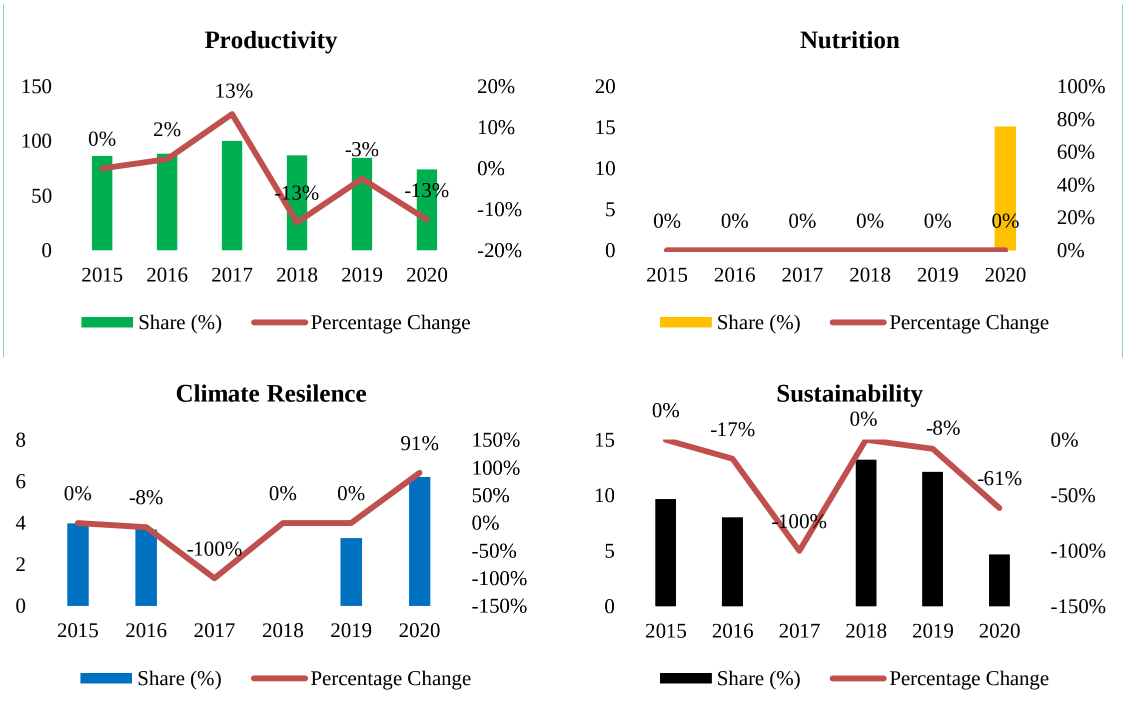
Table 3.28. The amounts and shares of R&D spending on beef by impact areas from 2015 to 2020

Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	394.65	451.21	169.35	210.91	655.57	291.99	362.28
Share (%)	86.36	88.30	0.00	86.79	84.61	0.00	85.25
Nutrition:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	59.59	9.93
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	2.34
Climate resilience:							
Amount (thousand USD)	18.19	18.81	0.00	0.00	25.29	24.56	14.47
Share (%)	3.98	3.68	0.00	0.00	3.26	0.00	3.41
Sustainability:							
Amount (thousand USD)	44.17	40.95	0.00	32.09	93.96	18.50	38.28
Share (%)	9.66	8.01	0.00	13.21	12.13	0.00	9.01
Total:							
Amount (thousand USD)	457.00	510.97	169.35	243.00	774.82	394.64	424.97
Share (%)	100.00	100.00	0.00	100.00	100.00	0.00	100.00

Source: IAARD, ICARD, IRIAP, IRCVS, 2015-2020

The R&D spending was allocated to two impact areas that demonstrated Indonesia's contribution to global concerns: climate resilience and environmental sustainability (Figure 3.27). The R&D spending saw a positive trend that significantly impacted sustainability, particularly in 2018. During this period, R&D spending was allocated for research on optimizing forage productivity in sub-optimal land. However, the trend of R&D spending by impact areas for environmental sustainability decreased in 2019 and 2020.

Figure 3.27. The trend of R&D spending on beef by impact areas from 2015 to 2020



Source: IAARD, IAARD, ICARD, IRIAP, IRCVS, 2015-2020

Poultry

The R&D spending on poultry by impact areas was primarily allocated to productivity, with a relatively stable amount from 2015 to 2020, between USD0.16 and 0.18 million. However, R&D spending on productivity improvement dipped in 2018 since the government introduced the rice-maize-soybean production acceleration program (*Pajale*) as the MoA priority. Nevertheless, Table 3.29 illustrates that the overall R&D spending on this commodity remained high.

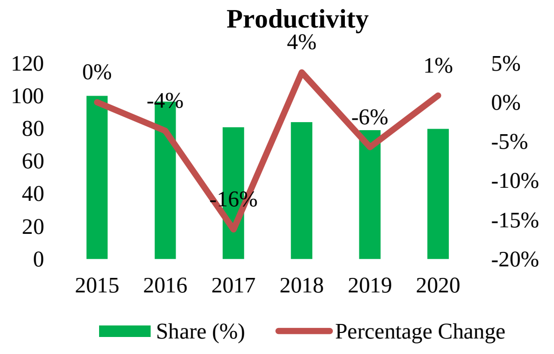
Table 3.29. The amount and share of R&D spending on poultry by impact areas from 2015 to 2020

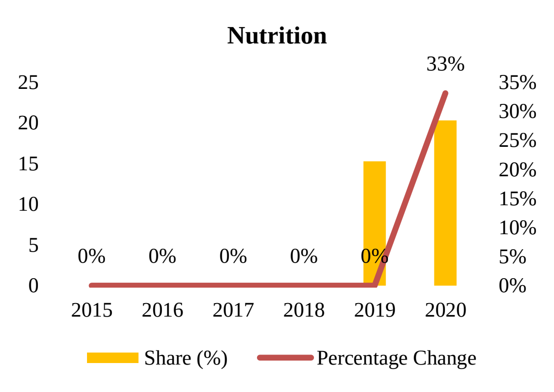
Item	2015	2016	2017	2018	2019	2020	Average
Productivity:							
Amount (thousand USD)	0.16	0.19	0.14	0.05	0.18	0.18	0.15
Share (%)	100.00	96.36	80.72	83.81	79.01	79.69	86.23
Nutrition:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.03	0.05	0.01
Share (%)	0.00	0.00	0.00	0.00	15.26	20.31	7.60
Climate resilience:							
Amount (thousand USD)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Share (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sustainability:							
Amount (thousand USD)	0.00	0.01	0.03	0.01	0.01	0.00	0.01
Share (%)	0.00	3.64	19.28	16.19	5.74	0.00	6.17
Total:							
Amount (thousand USD)	0.16	0.20	0.18	0.07	0.23	0.23	0.18
Share (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00

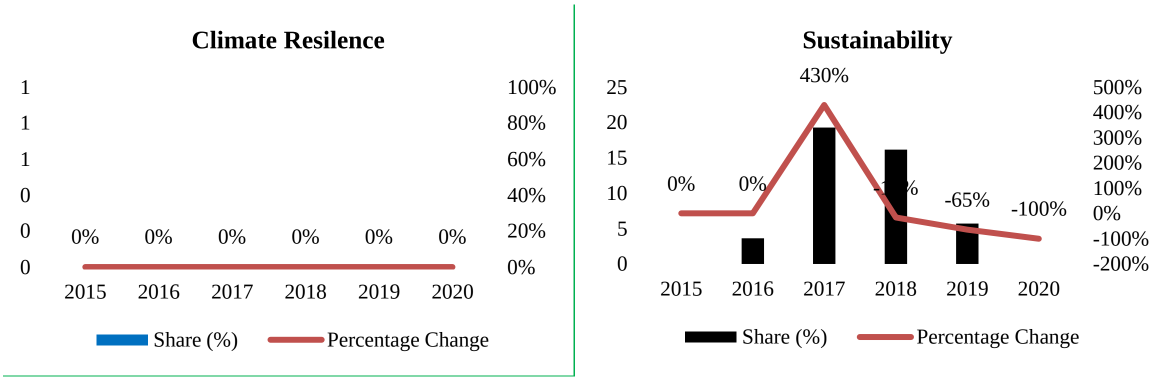
Source: IAARD, ICARD, IRIAP, IRCVS, 2015-2020

In 2019 and 2020, there was R&D spending on nutrition and technology for poultry products, such as to increase eggs' shelf life, and modern technology for developing halal gelatin. The R&D budget was also spent on sustainability (Figure 3.28). In addition, the budget was allocated for research in biodiversity resources; especially genetics because the high-quality breeds of native chickens and ducks need to be preserved.

Figure 3.28. The trend of R&D spending on poultry by impact areas from 2015 to 2020







Source: IAARD, ICARD, IRIAP, IRCVS, 2015-2020

The focus of agriculture's R&D by the public sector during 2015-2020 had been more directed to activities to increase productivity. However, based on interviews with the expert, implementation at the field level was still found that farmers had not fully adopted the technology. There are still gaps faced by small-scale farmers and food consumers that are not supported by the current public R&D system.

The output of R&D spending by impact areas is presented in Chapter Four, which includes strategic aspects such as productivity, nutrition, climate resilience, environmental sustainability, technology introduction, and poverty-related matters.

3.3.3.5. Comparative analyses of R&D spending by impact and thematic areas across sub-sector commodities

The analyses focus on four sub-sectors with their selected commodities: (1) Food crops comprising rice, maize, and soybean; (2) Horticulture comprising mango, pineapple, shallot, and chili; (3) Estate crops consisting of coffee and cocoa; and (4) Livestock consisting of beef and poultry.

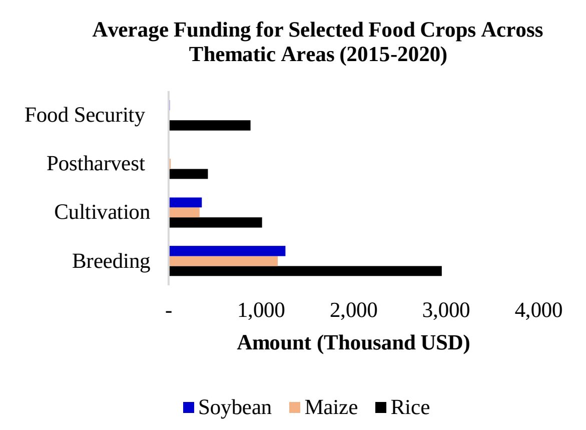
Sub-sector 1: Food crops

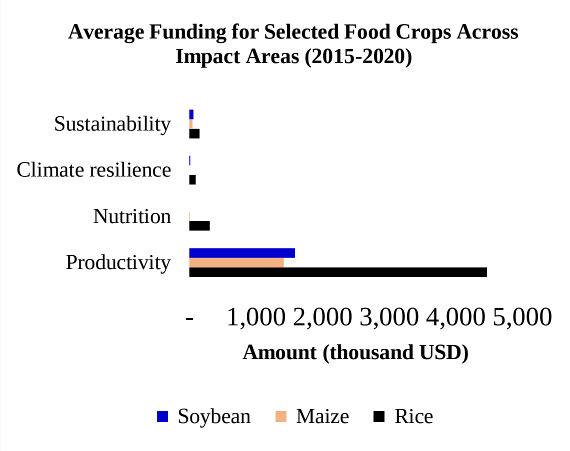
The R&D spending on food crops from 2015 to 2020 favored rice (Figure 3.29), with allocation amounting to 62.36%. Meanwhile, corn and soybean received only 18.30% and 19.35%, respectively. Rice is a staple food for the majority of Indonesians so achieving self-sufficiency is necessary. The availability needs to be ensured, and price levels must be protected because they can lead to inflation. The government also issued a policy to minimize or avoid imports. Rice self-sufficiency is a target that is goal of every government regime. This effort has been carried out since the green revolution in 1970.

By thematic areas, the focus in this sub-sector was on plant breeding, which was about 55.98% on rice, 76.34% on maize, and 77.24% on soybean. The plant breeding program was one of the IAARD key performance indicators. This is different from other R&D thematic areas, which are not explicitly mentioned in the IAARD's key performance indicators.

The R&D spending by impact areas focused the efforts on increasing productivity, reaching 88.92% for rice, 96.12% for maize, and 95.43% for soybean. This is in line with the high spending on seed development since it supports productivity. However, in generating new varieties, breeders also consider the impact on sustainability, climate resilience, nutritional content, and socio-economics. Thus, the development of seeds is generally oriented to high potential yield, resistance to pests, diseases, and climate change, and well as suitability to market demand.

Figure 3.29. Average funding for selected food crops across thematic and impact areas (2015-2020)



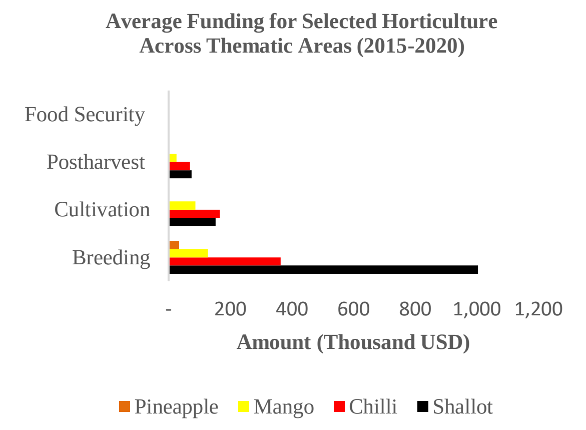


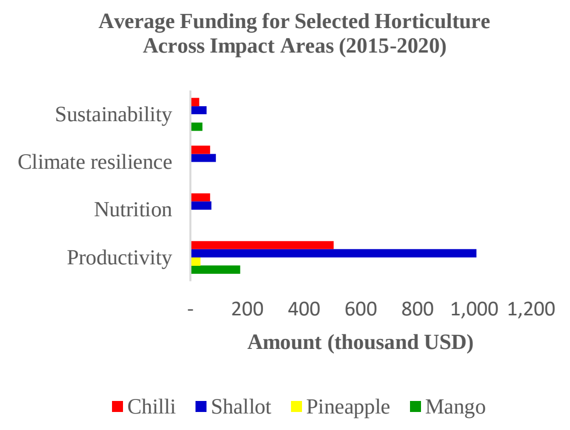
Source: IAARD, ICFCRD, ICRR, TDRS, IRICC, ICRI, ILTCRI, ICAPOSTRD, ICASEPS, 2015-2020

Sub-Sector 2: Horticulture

In the horticulture sub-sector, the R&D spending on shallot and chili was higher than on mango and pineapple (Figure 3.30). These strategic agricultural commodities in Indonesia can significantly influence inflation, so the government maintains the price level carefully, especially during the off-season. Innovation to maintain the production of shallots and chilies during the off-season is highly encouraged. Therefore, R&D spending is allocated for off-season seed development, such as the annual True Seed Shallot (TSS) and was conducted intensively in between 2018 and 2020. Additionally, the Indonesian government expects to increase the productivity and production of shallots and chilies through seed technology engineering. The availability of these commodities throughout the year can avoid high inflation.

Figure 3.30. Average funding for selected horticulture across thematic and impact areas (2015-2020)





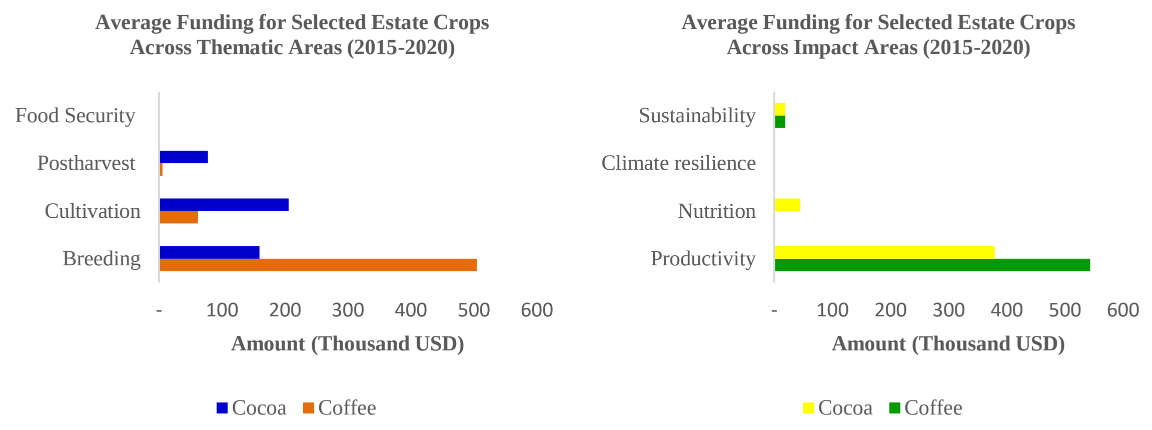
Source: IAARD, ICHORD, ITFRI, IVRS, 2015-2020

Sub-sector 3: Estate crops

In the estate crops sub-sector, the R&D spending by impact areas for coffee and cocoa was almost equal (Figure 3.31), at about 96.62% (coffee) and 85.63% (cocoa), respectively. The main goal of the spending was to increase productivity as both commodities had a strategic role in increasing foreign exchange through export and in providing employment opportunities for smallholder farmers.

In the context of increasing productivity, the focus of R&D spending on coffee and cocoa was different. For coffee commodities, much of the funding aims to develop seeds. The biodiversity of Indonesian coffee is an area to explore, especially the highland coffee types like *arabica*. Thematic R&D areas such as exploration, conservation, characterization, evaluation, utilization, and documentation of coffee germplasm are carried out almost every year. For cocoa, aside from seed development, the focus was also on cultivation technology, such as biological fertilizers and growth hormones. Meanwhile, the post-harvest includes research on fermentation technology and diversification of cocoa products, which is carried out almost every year.

Figure 3.31. Average funding for selected estate crops across thematic areas (2015-2020)



Source: IAARD, ICECRD, 2015-2020

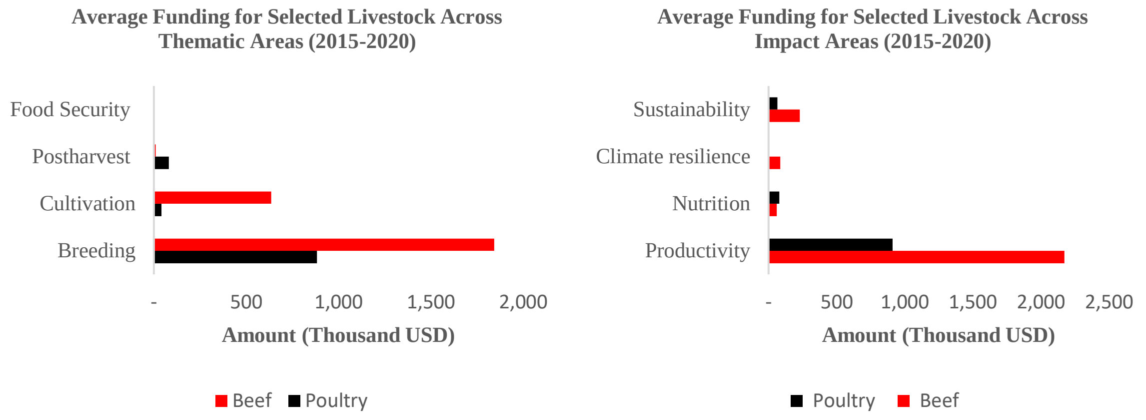
Sub-sector 3: Livestock

In the livestock sub-sector, the R&D spending on beef was greater than poultry. In the last 20 years, Indonesia has targeted to increase beef production to reduce beef imports and avoid the foot and mouth disease. Meanwhile, poultry had a much lower R&D spending because the production is adequate, so Indonesia is relatively self-sufficient. In fact, the country has exported poultry such as Day Old Chicken (DOC), chicken meat, and eggs to certain countries. Since R&D spending has been focused on increasing productivity, spending on other impact areas was lower.

The R&D spending on beef and poultry has also focused on seed development. The development of local poultry breeds starts with the selection of lines to obtain superior grandparents, followed by the development of parent stock, and the improvement of breeding patterns with the nucleus-plasma system. For beef, local cattle superior breeds are developed by crossing local cattle and Belgian Blue cattle. The R&D spending for cattle rearing was also high, amounting to the budget for developing poultry seeds. The R&D

agendas for beef include improving cow reproduction, developing locally resourced feed technology, and improving vaccine and drug technologies.

Figure 3.32. Average funding for selected livestock across thematic and impact areas (2015-2020)



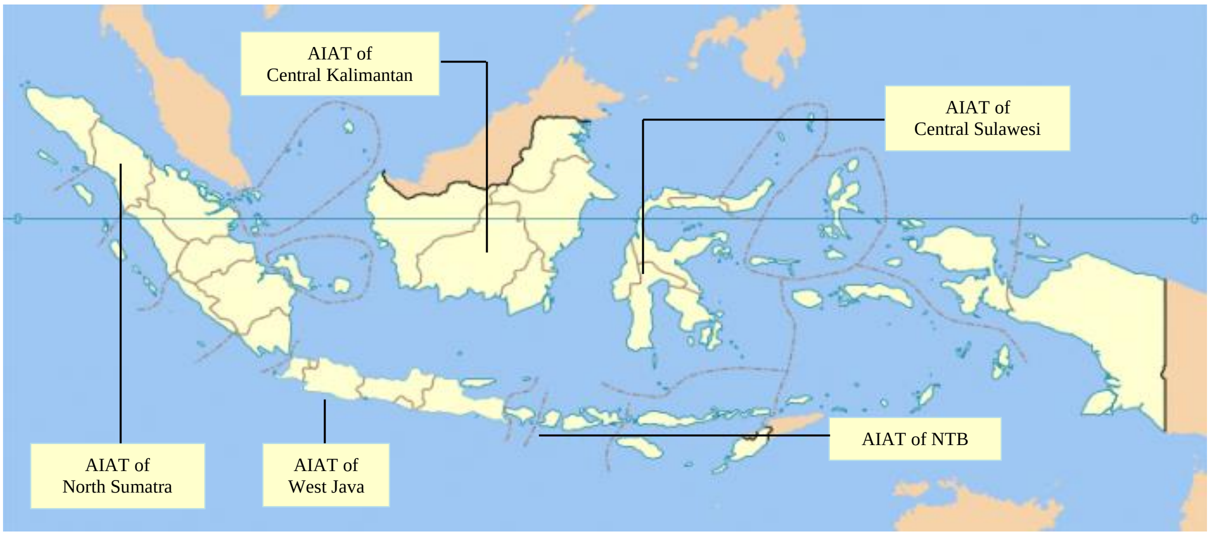
Source: IAARD, ICARD, IRIAP, IRCVS, 2015-2020

3.3.4. R&D Spending by Selected AIATs

The public agriculture and food R&D in Indonesia are disseminated mainly by Assessment Institutes for Agricultural Technology (AIATs). There are 33 AIATs in 33 provinces in Indonesia, and one Assessment Center for Agricultural Technology (ALAT) in West Sulawesi province, whose status is lower than AIAT. Both institutions are managed by the Indonesian Center for Agricultural Technology Assessment and Development (ICATAD) under IAARD, to assess and assemble site-specific technology innovation produced by research institutions and disseminate to farmers and other relevant end-users.

In this study, five IAATs were selected, representing each region of Indonesia (Figure 3.31), namely: (1) Sumatra region (AIAT of North Sumatra province); (2) Java region (AIAT of West Java province); (3) Kalimantan region (AIAT of Central Kalimantan province; (4) Nusa Tenggara region (AIAT of West Nusa Tenggara/NTB province); and (5) Sulawesi, Maluku, and Papua regions (AIAT of Central Sulawesi province). The average R&D spending for all AIATs was USD51.59 million or about 39.38% of the total IAARD's R&D spending.

Figure 3.33. Map of selected AIATs



The tasks of AIATs consist of: (1) Technology assessment; (2) Technology innovation and dissemination; (3) Technology development; and (4) Seed/breed production. The R&D spending by selected AIATs in Indonesia can be seen in Table 3.30.

The largest R&D spending (69%) was for technology innovation and dissemination, followed by technology development (14%), seed/breed production (11%), and technology assessment (6%). Each IAAT has a priority R&D based on specific local requirements. Consequently, the R&D spending varied among AIATs, depending on the region's priorities and specific requirements. The R&D spending in Sumatra was almost equal to Sulawesi, allocated mostly to technology development. Java and Kalimantan concentrated spending on technology innovation and dissemination, while the Nusa Tenggara region focused on seed/breed development and multi-site testing of R&D results.

Between 2015 and 2020, R&D spending on innovation and dissemination significantly increased by about 52%. However, R&D spending for technology development, seed/breed development, and technology assessment tended to decrease during this period.

Table 3.30. R&D spending by selected IAATs from 2015 to 020

IAATs	2015		2020	
	Amount (Million USD)	Share (%)	Amount (Million USD)	Share (%)
North Sumatra:				
Assessment	0.11	28.15	0.02	6.26
Dissemination	0.09	24.88	0.15	39.25
Development	0.07	19.19	0.17	45.58
Production	0.11	27.78	0.03	8.92
Total	0.38	100.00	0.37	100.00
West Java:				
Assessment	0.08	3.81	0.05	0.77
Dissemination	1.58	73.32	6.30	98.28
Development	0.08	3.62	0.02	0.28
Production	0.42	19.25	0.04	0.67

Table 3.30. Continued…

IAATs	2015	2020	2015	2020
	Amount (Million USD)	Share (%)	Amount (Million USD)	Share (%)
Total	2.16	100.00	6.41	100.00
Central Kalimantan:				
Assessment	0.04	7.32	0.03	19.21
Dissemination	0.42	76.34	0.07	48.96
Development	0.05	8.77	0.02	10.76
Production	0.04	7.58	0.03	21.07
Total	0.55	100.00	0.15	100.00
West Nusa Tenggara:				
Assessment	0.10	14.77	0.12	37.35
Dissemination	0.24	34.60	0.03	9.08
Development	0.06	8.96	0.07	20.81
Production	0.29	41.67	0.11	32.77
Total	0.69	100.00	0.33	100.00
Central Sulawesi:				
Assessment	0.05	4.85	0.03	16.00
Dissemination	0.06	5.69	0.10	48.94
Development	0.93	83.78	0.01	5.84
Production	0.06	5.68	0.06	29.22
Total	1.11	100.00	0.21	100.00

Source: IAARD, 2021, IAATs of North Sumatra, West Java, Central Kalimantan, West Nusa Tenggara, and Central Sulawesi, 2021

3.3.5. R&D Spending by Selected Higher Education Institutions

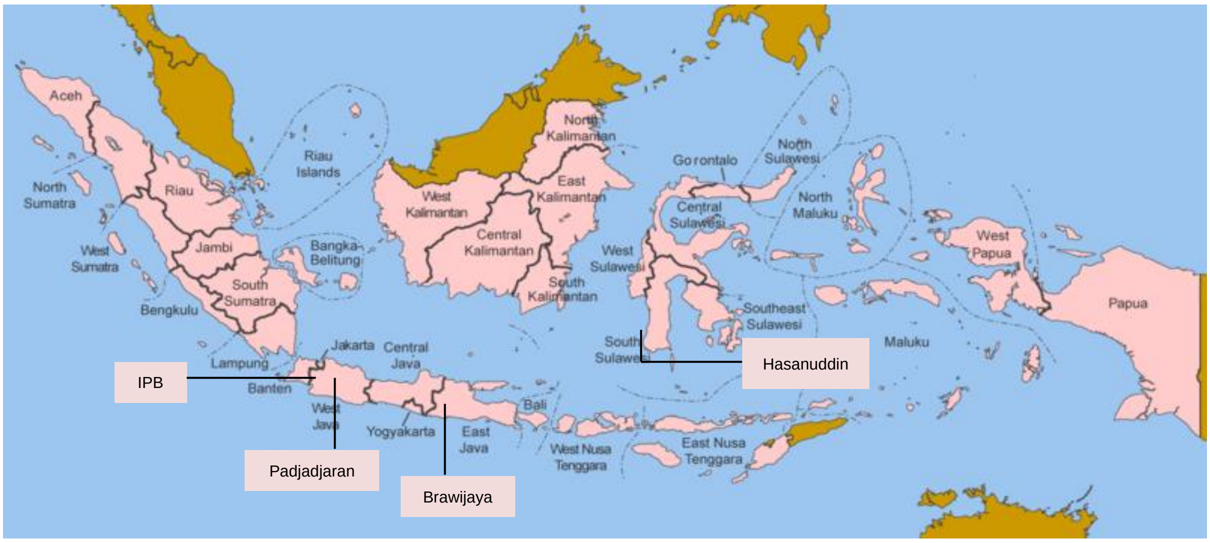
The contribution of higher education institutions is essential in Indonesia's public agriculture and food R&D because research is part of their missions (Box 3.13). This study involves four universities: (1) Bogor Institute of Agriculture (IPB) in Bogor, West Java; (2) Padjadjaran University in Bandung, West Java; (3) Brawijaya University in Malang, East Java; and (4) Hasanuddin University in Makassar, South Sulawesi (Figure 3.34). The considerations of choosing these universities are: (1) They are state-owned universities; (2) They have a faculty of agriculture; (3) They represent western and eastern regions of Indonesia; and (4) They have many collaborative research activities in the agriculture sector. A detailed description of these universities is provided in Appendix 16.

Box 3.12. Indonesian Universities' Triple Missions (*Tri Dharma*)

Apart from teaching, higher education (HE) institutions in Indonesia also conduct R&D. This is a part of its triple missions (*Tri Dharma*) comprising: (1) Education and training; (2) Research and management; and (3) Community services as mandated in Law Number 20/2003 concerning the National Education System (GoI, 2013).

Indonesian universities' research output and contribution, including agriculture and food, are essential to support national R&D. The total number of universities is 3,115, comprising 2,990 public universities (95.99%) and 125 private universities (4.01%). Indonesia was ranked third in university numbers globally (BPS, 2021b; katadata.co.id, 2022). Nevertheless, some universities do not have agricultural study programs.

Figure 3.34. Map of selected AIATs



Over the last five years (2016-2020), the total R&D spending of these four selected universities was USD25.02 million. The highest R&D spending was allocated to IPB, followed by Brawijaya, Padjadjaran, and Hasanuddin University. Agricultural R&D spending at universities fluctuated in the 2016-2020 period (Table 3.31).

Table 3.31. R&D spending of four selected universities, 2016-2020 (million USD)

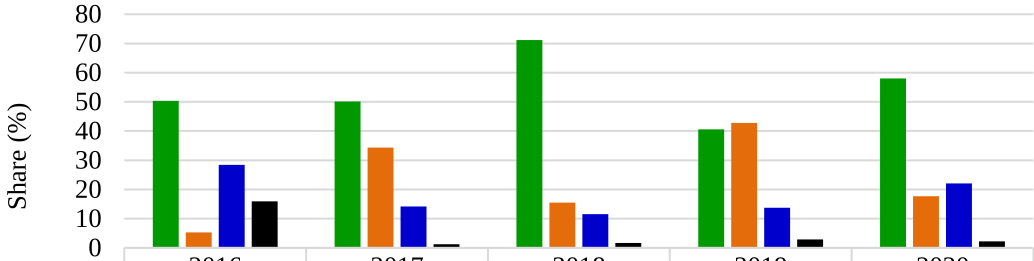
University	2016	2017	2018	2019	2020	Total
IPB	n.a.	n.a.	4.74	4.71	4.27	13.72
Padjadjaran	0.50	1.23	0.98	0.70	0.54	3.95
Brawijaya	n.a.	0.41	2.00	2.21	1.67	6.29
Hasanuddin	0.15	0.26	0.21	0.30	0.14	1.06
Total	0.65	1.90	7.93	7.92	6.62	25.02

Note: n.a. (not available)
Source: IPB, Padjadjaran, Brawijaya, and Hasanuddin University, 2021

Based on the availability of data and information, the following section discusses the four higher education institutions' R&D spending by thematic areas. Padjadjaran University and Hasanuddin University represent the Western and Eastern parts of Indonesia, respectively. The data include the R&D spending of the two universities over the six-year period (2016-2021). Since the universities had numerous study topics, some were purposively selected for this study. From thousands of research titles found at several selected universities, the R&D spending was grouped into the thematic and impact areas by commodities. The R&D spending depends on the allocated amount each year. As a result, the amount was either exceptionally high or low in specific periods. The amounts of R&D spending in thematic areas by both universities can be seen in Figures 3.35 and 3.36. Detailed R&D spending from Padjadjaran and Hasanuddin University based on the thematic and impact areas are presented in Appendix 17 and Appendix 18.

The highest R&D spending by Padjadjaran University was allocated to breeding technology (54.08%), followed by cultivation technology (23.14%), post-harvest technology (17.98%), and technology support for food security and self-sufficiency (4.80%). On the other hand, Hasanuddin University spent most R&D funding on post-harvest and cultivation technologies (81%), and the rest was on technology support for food security and self-sufficiency and breeding technology (19%).

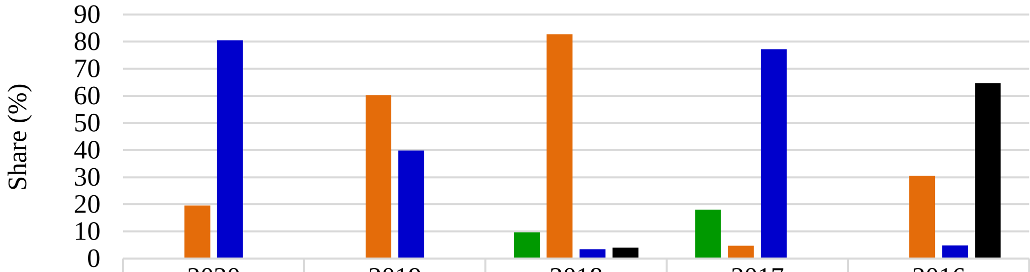
Figure 3.35. R&D spending by thematic areas based on research titles by Padjadjaran University from 2015 to 2020



	2016	2017	2018	2019	2020
Breeding	50.37	50.18	71.20	40.64	58.01
Cultivation	5.31	34.38	15.54	42.74	17.73
Postharvest	28.40	14.16	11.56	13.72	22.07
Food Security	15.92	1.28	1.70	2.90	2.19

Source: Padjadjaran University, 2021

Figure 3.36. R&D spending by thematic areas based on research titles by Hasanuddin University from 2015 to 2020



	2020	2019	2018	2017	2016
Breeding	0.00	0.00	9.64	18.04	0.00
Cultivation	19.54	60.21	82.79	4.71	30.50
Postharvest	80.46	39.79	3.49	77.25	4.83
Food Security	0.00	0.00	4.07	0.00	64.67

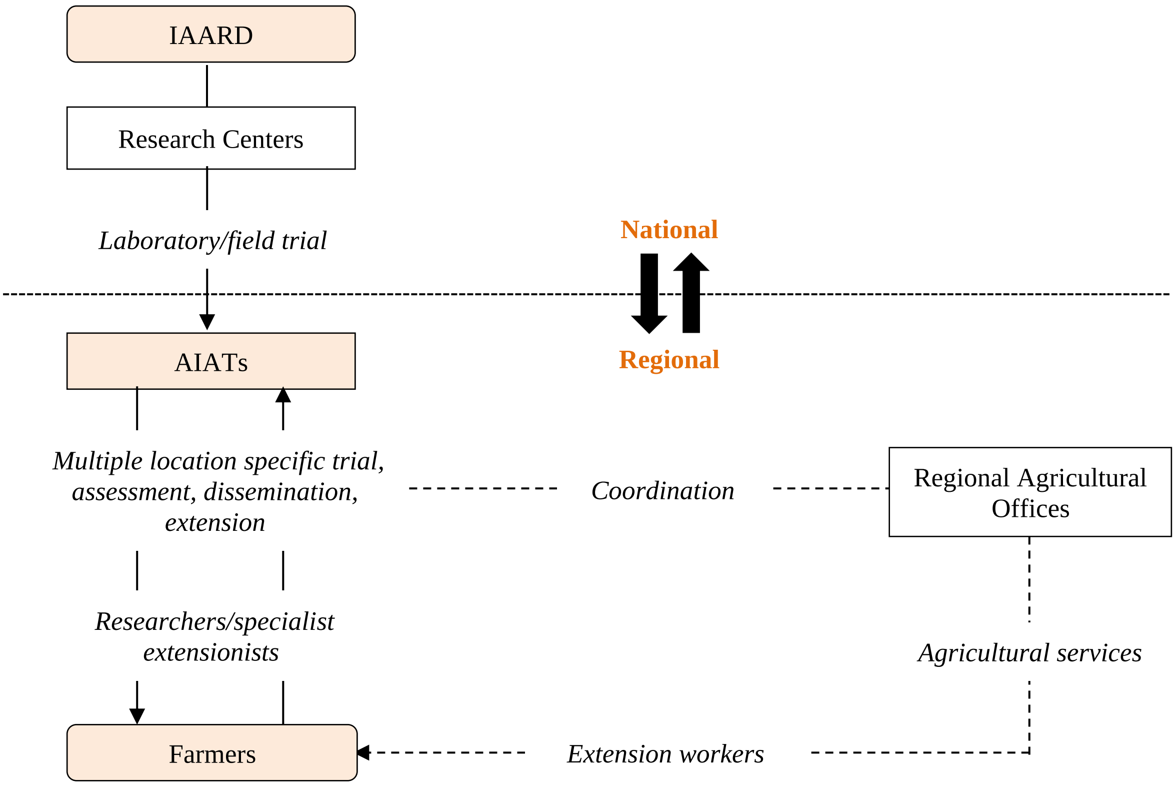
Source: Hasanuddin University, 2021

3.4. Mechanisms of Delivery Products and Services

IAARD creates agricultural technology and innovation according to its mandate as stated in Presidential Regulation Number 45/2015 concerning MoA and MoA Regulation Number 43/2015. IAARD has played a key role in driving agricultural development. Research-based technology adopted by users, especially small-scale farmers, can help improve the agriculture sector and boost national economic development. With advanced technology, farmers can improve yields, provide more varieties, and meet the market demand. As such, food sovereignty can be achieved. Farmers' welfare will also improve, and poverty in rural areas can be reduced, which will lead to economic growth. Additionally, the production can also be used for industrial raw materials and export.

The technology produced by various research institutes within IAARD or from other sources is tested, adapted, and utilized through a transmission process at the directorate general of technical and agricultural work units in the regions. This technology will then be disseminated to users, especially farmers and breeders. In the dissemination process, researchers and extension workers work synergistically in providing demonstrations and counseling to empower farmers in utilizing agricultural technology. Meanwhile, IAARD accelerates technology dissemination with a research-extension farmer-linkage approach and a technology feedback process from user farmers. The process of R&D management from agricultural research system to farmers can be seen in Figure 3.37.

Figure 3.37. Public R&D management process from agricultural research systems to farmers



The role of AIAT is to strengthen the relationship between research extension and farmers (Research-Extension Farmer-Linkage or REFL), championing the dissemination of agricultural innovations and information from IAARD research to farmers. The REFL concept is an important reference in the transfer of agricultural technology innovation to make agricultural development more targeted. Through AIAT, agricultural technology innovations resulting from IAARD research can be quickly distributed. Farmers can utilize this technology and gain added value so that they can increase their income and welfare.

Since 1994, AIAT various activities have contributed to the development of agriculture. This includes the acceleration of the innovation dissemination and adoption process, which contribute to the improvement of farming performance. Some of the innovations and technologies are high-yielding varieties for agricultural commodities, source seeds for in-situ seed production, productivity improvements, efficient use of inputs, and many others. Although the desired target was not 100% achieved, these efforts have produced satisfactory results in implementing the REFL concept through AIATs across Indonesia.

The important role of extension workers in disseminating R&D results by IAARD only began in 1994. Before 1994, extension workers only conveyed the results of the resulting technology without being involved further to assess whether the technology was suitable or not for farmers. The dissemination process and the role of extension workers before 1994 can be studied in Box 3.14.

Box 3.13. The focus of IAARD activities before 1994

Prior to 1994, IAARD focused more on conducting research than the process of delivering the research results to end-users. On the other hand, agricultural extension workers focused more on their duties and work in the field without thinking much about whether the technology being delivered is feasible or not, valid or not, profitable or not.

The establishment of AIAT in all provinces in Indonesia is a breakthrough in the management of the agricultural R&D system so that the technology can be immediately distributed and utilized. The main benefit of the integration between researchers and extension workers in one institution AIAT are: (1) Research results suit the needs of farmers because of the establishment of effective and efficient intensive communication between researchers and extension workers; (2) Efforts to downstream agricultural technology innovations become more targeted because the material suit the farmers' needs and scientifically justified; and (3) Researchers can obtain technological feedback and innovation for improvement real-time. The task delineation starts at AIAT. The extension materials are prepared for extension workers in the field and region. Then, researchers adapt, develop and modify technology, to suit the needs of users (extension workers, farmers, and private companies).

IAARD carries the convergence of R&D management of research, development, assessment, and application. The orientation work of IAARD is to produce innovative technologies and institutional agriculture systems that propel agricultural development. As a result, R&D activities will be more user-oriented. As such, the science, technology, and agricultural, institutional systems produced will be more contextual and targeted. Finally, this shift should be accompanied by a progressive agricultural R&D policy direction to respond to the strategic environment and achieve advanced, independent, and modern agriculture.

The performance of IAARD relies upon the synergy between the R&D program and the work/technical implementation units. The convergence of programs in IAARD's scope can be seen in Table 3.32.

Table 3.32. The convergence of programs in IAARD's scope

Work/Technical Implementation Unit	Description
Indonesian Center for Food Crops Research and Development	Coordinating R&D activities for food crops supported by a synergy of R&D activities in the scientific field and site-specific technology assessments
Indonesian Center for Horticulture Research and Development	Coordinating horticultural R&D activities supported by the synergy of scientific R&D activities and site-specific technology assessments
Indonesian Center for Estate Crops Research and Development	Coordinating plantation R&D activities, supported by a synergy of scientific R&D activities and site-specific technology assessments
Indonesian Center for Animal Research and Development	Coordinating livestock R&D activities, supported by a synergy of scientific R&D activities and site-specific technology assessments

Source: IAARD, 2020

3.4.3. R&D Representation of the Private Sector

This section assesses some cases from the private sector's and non-government organizations' R&D activities. Data and information were collected from guided interviews, the results of circulated questionnaires, and other applicable document sources.

3.4.3.1. PT Syngenta Indonesia[9]

Company Profile

PT Syngenta Indonesia came out of a merger between PT. Zeneca Agri Products and PT. Novartis Agro Indonesia in 2001, although its predecessor dates back to 1960. The global headquarter is in Switzerland. Indonesia is under the Asia Pacific/APAC region based in Singapore. This company works in the agrochemical industry, supplying pesticide products to improve farm and plantation produce. PT Syngenta Indonesia is the only agrochemical company in Indonesia, with two research stations in Cikampek and Lembang and filling formulation and packing plants in Gunung Putri. The Syngenta Gunung Putri plant has been certified for ISO 9001-2000, ISO 14001, and SMK3 and has the right to use the KNRCI logo. The products are not just for the domestic market but are also exported to other Asia Pacific countries.

The business scope of PT Syngenta Indonesia includes crop protection and seeds. In the field of crop protection, in addition to providing technology in plant protection, Syngenta Indonesia also offers technology in services, such as the protection of livestock and public health/public health from parasites/disease vectors. Furthermore, this company has also begun to strengthen and expand its coverage in estate crops such as oil palm, cocoa, coffee, and pepper to support Indonesia's effort to increase agriculture commodities exports.

R&D Activities

The R&D activities by PT Syngenta Indonesia are part of Syngenta Global Corporation's (SGC) network. The main task of the R&D division of Syngenta Indonesia is to oversee the company's long-term portfolio with flexibility in product development according to the needs of Indonesian farmers, based on the vision of "putting farmers at the center". In other words, the vision of this company is business sustainability by improving farmers' welfare. In addition to being directed globally, the activities of PT Syngenta Indonesia R&D division are designed to respond to the Indonesian government's food and agriculture policy by developing products that have good market prospects and support the government's policy objectives. PT Syngenta Indonesia has 15 productive scientists. This company has significant concern for environmental sustainability and the achievement of food and nutrition security.

[9] Source: questionnaire feedback as well as in-depth discussion with PT Syngenta Indonesia as well as http://www.responsiblecare-indonesia.or.id/index.php?lang=ENG&page=member&id=63

3.4.3.2. PT Pupuk Indonesia Persero (PTPI)[10]

Company Profile

PTPI is a state-owned enterprise (SOE).) in the fertilizer business. PTPI is a holding company with three major subsidiary groups, namely production and distribution of fertilizer and ammonia (five subsidiaries); trade, logistics, and energy (four subsidiaries); engineering, procurement, and construction (EPC) services (one subsidiary).

In 2021, PTPI produced 12.24 million tons of fertilizer, consisting of 7.97 million tons of Urea and 4.27 million tons non-Urea (P and K fertilizer). The total sales and other revenues were IDR78,603 billion, with 95.9% coming from fertilizer and ammonia product sales. PTPI is the only SOE the government assigns to procure and distribute subsidized fertilizer. In 2021, the amount of subsidized fertilizer distributed to small-scale farmers (<2.0 ha of farming) was 7.92 million tons (64.7% of total production), with the amount of remuneration subsidy from the government reaching IDR25,259 billion or USD1.79 billion (32% of sales and other revenues).

The company is instrumental in achieving sustainable, nutritious, and climate-resilient food systems in Indonesia by providing and distributing subsidized fertilizer for small-scale farmers. Fertilizer is an essential input to ensure high productivity of food farming, mainly as a source of leading staple food and horticultural crops. The company is also highly concerned about decarbonization and effort to achieve sustainability by developing products of environmentally friendly.

R&D Activity

PTPI views its research activities as essential for supporting continuous business performance. The company believes that research will add value to the performance. The focus of its research is to support the development and growth of the company business through identifying, improving or refining, and solving business problems, primarily related to supporting raw materials, technology processes, products, markets, and environmental issues.

Research is carried out by the Indonesia Fertilizer Research Institute (IFRI) compartment under the Director of Business Transformation of PTPI. The primary function of IFRI is to coordinate, direct, evaluate, formulate targets, and manage all research activities. IFRI also oversees the Research Planning Department and functional groups, namely product research, technology research, and fertilizer policy research. Research units conduct those research activities at the holding company and eight subsidiaries. Each research unit focuses on specific topics and scientific fields.

Research topics at PTPI are concentrated on supporting the company's business performance, namely: (1) Product development tailored to farmers' needs and prospective market trends; (2) Advanced products development such as micronutrients, controlled released fertilizers, water-soluble, and bio-stimulants; (3) Technology development to support the Good Agricultural Practice and Precision Farming concepts, from land preparation to harvesting and environmental and sustainable development issues; and 4)

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[10] Source: PT Pupuk Indonesia (Persero). Annual Report 2021. Jakarta

Policy analyses, regulation and policy review, and recommendations to the board of directors, stakeholders, and related parties.

In 2021, there were 59 researchers in PTPI, with nine persons in IFRI (holding) and 50 employees in eight subsidiaries. Researchers come from various scientific fields, including agriculture, chemical engineering, engineering, management, biotechnology, and others, with degrees ranging from Bachelor to Ph.D. levels. IFRI collaborates with external parties such as government/non-government research institutions, universities, and other potential partners to enhance research capacity. These activities and preliminary results are communicated and synergized with the marketing and production teams to gain feedback and market insights needed to initiate research.

In 2021, the direct research budget was relatively small, around IDR27.9 million (USD0.002 million), which was about 0,035% of total sales and other revenues (IDR78,603.1 million or USD5.56 million) or 0.54% of profit (IDR5,134.7 million or USD0.36 million).

3.4.3.3. PT BISI International Tbk[11]

Company Profile

PT BISI International Tbk is a seed company established in Indonesia under the name PT Bright Indonesia Seed Industry in 1983, headquartered in Sidoarjo City, Eat Java Province. PT BISI claims as a science-based company. This company produces and sells seeds (hybrid corn, vegetables and fruits, pulses, hybrid and inbreed paddy), pesticides, and fertilizers. In 2021, the company's sales value was IDR2,015.4 billion (USD0.14 billion), with a gross profit of IDR810 billion (USD0.06 billion), and profits for the year 2021 reaching IDR381 billion (USD0.03 billion), respectively. The sales value of seeds, pesticides, and fertilizers was about the same, namely 52.7% and 47.3%, respectively.

R&D Activities

R&D plays a vital role in this company, managed by one out of four Directors and directly under the President Director. Under the R&D Directorate are the biotechnology laboratory, quality control (QC) corn seeds, and QC vegetable seeds units.

The R&D activities of PT BISI is as a part of business processes to produce quality seeds, pesticides, and fertilizers, maintain market share and stay ahead in this business venture. The R&D Directorate is responsible for delivering quality breeder seeds as upstream activities before production lines move to the next steps, starting from the production of foundation seeds, then processing for commercial products, and, finally, the production of finished goods (seeds, pesticides, and fertilizers). For pesticides and fertilizers, the upstream line production processes that involve the R&D Directorate are mixing techniques of raw material and supporting materials. In 2021, PT BISI expenses on R&D were IDR65.4 billion (USD0.5 billion) or 3.2% and 17.2% of respective gross profit and net profit for the year 2021.

[11] Source: PT BISI International Tbk. Annual Report 2021. Sidoarjo

3.4.3.4. PT East West Seed Indonesia[12]

Company Profile

PT East West Seed Indonesia, established in 1960, is the first integrated vegetable seed company in Indonesia that produces vegetable seeds through plant breeding. This company primarily aims for the development of local, cutting-edge seeds to produce high-quality vegetable seeds.

In developing seeds, PT East West Seed Indonesia employs professionals who are experienced in the area of plant breeding and seed science. Vegetable seeds from the R&D are produced, processed, packed, and marketed for Indonesian farmers with the "*Cap Panah Merah*" brand.

For over two decades, PT East West Seed Indonesia has always provided healthy seeds with high genetic purity and good germination to achieve good results aligning with the consumers' needs and preferences and becoming the key to success for Indonesian farmers. The vision of this company is to "believe in high-quality vegetable seeds for better living", and its mission is to "provide high-quality seeds to increase farmer's income and promote vegetable consumption".

PT East West Seed Indonesia has a motto, "all started with a seed", which means a good seed can change the lives of millions. The company positions farmers at the center of development to produce agricultural products that are profitable, successful, and prosperous. It aims to provide solutions to farmers, who face challenges related to low productivity, pest and diseases, low quality of the harvest, and uncertain selling price. Therefore, the company offers suitable varieties to increase farmers' productivity and welfare.

R&D Activities

R&D activities in PT East West Seed Indonesia aim to increase product competitiveness and support food and nutrition development, so the activities focus on producing seeds, particularly vegetables, for domestic use. With more than 30 years of experience, this company serves Indonesian farmers, supported by 1,000 employees (including 200 researchers) and partners with 17,000 production farmers and 70,000 pollinator workers in the provinces of East Java, West Java, and Lampung.

This company has the latest molecular market technology to accelerate the discovery of superior sources. As a result, this company has produced more than 150 high-quality seed varieties used by seven million Indonesian vegetable farmers. PT East West Indonesia has an R&D budget of about 9-10% of total sales. This company has the latest molecular market technology to accelerate the discovery of superior seeds, including Suprema pumpkin, Amar watermelon, Servo tomatoes, Steel chili, Erina and Zatavy cucumbers, Locananta shallot, and Mustang eggplant.

[12] Source: in-depth discussion with Senior Product Manager of PT East West Seed Indonesia) and https://www.linkedin.com/company/pt-east-west-seed-indonesia/about/

3.4.3.5. Indonesian Coffee and Cocoa Research Institute (ICCRI)[13]

Company Profile

The Indonesian Coffee and Cocoa Research Institute (ICCRI), a semi-public institution, was established on 1 January 1911 under *Besoekisch Proefstation* in Jember, East Java province. ICCRI has played an important role for more than a century of R&D to produce technologies and innovations for coffee and cocoa commodities. The scope of the R&D includes plant breeding and biotechnology, agronomy, soil science and water management, plant protection, post-harvest technology, machinery, and social economy. ICCRI is supported by qualified researchers, research facilities, and a robust collaborative network with various national and international stakeholders. Currently, ICCRI is a subsidiary under PT *Riset Perkebunan Nusantara* (RPN) or Nusantara Estate Crops Research company, which focuses on research and development for estate crop commodities. PT RPN is a research unit under the Ministry of State-Owned Enterprises.

R&D Activities

ICCRI's strategic mission is to develop science and technology to support national coffee and cocoa production. Besides achieving science and technology innovations, ICCRI also disseminates products to farmers' communities. Many success stories have been produced by ICCRI in collaboration with regional and national governments.

ICCRI was designated as the Center of Excellence for Science and Technology for cocoa and coffee in 2012 and 2013 by the Ministry of Research and Technology. This was to support the implementation of the Master Plan for Acceleration and Expansion of Indonesian Economic Development. Since 20 May 2016, ICCRI has expanded its duties and functions, including educating new entrepreneurs about coffee and cocoa commodities. This was done through the establishment of the Coffee and Cocoa Science Techno Park (CCSTP) as a strategic unit of ICCRI by the Ministry of Research, Technology, and Higher Education. In addition, the highest achievement of ICCRI in 2020 was being named the best innovation institute in research, development, assessment, and application by BRIN.

As a research station that has served the country since 1911, ICCRI has experienced dynamic changes in its institutional role. ICCRI used to be a research unit under MoA, but since March 2019, ICCRI has maintained its role as a research center under the Ministry of State-Owned Enterprises Holding Company. As part of the holding company, ICCRI has to transform into a profit unit. The changes have created significant challenges since the research activities, as the primary role of ICCRI, are not profit-generating. Moreover, since 2020, the COVID-19 pandemic has increased the financial burden on the center.

Currently, R&D funding for ICCRI comes from research collaboration with the private sector. Before 2019, every year, ICCRI received a regular grant from the Indonesian Agency for Agriculture Research and Development for about IDR1 billion. ICCRI used this funding to conduct primary research, e.g., breeding research in multi-location and managing biodiversity resources for breeding technology purposes. However, with the transformation

[13] Source: questionnaire feedback and in-depth discussion with Director of ICCRI

of the Ministry of State-Owned Enterprise, ICCRI sourced the research funding independently.

ICCRI's source of funding comes from seedling sales (50%), cocoa processing machinery (20-30%), and end-products such as chocolate bars, powder, chocolate drinks, and other cocoa and coffee-based processed food and drinks (15%), and services (15%).

Research in ICCRI is developed based on clients' needs since the institution now acts as a profit organization. The nature of the study is the business-to-business format. The center finds it challenging to access a research grant, so conducting multi-year research projects like in the past is not feasible. Although ICCRI has developed collaboration with many international partners, the networks are insufficient to support the center. Currently, ICCRI is expected to generate commercialized research to generate revenue for the center. With funding limitations, the center finds it challenging to allocate a budget for dissemination. As a prominent center for coffee and cacao, ICCRI needs support to maintain the primary research to produce high-quality seedlings for coffee and cacao.

ICCRI prioritizes the research to find new clones resistant to pests and diseases, and climate changes and generates specialty flavor, produce organic fertilizer, pest and diseases research development, and develop a new prototype for cacao roasting. In conducting their research, the center has accommodated global concerns toward agriculture sectors, such as food safety issues, climate change, and increased demand for geographic indication and specialty (single origin) clones. As a result, research in ICCRI has become a consumer-driven.

3.4.4. Roles and Responsibilities of the Public and Private Sectors in R&D

Essentially, a public institution manages the series of activities in terms of administering, planning, implementing, developing, disseminating, monitoring, evaluating, and reporting of R&D activities. Meanwhile, the private sector more focuses on supporting business orientation.

The roles and responsibilities of public institutions in R&D include producing and developing agricultural innovations, as well as supporting the industrial system. It includes improving the quality of R&D, enhancing its efficiency and effectiveness, and developing collaborative networks among stakeholders. The policy direction and strategy of public institutions in R&D can be seen in Table 3.33.

Table 3.33. Public agriculture and food R&D policy directions and strategies

Policy	Strategy
Encouraging the creation of integrated and innovative agricultural technology	Collaborating with various parties and conducting monitoring-evaluation as well as synchronizing R&D with extension programs
Driving the development of innovative technology	Developing technology innovation and accelerating R&D results, as well as strengthening the synergy of research and assessment of agricultural technologies
Developing site-specific agricultural technology assessment	Assessing specific locations for innovative agricultural technologies and improving innovative technology studies to produce anticipatory and responsive policy recommendations for solving regional agricultural development problems

Table 3.33. Continued…

Policy	Strategy
Strengthening the use of innovative technology	Developing a multi-channel dissemination spectrum towards accelerating the R&D results; strengthening the management of agricultural technology transfer through accelerating the commercialization of R&D results, as well as increasing the effectiveness of technical assistance supporting the MoA strategic programs
Reinforcing corporate organization	Strengthening program management, mindset, timing, human resources, budget, and infrastructure/facilities

Source: IAARD, 2020b

The roles and responsibilities of private sector are related to business orientation in carrying out activities toward generating the best products and services for each company. Therefore, this sector's policy direction and strategy are closely related to its mission and vision, including the interest and sustainability of businesses.

3.4.5. Differences in R&D Spending between the Public and Private Sectors

The IAARD funding framework sourced from the State Budget (APBN) refers to the grouping of the scope of agricultural R&D as follows: (1) 60-70% were directly allocated to support the achievement of National Priorities, National Research Priorities, Strategic Programs of the MoA and IAARD; and (2) 30-40% were allocated to upstream research-based policy determination of IAARD. Apart from APBN, R&D activities can be carried out using other funding sources through collaboration with domestic and foreign research and private institutions. Meanwhile, the R&D fund allocation of the private sector highly depends on the business mission and their client-based internal policies.

To encourage innovation activities, the government has allocated funds for R&D activities, but the government has limited funds, so the allocation of R&D funds is still relatively small. Therefore, the government wants to encourage the role of the private sector to participate in R&D activities. One of the policies to encourage the private sector to participate in R&D activities is through policies in the field of taxation with the provision of incentives. The Government of Indonesia, through the Ministry of Finance, has issued Minister of Finance Regulation Number 153/2020 concerning the provision of gross income reductions for certain research and development activities in Indonesia. This regulation stipulates that taxpayers who carry out certain research and development activities in Indonesia get a gross income reduction of up to 300% of the amount of costs incurred for R&D activities within a certain period of time. Food is one of the themes of research and development activities that can be provided facilities under these provisions.

From the researcher's own side, the government of Indonesia has also implemented the granting of royalty/patents from the results of the R&D. This policy is stated in the regulation of the Minister of Finance of the Republic of Indonesia Number 136/2021 which regulates guidelines for providing compensation derived from state revenues not copyright royalties to creators, patent royalties to inventors, and/or plant variety protection rights royalties to plant breeders (MoF, 2021). The amount of tariff given is detailed in the regulation. With the enactment of this regulation, the Government provides appreciation and incentives to researchers, including agricultural researchers.

Chapter Summary

R&D Management

- The work units under IAARD do not only carry out R&D activities but also technical services supported by external funding sources. Technical services in certain work units of IAARD absorb a large budget.
- The technology and innovations produced by IAARD are primarily assessed by multi-location processes before being delivered to end-users. ICATAD and 34 AIATs in each province play a role in the implementation of the multi-location assessment. Thus, the multi-location assessment process became a challenge when IAARD was transformed into BRIN.
- R&D results from IAARD provide input to the MoA strategic policy formulation. With the transformation of IAARD into BRIN, the process of providing input to the MoA becomes a challenge that also needs to be considered.

R&D Spending

- The shares of the IAARD budget in the national and agricultural GDPs from 2010 to 2020 were minor, namely about 0.014% and 0.135% per year, respectively. In the same period, the share of budget of IARRD in the MoA's budget was moderate, at about 8% per year.
- From 2015 to 2020, the largest IAARD R&D spending was for ICATAD, comprising 34 AIATs in every province of Indonesia. The R&D budget was spent on AIAT technology assessment, technology dissemination, technology development, and technology production. The amount of R&D spending on each component varied depending on the focus of activities in each AIAT.
- Agricultural R&D spending based on the thematic areas focused on developing breeding technology. For cocoa, the R&D spending was larger for cultivation development than for breeding technology development. Agricultural R&D spending based on impact areas focused on increasing productivity.
- Over the six-year period (2015-2020), the focus of R&D in agriculture by the public sector had been more directed to productivity improvement. However, implementation at the field level still found that farmers had not fully adopted the technology. There are still gaps faced by small-scale farmers and food consumers unsupported by the current public R&D system. Therefore, farmers should a focus of agricultural research activities.

CHAPTER FOUR

GAPS FACED BY SMALL-SCALE FARMERS AND CONSUMERS

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This chapter discusses the gaps between the needs and the availability of technology and innovation generated by the current public R&D system. The first section reviews the existing agricultural technologies for small-scale farmers developed by IAARD over the last 17 to five years. These technologies aim to improve agriculture and food production (such as breeding, farming, and resource efficiency), and post-harvest and food processing aiming at food diversification based on local resources. Another issue discussed in this chapter is technology dissemination, its acceleration, technology adoption by farmers, and the extent to which technology and innovation impact agricultural productivity and income. The last sub-section discusses the problems small-scale farmers face in increasing productivity and competitiveness.

The second section discusses issues in food consumption patterns in the last decade. The first part of the discussion focuses on the changes in food consumption patterns, poverty, food insecurity, and malnutrition. This evaluation leads to the second part of the discussion: the estimation of future food consumption patterns. The final part presents the problems food consumers face in fulfilling their needs and the extent to which technologies can help solve these problems to achieve food and nutrition security.

4.1. Issues of Small-scale Farmers

In the last three development cycles, the government of Indonesia's (GoI) five-year development plan related to agriculture has address the abovementioned issues. The objectives of agriculture development remain the same, namely: (1) Improving farmers' welfare; (2) Providing sufficient food for the national population; (3) Supporting national economic growth; and (4) Reducing rural poverty. Therefore, IAARD's R&D plan target these objectives.

Agriculture actors are mainly small-scale farmers, especially in the food crops, horticulture, and livestock subsectors. Based on the 2018 Inter-Census Survey (SUTAS), the number of farm households in Indonesia was 27.68 million, with each household often participating in more than one farming activity. Statistics Indonesia (Badan Pusat Statistik/BPS (2021a)reported that of the total farm households, 73.27% work in food crop farming, 43.61% in estate crop farming, and 36.43% in horticulture farming. Farm households' average land holding size was 0.18 hectares of lowland (suitable for rice farming) and 0.55 hectares of dry land. The proportion of households with ownership of fewer than 2.0 hectares, categorized as small-scale, was 89.1%[14].

Since small-scale farming is predominant, IAARD prioritizes this segment as the beneficiaries of the technologies and inventions. Small-scale farmers are often associated

[14] Based on Law Number 19/2013 on Protection and Empowerment of Farmers, a small-scale food crops farmer is a farmer with a maximum landholding size of 2.0 hectares.

with low education attainment, limited access to financial and production sources, and becoming an aging population. Table 4.1 shows that in 2018, more than 60% of farmers completed or dropped out of primary school, and more than 35% were over 55 years old (BPS, 2018). Although there is no standard numerical criterion to classify the aging population, a past study defines it as age cohort's ≥ 55 and 65 (Heide-Ottosen, 2014). With this reference, it can be concluded that the aging population among farmers increased during the study period. In 2013, the proportions of farmers aged ≥ 55 and 65 were 32.8% and 12.75%, respectively. In 2018 the proportions increased to 36.0% and 13.8%, respectively (BPS, 2014). With these characteristics, it is understandable that small-scale farmers have less capacity and ability to adopt new agricultural technology and innovation properly.

Table 4.1. Farmer's characteristics: age, education attainment, and landholding size, 2013 and 2018

Farmer' characteristics	2013	2018
Number of farmers	26,135,469[1)]	27,682,117[2)]
The proportion of farmers by age group (%)		
<25 years	0.89[1)]	0.99[2)]
25-34 years	11.97[1)]	10.65[2)]
35-44 years	26.34[1)]	24.17[2)]
45-54 years	28.03[1)]	28.23[2)]
55-64 years	20.01[1)]	22.16[2)]
≥65 years	12.75[1)]	13.81[2)]
The proportion of farmers by education (%)		
Not attending school	5.23[4)]	5.88[4)]
Not passing elementary school	21.90[4)]	14.39[4)]
Passing elementary school	36.60[4)]	41.93[4)]
Graduated from secondary school	15.20[4)]	16.65[4)]
Graduated from high school	15.36[4)]	16.40[4)]
Diploma/Bachelor	5.72[4)]	4.76[4)]
The proportion of household income from agriculture (%)	53.59[3)]	55.98[4)]

Source: [1)] Ashari et al. (2021); BPS (2014, 2015, 2018)

4.1.1. Technology Availability for Small-scale Farmers

4.1.1.1. Breeding Technology

During 17 years between 2005 and 2021, IAARD developed various new high-yielding varieties of food crops, horticulture crops, estate crops, and livestock breeds. However, breeding activities were mainly concentrated on prioritized food crops, i.e., rice, maize, and soybeans. Table 4.2 shows the figures, which concur with IAARD budget allocation and activities, as presented in Chapter Three. The prioritization is only natural because the three commodities are essential to Indonesian diets and the country's economy. Rice is the main staple food for more than 95% of the Indonesian population, maize is the main ingredient for poultry feed, and soybean is a primary raw material for soy cake (tempeh) and tofu. However, breeding activities of other food crops were also conducted, albeit with much lower intensities; for example, cereals (sorghum), pulses (mung beans), and root crops (sweet potatoes and cassava). During this period, hybrid crop varieties were also developed, mainly for rice and maize. Meanwhile, genetically modified (GM) varieties were also under research, but IAARD has not released any GM crop variety to date.

Between 2005 and 2021, IAARD created 63 new superior varieties of vegetables, e.g., shallot, chili, potatoes, tomatoes, and 84 fruits, e.g., oranges, mangoes, snake-fruit (*Salacca* *zalacca*), papaya, and melons. IAARD released 130 varieties for estate crops, consisting of 20 spices and medicinal plants, and other superior estate crop varieties, such as cotton, coconut, cashew, and sugarcane. The selection of crops to be developed into new superior varieties refers to the priority crops set by the Ministry of Agriculture.

Table 4.2. New crop varieties and animal breeds developed by IAARD from 2005 to 2021

Crops and Animals	Number of new varieties/breeds			
	2005-2009	2010-2014	2015-2019	2020-2021
Food Crops:				
Rice	21	53	37	6
Maize	6	23	11	0
Soybean	11	12	13	4
Pulses	1	10	4	0
Other cereals	0	10	1	0
Roots	5	4	7	1
Horticulture:				
Vegetables	17	26	17	3
Fruits	36	33	13	2
Estate Crops:				
Spice and medicinal plants	12	5	3	0
Estate crops	34	33	43	0
Livestock:				
Cattle	0	0	1	0
Goat and sheep	0	1	2	0
Chicken	0	1	1	0
Duck	0	1	3	0

Source: IAARD's Strategic Plan and Annual Report, 2005-2020

Unlike the development of crop varieties, IAARD released fewer improved livestock breeds during this period, namely, one cow breed, three sheep/goat breeds, two chicken breeds, and four duck breeds. This is because livestock breeding activities need a much longer time than crop breeding, especially perennial crops. Sutarno and Setyawan (2016) confirmed that the low performance of breeding new livestock breeds was due to the lengthy process. They also believed that the breed quality might change after several generations. Another reason for the low breeding performance is that Indonesia does not have a gene bank for animals. IAARD, universities, and local governments have actively conserved life animal resources through exploration and determination of conservation areas for domestic breeds, as well as legally preventing the collection or use of domestic genetic animal resources[15]. GoI, through the MoA Regulation, also issued the Establishment and Release of Clumps or Breeds of Livestock Regulation Number 117/2014 (MoA, 2014). However, a concerted effort to build an animal gene bank remains to be sought.

The development of food crops by IAARD mainly aims to improve plant quality. For example, the new rice varieties have shown improved characteristics. As discussed in Chapter Three, the rice varieties released in the 2015-2020 period display suitability with specific agroecosystems, such as wetland or irrigated rice fields (Inpari series), dry land (Inpago series), feat, swampy and tidal lands (Inpara series); and a degree of resistance to drought and inundation. Aside from the improved resiliency, a few newly-released rice

[15] https://ugm.ac.id/id/berita/3907harus-dilaksanakan-pelestarian-...

varieties also contain more nutrition, such as Inpari IR Nutri Zinc and Inpago 13 Fortiz, with higher Zn content (Table 4.3).

Table 4.3. List of selected new rice varieties generated by IAARD and their agroecosystem suitability, 2015-2020

No.	Variety Name	Year of release	Potential yield (ton/ha)	Agroecosystem suitability
1.	Inpari 38 Agritan	2015	8.16	Moderately tolerant to drought, suitable for irrigated lowland rainfed ecosystems with an elevation of 600 meters above sea level (MASL)
2.	Inpago 11 Agritan	2015	6.00	Moderately tolerant to drought during the vegetative phase, optimal for lowland ecosystems with an elevation of <700 MASL
3.	Inpari 42 Agritan GSR	2016	10.58	Suitable for optimal and sub-optimal lowland irrigated ecosystems with an elevation of 600 MASL
4.	Inpari 43 Agritan GSR	2016	9.02	Suitable for fertile and non-fertile paddy ecosystems with an elevation of 0-600 MASL
5.	HIPA 18*)	2017	10.30	Hybrid paddy variety, suitable for paddy ecosystems
6.	Rindang 2 Agritan	2017	7.39	Tolerant to shade, moderately tolerant to drought, highly tolerant to aluminum contamination up to 40 ppm, and adaptive to dryland on lowland areas
7.	Inpago 12 Agritan**)	2017	10.20	Brown rice with white color and medium size, adaptive in fertile and acid dryland in lowland paddy ecosystems with elevation up to 700 MASL
8.	Inpara 8 Agritan	2018	6.00	Suitable for tidal land and low to moderate swamp ecosystems, able to elongate in level with the water, tolerant to stagnant inundation between 60-80 centimeters until the generative phase
9.	Inpago 10	2018	7.31	Moderately tolerant to drought and contamination, suitable for dryland on lowland with an elevation less than 700 MASL
10.	Inpara 10 BLB	2018	6.80	Tolerant to iron contamination and suitable in a freshwater swamp and tidal swamp land
11.	Bio Patenggang Agritan	2019	6.00	Moderately tolerant to aluminum contaminant up to 40 ppm, and moderately tolerant to drought and vegetative phase
12.	Inpari IR Nutri Zinc**)	2019	9.98	Potential content of zinc at 34.51 ppm with an average level of 29.54 ppm, suitable for wetland areas with an elevation of 600 MASL
13.	HIPA 20*)	2019	12.08	Hybrid rice, a potential increase in productivity of 20% from the non-hybrid, is suitable for wetland areas with an elevation of 300 MASL
14.	Biosalin 1 Agritan	2020	8.70	Suitable for wetland ecosystems with the high salinity in coastal and intrusion sea-water areas, tolerant to salinity during the seedling process (score 3.33)
15.	Biobestari Agritan	2020	7.90	Tolerant to abiotic stress ecosystems such as aluminum contamination and drought, expandable to other land ecosystems, including dryland and acid land
16.	Inpago 13 Fortiz**)	2020	8.11	Potential content of zinc of around 34 ppm and protein 9.83%, suitable for infertile and acid and up to 700 meters above sea level

Source: ICFCRD, 2021

Meanwhile, the newly released maize varieties were developed to be drought- and shading-tolerant for cultivation in various agroecosystems, especially for the lowland and sub-optimal lowlands (Table 4.4). Likewise, the newly released soybean varieties were developed to be tolerant to drought, especially during the reproductive phase, and saturated water stress (Table 4.5). The crop seed improvement of several maize and soybean varieties also enhanced the nutritional content, especially those for food consumption. IAARD also developed hybrid maize seeds, but the adoption rate for these seeds was relatively low.

Table 4.4. List of selected maize varieties generated by IAARD, 2015-2020

No	Variety Name	Year of release	Potential yield (ton/ha)	Agroecosystem suitability
1.	JH 27	2015	12.60	Highly adaptive to lowlands or highlands
2.	JH 36	2016	12.20	Adaptive to lowlands
3.	Nakula Sadewa 29	2017	13.70	Adaptive to lowland and highland ecosystems, productive of more than 30% in ideal ecosystems
4.	JH 47	2017	12.80	Moderately tolerant to drought, suitable for lowlands
5.	HJ 28 Agritan	2018	12.90	Adaptive to areas with an elevation of 5-650 MASL
6.	Srikandi Ungu 1	2018	8.50	Adaptive and stable in sub-optimal lowlands
7.	Jhana 1	2019	12.45	Tolerant to drought shading with light less than 50%
8.	JH 29	2019	13.60	Adaptive to lowlands and highlands with an elevation of 17-1024 MASL
9.	JH 30	2020	12.60	Highly adaptive to lowlands and highlands with an elevation of 17-1024 MASL
10.	JH 32	2020	13.60	Highly adaptive to lowlands and highlands with an elevation of 17–1024 MASL

Source: ICFCRD, 2021

Table 4.5. List of selected soybean varieties generated by IAARD, 2015-2020

No.	Variety Name	Year of release	Potential yield (ton/ha)	Agroecosystem suitability
1.	Devon 1	2015	3.09	Adaptive to wetland areas
2.	Dega 1	2016	3.82	Adaptive to wetland areas
3.	Deja 1	2017	2.87	Highly tolerant to saturated water stress from 14 days after planting until the maturity phase
4.	Deja 2	2017	2.75	Tolerant to saturated water stress from 14 days after planting until the maturity phase
5.	Derap 1	2018	3.16	Harvesting at 76 days
6.	Biosoy 1	2019	3.30	As food, protein content is 39.7% and fat 18.4%, suitable for raw material for tempeh, tofu, soymilk, and other soy-based processed products
7.	Dering 2	2020	3.32	Highly tolerant to drought stress during the germination period

Source: ICFCRD, 2021

Table 4.6 presents examples of shallot and chili varieties developed by IAARD for a specific location, released by MoA, between 2018 and 2020. Table 4.7 shows new coffee and cocoa varieties originally generated by the Indonesian Coffee and Cocoa Research Institute (ICCRI). The improvement aims for higher yield, better resistance to pests and diseases, and higher quality of beans in response to consumer preferences.

Table 4.6. List of selected shallot and chili varieties generated by IAARD between 2018 and 2020

No	Variety Name	Year of release	Potential yield (ton/ha)	Agroecosystem suitability
Shallot				
1	Violetta 1 Agrihorti	2018	17.32–24.66	Harvesting period: 68-74 days after planting, suitable for highlands
2	Violetta 2 Agrihorti	2018	23.12-29.07	Harvesting period: 86 days after planting, suitable for highlands

Table 4.6. Continued…

No	Variety Name	Year of release	Potential yield (ton/ha)	Agroecosystem suitability
3	Ambassador 1 Agrihorti	2018	21.88-26.54	Harvesting period: 71 after planting, suitable for lowlands in the West Bandung district in the rainy season
4.	Ambassador 3 Agrihorti	2019	21.64-23.92	Harvesting period: 78 days after planting, suitable in highland areas in the West Bandung district in the rainy season
		Chilli		
1.	Rabani Agrihorti	2018	13.00	Adaptive to highland
2.	Inata Agrihorti	2019	14-20	Fruit maturity: 97-120 days after planting, adaptive to highlands in the dry season
3.	Carla Agrihorti	2020	8-20	Fruit maturity: 107-114 after planting, adaptive in highlands in the rainy season

Source: ICHRD, 2021

Table 4.7. List of coffee and cocoa varieties generated by ICCRI in 2019

No	Variety Name	Year of release	Potential yield (ton/ha)	Product characteristics
		Coffee		
1	Hibiro 1	2019	2.80	Stable, highly adaptive, cupping score of 83 (premium), good bean quality
2	Hibiro 2	2019	2.70	Stable and adaptive, cupping score of 83.25 (premium), good bean quality
3	Hibiro 3	2019	2.60	Stable and highly adaptive, cupping score of 85 (premium), with potentially flavorsome, medium-sized, high-quality beans
4	Hibiro 4	2019	2.50	Stable and adaptive, cupping score of 82,75 (premium), medium bean quality
5	Hibiro 5: (BP 534 X Sa 13)	2019	2.40	Stable and adaptive, cupping score of 84,25 (premium), with potentially flavorsome, medium-quality beans
		Cocoa		
1	Klon ICCRI 09	2019	1.84-2.75	Resistant to VSD, the bean’s weight of 1,07-1,55 grams, skin content 11,0-21,7%; and the fat content 48,55%

Source: ICCRI, 2021

A common thread among the variety-enhancement programs by IAARD is the aim to: (1) Achieve food security and nutrition fulfillment by generating higher productivity, product quality, and nutrition content; (2) Adapt to climate change by increasing plants’ tolerance to drought and inundation, as well as land salinity and acidity; and (3) Improve sustainability by suiting plants to local agroecosystems, e.g., land types and geographical locations. This achievement results from IAARD’s policies and programs to improve varieties and breeds, as well as the budget allocation to relevant centers and institutions.

4.1.1.2. Farming and Resource-Efficient Technology

In the last 17 years, IAARD has designed and created agriculture technology components or packages to improve farming methods, including cultivation, sub-optimal land utilization, livestock rearing, and feed composition. At the same time, the technology development seeks to improve the efficiency of resources (land and water) and input use (fertilizers and pesticides), leading to higher income and more sustainable agriculture. In the livestock sub-sector, one of the research topics was to enhance feed composition for poultry and ruminants.

IAARD has also created agricultural tools and machinery prototypes to increase efficiency in farming practices, including rice planting tools, nutrient detection drones with remote-sensing, various seedling machines, portable dryers, cocoa grafting robots, shallot harvesters, and ozone technology preservation (IAARD, 2022). Table 4.8 shows the selected tools and machinery to improve farming efficiency. Table 4.9 presents a list of selected improved feed compositions with locally-resourced high nutrient content for poultry and cattle.

Table 4.8. Selected technology components and packages generated by IAARD to improve farming efficiency, 2015-2021

Aspect	Technology Component and Packages
Food crops	▪ Fertilizer test kit for N, P, and K; ▪ Phosphorus nutrient management technology for irrigated paddy fields; ▪ Double-rotary groove tools; ▪ Rice planting/transplanters (*Jajar Legowo*) and highland rice seeder; ▪ Maize and soybean planting and fertilizer application machines; ▪ Cassava production technology in tidal swamps; and ▪ Maize-based dual cropping patterns on rainfed lowlands.
Horticulture	▪ Dryland soil test kits for horticulture farming; ▪ Seed separator machines for shallot and chili; ▪ Shallot harvest tool; ▪ Off-season mango cultivation technology; and ▪ Pineapple plant propagation technology.
Estate crops	▪ Processing technology of *Jatropha* seeds; ▪ Alfalfa (*Medicago Sativa*) propagation techniques; ▪ Cocoa grafting robot, integrated dripline mounting, sugarcane planter; ▪ Multifunction estate crops harvesting machines; and ▪ Robusta coffee fertilization using indigenous microbes.
Plant protection	▪ Distribution map of plant pests and diseases for main food crops; • Technology for pest control in highland rice with seed treatment techniques; • Integration of major pest and disease controls for soybean and mung bean; • Bio-pesticide formulation from entomopathogenic fungi; and • Combined formula of bio-pesticides and botanical pesticides to control *upih* blight (*Rhizoctonia solani*)
Sustainable agriculture	▪ Nutrient detection using remote sensing; ▪ Hydrology with a telemetry system; ▪ Rainwater harvesting technology; ▪ Fan-shaped spray irrigation techniques; ▪ Smart irrigation; and ▪ Information system of integrated cropping calendar (KATAM).

Source: AARD, 2015, 2016a, 2017, 2018, 2019, 2020a

Table 4.9. List of selected poultry and cattle improved feed composition generated by IAARD, 2018-2021

No.	Livestock	Component or Package of Technology	Year of the First Dissemination
1.	Poultry	Enzyme Manganese BS4 for feed additive	2021
2.	Poultry	Herbal ‘antioxidant’ drinks formula for poultry	2019
3.	Poultry	‘Bioviab’ probiotic as a feed additive for poultry	2018

Table 4.9. Continued…

No.	Livestock	Component or Package of Technology	Year of the First Dissemination
4.	Cattle	Palm kernel feed oil with low fiber and high protein	2021
5.	Cattle	Feed concentrate (pellet) production using *Gliricidia sepium* leaf for cattle fattening	2019
6.	Cattle	Complete rumen-modifier additive	2019
7.	Cattle	Formulation and production of feed additive as cattle's source of antioxidants	2019
8.	Ruminant	Formulation of green leaves concentrate for cattle feed additive	2019
9.	Ruminant	Formulation defaunation agent for rumen protozoa using molasses and *waru* leaves	2019
10.	Ruminant	High-yielding (*Indigofera gozollagribun)* plants for feed	2019

Source: IAARD, 2021

The descriptions of technology components and packages are presented below. These farming technologies were designed for small-scale farmers to increase input use efficiency.

1. **'*Jajar Legowo*[16]' Rice Planting Tool.** This rice planting distancing tool aims to achieve a plant population of more than 160,000 clumps per hectare. The technology increases the paddy population per hectare while allowing plants to photosynthesize optimally. Applying *Jajar Legowo* planting with a spacing of 25x25 centimeters between clumps in rows, 12.5 centimeter spacing within rows, and 50 centimeters as the distance between rows/aisles (25x12.5x50 cm) can optimize plant population per hectare. The 2:1 *Jajar Legowo* planting system produces a total paddy plant population of 213,300 clumps per hectare, increasing it by 33.31% compared to the tile (25x25 cm) planting system, which is only 160,000 clumps per hectare. With this system, farmers can expect higher rice production. Past research has also suggested avoiding tight spacing (20x10x40 cm or tighter) because the narrow spacing reduces plants' ability to receive sunlight (Jumakir et al., 2012; Misran, 2014; Witjaksono, 2018; Prasetyo and Kadir, 2019).

2. **The Soil Test Kit**. The soil test kit determines fertilizers' nutrient and pH levels in lowland rice fields or dryland for the cultivation of food crops, horticulture, or plantation crops. Since it is a qualitative simplification laboratory test, the results are not as accurate. However, it can provide quantitative estimation within a specific value range. Farmers, traders, and extension workers can utilize the kit to determine the quantity and type of fertilizer (N, P, or K) needed for a specific rice field (Prasojo M, 2018). Auditors can also use this kit to monitor fertilizer quality in the market and take the necessary action. The impact of soil testing on agricultural land quality and sustainability is also positive because the use of fertilizer can be optimized. A new version of the test kit is called the Smart Soil Sensing Kit (S3K), produced by the Indonesian Research Center for Soil and Agro-Climate (IRCSAC), launched on World Soil Day, 5 December 2019. The breakthrough kit uses advanced technology, i.e., a Near Infrared Sensor (NIR), to

[16] *Jajar Legowo* is a rice cultivation system where several rows of rice plants are interspersed with an empty row.

measure soil's chemical and physical properties, including pH, texture, C, N, P, K, Ca, Na, and Mg.

3. **Integrated Plant and Resource Management of Rice (IPRM Rice)/ *Pengelolaan Tanaman dan Sumber Daya Terpadu (PTT Padi)*.** This technology package was first developed in 2002 in collaboration with the International Rice Research Institute (IRRI). The application of PTT Padi was based on four principles: (1) The goal is to increase production through holistic and sustainable management of plants, soil, water, nutrients, and plant pests and diseases; (2) The agricultural technology should be optimized by taking into account the integration with other technologies; (3) The technology application consider the suitability with the farmers' physical and socio-economic environment; and (4) The implementation employs participatory approaches, where farmers take part in the selection and testing of technologies for specific or local conditions and upskill themselves through the learning process (IAARD, 2007). The PTT Padi technology package potentially increases rice yield per hectare by about 42 % and farmers' income by 53% (Mulyani and Jumiati, 2015). In 2007 the Directorate General (DG) for Food Crops adopted and used the PTT Padi technology package as the leading activities in the program to increase rice production growth. Later, the DG of Food Crops also implemented the PTT approach to maize and soybean farming.

4. I**nformation systems of integrated cropping calendar technology package/ *Kalender Tanam* (KATAM)[17].** This calendar is an adaptation approach to the impacts of climate change. The IRCSAC-IAARD created this KATAM technology package based on the cropping calendar maps of Java (Las et al., 2007), Sumatra (Las et al., 2008), and Sulawesi (Las et al., 2009). In 2011, IAARD developed KATAM as an information system and made it available publicly through the web system (http://litbang.deptan.go.id). The KATAM offers key information covering all sub-districts in Indonesia, about: (1) Early prediction of planting time; (2) Estimation of planting area; (3) Flood and drought-prone areas; (4) Areas with potential pest attacks; (5) Recommendation of plant varieties; and (6) Recommendation of locally specific balance fertilizers. This content of KATAM was developed and updated using the latest climate data (F. Ramadhani et al., 2013; Runtunuwu et al., 2012) and adopted by the DG of Food Crops to be disseminated to Regional Agriculture Offices at the district level. However, it should be noted that KATAM content is dynamic following the dynamic climate change variables. Implementing the KATAM technology package improved yearly cropping patterns, planted acreage/cropping index, and crop productivity and food production (Fahri et al., 2019; Murni and Purnama, 2020). Furthermore, KATAM technology can also avoid production risks such as yield loss due to flooding or drought (Fahri and Yusuf, 2018). The KATAM technology also makes it easier for extension workers to explain planting time to farmers (Kaliky et al., 2020).

[17] KATAM (cropping calendar) is a guide or tool that provides spatial and tabular information regarding season predictions, early planting time, cropping patterns, potential planting area, drought- and flood-prone areas, recommended doses and fertilizer requirements, appropriate varieties (on irrigated, rainfed and swampy paddy fields) based on climate forecasts.

5. ***Climate Field School*** **(CFS).** Developed by IRCSAC, CFS is sustainable agriculture with a climate change adaptation approach, providing practical training in the open setting (field) to empower farmers to understand climate change and its impacts on farming practices. With knowledge of climatic conditions, farmers can carry out site-specific agricultural farming and minimize climate impact on productivity and production. Farmers and extension workers work with researchers to utilize climate forecast information, e.g., about floods, droughts, or other disasters, to manage their farming activities (IAARD, 2016b; Las et al., 2018). Studies reported that CFS improved farming practices in response to climate change dynamics and increased the production of rice, maize, and vegetables (Novela et al., 2012; R. Ramadhani et al., 2018; Servina, 2019).

4.1.1.3. Post-harvest technology

IAARD tasks include R&D on post-harvest food technology, mainly conducted by the Indonesian Center for Agricultural Post-Harvest Research and Development (ICAPHRD). The main objective is to increase the added value and diversity of processed food and help achieve food security and nutrition fulfillment through local-based staple-food diversification. ICAPHRD's post-harvest technology targets micro, small, and medium enterprises (MSMEs) because data show that 43.6% out of 4.21 million MSMEs were in the food business [BPS, 2021b). MSMEs need R&D results in post-harvest technology to advance their business, create employment, and help achieve food security and nutrition fulfillment.

One of the ICAPHRD's R&D outcomes is to create flour from local starch, such as cassava, sweet potatoes, maize, sago, and breadfruits. This can be a substitute for rice and imported wheat flour as carbohydrate sources. In 2020, Indonesia imported wheat products of around 10.2 million tons (BPS, 2021b). The country imports almost all wheat products and wheat flour to fulfill domestic needs. The import volumes are increasing over time. For the business players, big or small, flour is a raw material for noodles, bread, and other processed food. Meanwhile, other research projects on food post-harvest create healthy food technology, such as fortified rice milk, low-glycemic sweet-potato noodles, and low unsaturated fat in vegetable oils. The research projects also develop technology that has added value (such as vinegar from coconut water, antioxidant coffee powder, and shallot powder), as shown in Table 4.10.

However, a significant gap exists between the availability of post-harvest technologies created by ICAPHRD and its implementation by the food industry, especially MSMEs. In addition, the adoption rate was relatively low because researchers sometimes do not consider the economic feasibility and consumer preferences in designing end products. Other problems were: (1) A lack of collaboration with the food industry or prospective end users; and (2) The low adoption capacity among SMSEs to adopt because of the limited technical and financial capacity.

Table 4.10. List of selected post-harvest technologies generated by IAARD, 2016-2020

No.	Component or Package of Technology	Processed Food Products	Year of the First Dissemination
Staple food diversification (carbohydrate sources)			
1.	The production process of artificial rice from flour made from local food sources (cassava, sago, and maize).	Local food flour and artificial rice	2020
2.	The production process of cassava pastes without additional wheat flour	Cassava paste	2020
3.	The production process of noodles from sago with natural red color extract	Noodle from sago	2020
4.	The production process of instant *tiwul* (processed cassava)	Processed cassava	2018
5.	Technology for pre-gelatinized cassava flour	Cassava flour	2018
6.	The production process of *kimpul* (local root sweet bread)	Bread from a local root	2017
7.	Technology for making sweet potato noodles	Noodle from sweet potato	2016
8.	Technology for making breadfruit noodles	Noodle from breadfruit	2016
Healthy food			
1.	The production process of gluten-free noodles from cassava-based ingredients	Gluten-free noodles	2020
2.	Formulation and production process of fortified rice-milk	Fortified rice-milk	2019
3.	Technology for reducing glycemic index on sweet potato noodles	Sweet potato low glycemic index	2019
4.	Technology for reducing unsaturated fat in vegetable oils	Vegetable oil	2017
Value added			
1.	The production process of vinegar from coconut water	Vinegar	2020
2.	The production process of antioxidant coffee powder	Coffee antioxidant	2019
3.	The process of removing bitterness in aloe vera jelly drink	Aloe Vera drink	2019
4.	The production process of instant rice	Instant rice	2019
5.	The production process of gelatin from chicken feet	Chicken gelatin	2019
6.	The production process of shallot powder	Shallot powder	2019
7.	The production process of extracting shallot oil	Shallot oil	2018
8.	The production process of probiotic yogurt	Yogurt	2018

Source: IAARD, 2021

4.1.2. Agricultural Technology Dissemination

4.1.2.1. Acceleration of Technology Dissemination

Dissemination of agriculture technology and innovation is one of ’AARD's essential tasks. This function is carried out by Assessment Institute for Agriculture Technology (AIAT) in 33 provinces, coordinated by the Indonesian Center for Agricultural Technology Assessment and Development (ICATAD). AIATs’ service area covers the entire territory of Indonesia, so the budget allocation to all AIAT’s activities in the last five years absorbed one-third of the budget allocation for IAARD (see Chapter Three).

The functions of AIATs are: (1) To identify and to make an inventory of farmers’ agriculture technology needs in specific areas; (2) To conduct feasibility studies of prospective technology according to specific agroecosystem; (3) To prepare extension materials of the introduced technology; and 4) To identify feedback for introduced technology for further improvement. Another important AIATs task is assisting the implementation of strategic programs done by Directorate Generals of MoA, especially in the technology application. This task is beyond the boundary of R&D, but AIATs carry it out regardless.

Most AIATs dissemination activities involve multi-location and adaptation testing to see a new technology's suitability for the specific local agroecosystems. Researchers worked with senior agricultural extension workers to: (1) Translate technical information into a more digestible format; (2) Develop a pilot model in the fields to demonstrate the technology application; and (3) Gather feedback from farmers to identify the technology needs.

AIATs work with local provincial and district-level agricultural offices, researchers, and extension workers to carry out these tasks. Social engineering underlies this implementation. An example of this is the PRIMATANI[18] Program. First implemented in 2006, the dissemination method aimed to accelerate farmers' adoption of new agriculture technologies to increase productivity, efficiency, and competitiveness in rural areas ([IAARD, 2006a). The working principle of PRIMATANI consists of: (1) An assessment of local resources' potential and technology that can help optimize these resources; (2) A selection of suitable agribusiness development programs and technology intervention; (3) The creation of a pilot model for the innovative technology-based agribusiness systems; (4) Implementation that integrates innovation, institutional systems, and agribusiness systems. In implementing the PRIMATANI program, two or three researchers were dispatched to stay and mingle with the community in the village for several months over a year. In collaboration with extension workers, these researchers acted as a mentor in the program implementation (IAARD, 2006b).

Several provincial governments, such as Central Java and Bali, have replicated PRIMATANI as a technology dissemination method (Anugrah, 2022; Kamandalu et al., 2012). PRIMATANI implementation in Bali had positive impacts on rice farming, as indicated by: (1) The application of balanced fertilizer and the practice of "*jajar legowo*" planting distance; (2) Increased rice production; (3) Improved grain quality to meet market demand; (4) livestock waste processing into organic fertilizer; and (5) The formation of women farmers' groups.

4.1.2.2. Adoption Rate of Agriculture Technology

Not every small-scale farmer adopts the introduced or promoted agricultural technology. Factors determining the adoption include the potential profitability generated from the use of technology, the technical suitability of the technology with farmers' preferences and local conditions, and the farmers' technical and economic capacity and capability to implement the technology. Therefore, the adoption rates of IAARD technologies and innovation vary.

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[18] PRIMATANI stands for *Program Rintisan Pemasyarakatan Inovasi Teknologi Pertanian* or the Socialization Pilot Program for and Agricultural Technology Innovation, first introduced by IAARD in 2006.

a. High adoption rate

Below are three examples of technology and inventions generated by IAARD that have been adopted widely and boosted yields and income significantly.

***First*, the Agro-ecological Zone (AEZ) Map**. The AEZ Map is thematic geospatial data derived from soil or land unit maps that indicate the distribution of land units with similar characteristics of climate, terrain, soils, and potency for agricultural commodity development. Derived from the available reconnaissance soil or land system maps, IAARD introduced the AEZ maps in the early 1990s at scales of 1:1,000,000 for an island basis and 1:250,000 for a provincial. The AEZ map provides general information on the direction of agricultural commodity zoning to support national and provincial land use planning. IAARD researchers created the AEZ maps at a scale of 1:50,000 on a district basis in 2012 (Hikmatullah & Ritung, 2014). The AEZ Map has been developed further to include more land resources data, with a scale of 1:50,000. This map is available in 511 regencies and cities in Indonesia. The data consist of soil maps, land suitability maps, and recommended land management and agricultural commodities, i.e., rice, corn, soybean, shallot, chili, sugarcane, plant for animal feed, cocoa, and palm oil.

The land resources data are essential for agricultural development planning. Request for the maps comes from various institutions, namely Directorate Generals within the MoA, the National Development Planning Agency (*Bappenas*) and related ministries, local governments, and the private sector (domestic and foreign investors). The most requested are land suitability maps for the development of agricultural intensification and extensification for strategic commodities. The province and district governments utilize these maps in designing regional agricultural development planning (A. Mulyani et al., 2020).

The map utilization Iill improve efficiIncy in the government budget (central and local), increase efficiency in farming practices, and improve farmers' income. At the national level, the research centers within IAARD responsible for this work are the Indonesian Center for Agricultural Land Resources Research and Development (ICALRRD), and AIATs with the assistance of ICALRRD at the regional level.

***Second*, High-Yielding Rice Varieties**. For 47 years, IAARD created more than 300 new rice varieties, but only a few were adopted by farmers, usually for a short period, then replaced by new ones. As a result, only a few improved rice varieties have been popular among farmers for a long time, more than 15-30 years, namely IR 64 (released in 1986), Ciherang (2000), Mekongga (2004), and Situ Bagendit (2003). The first three rice varieties are designed for irrigated rice fields, and the last is adapted to dry and lowland.

Farmers adopted IR 64 rice variety rapidly. In 2020, 14 years since its release in 1986, IR 64 was planted in 61% of rice farming in Indonesia. The Ciherang rice variety was released in 2000 and has surged in popularity and quickly taken over IR 64. For example, in 2022, Ciherang surpassed IR 64 in West Java, one of the central rice production provinces. Ciherang planting areas reached 39.9%, and IR 64 dropped to 27.6% (Nurhati, Ramdhaniati, Zuraida, 2008).

Table 4.11. Percentage of rice planting acreage in Indonesia by varieties, 2015, 2017, 2020.

Rank (2020 standing)	Rice varieties (year release)	2015	2017	2020
1	Ciherang (2000)	30.11	29.74	29.87
2	Mekongga (2004)	10.69	12.10	12.60

Table 4.11. Continued…

Rank (2020 standing)	Rice varieties (year release)	2015	2017	2020
3	Inpari 32 HDB (2013)	-	7.95	7.47
4	IR 64 (1986)	11.94	7.95	6.31
5	Inpari 30 Sub 1 (2012)	-	5.06	6.13
6	Situ Bagendit (2003)	6.58	5.39	412

Source: Directorate of Seeds, DG of Food Crops, MoA (2016, 2018, 2021)

In 2020, IR 64 decreased again to the fourth largest rice variety (6.31%), while Ciherang was still the first at 29.87%, followed by Mekongga at 12.60%, and newcomer Inpari 32 HDB (released 2013) at 7.47%. In the ten-year period (2010-2020), no newly-released rice varieties were cultivated by farmers at more than 1% of national rice planting acreage (see Table 4.11) (Directorate of Seeds, DG of Food Crops, MoA, 2016, 2018, 2019, 2021).

Differences in the adoption rate or the level of commercialization of newly introduced rice varieties are influenced by seeds' characteristics, namely productivity, suitability with consumer preferences (such as taste), high resistance to pests and diseases, rice selling prices, and seeds availability (Syahri and Somantri 2018). Another study concluded that the high popularity of IR 64 and Ciherang was because they have the characteristics sought by farmers, namely selling prices (relatively higher than other varieties), productivity, resistance to pests and diseases, ease of selling (Syamsiah, Nurmalina, and Fariyanti, 2015). This study found that Ciherang scored higher than IR 64 in these four criteria, so it outperformed IR 64. The study done by the Indonesian Center for Agricultural Technology Management (BBATP/ICATM) of IAARD (BPATP, 2015) in Lampung, West Java, Central Java, and South Sulawesi showed that farmers' preferences for rice varieties are: short cultivation time, resistance to pests and diseases, high productivity, high yield, and low percentage of broken rice. Besides consumer preferences, timely seed availability and intensive socialization of new superior seeds to farmers are the keys to adoption acceleration (Syahri and Somantri 2018).

Even though farmers adopted only a few newly released rice varieties out of hundreds, R&D on rice breeding recorded some success and significant impacts on food security achievement in Indonesia. The DG of IAARD mentioned that out of 12 million hectares of planted rice acreage nationally, 94% were planted by improved rice varieties created by IAARD breeders[19]. He stated that the benefits of replacing rice seeds with newly released varieties from 2014 to 2021 had reached around IDR10.5 trillion or USD733.7 million (DisKominfo Jatim, 2021).

Third**, Site specific fertilization dose recommendation**. Lowland rice fields consume most fertilizer distributed in Indonesia. Therefore, improving fertilizer efficiency in rice farming can increase profitability and farmers' income, sustain production systems, preserve environmental functions, and save energy resources. Before 2006, fertilizer recommendations for lowland rice farming were generic across provinces, so fertilizer use was not reasonable and often unbalanced. Based on research results by ICALRRD, in 2006 and updated in 2007, the MoA issued recommendations for N, P, and K doses in site-specific

[19] https://www.swadayaonline.com/artikel/7165

lowland rice fields through MoA Decree (Ministry of Agriculture Decree Number 40, 2007). These location-specific fertilizer recommendations are set for each sub-district across Indonesia, with three formulas: without using organic matter, combined with five tons of straw/ha, or mixed with two tons of manure per hectare. This fertilizer dose recommendation has increased fertilizer use efficiency on-site and saved some government expenditure on the fertilizer subsidy. MoA has regularly updated this fertilizer dose recommendation based on a suggestion from IAARD.

b. Low adoption rate

Unlike the R&D results above, the rate of several technologies was significantly low. The following are two examples of the newly introduced technologies that farmers did not adopt, despite the potential significant production and income increase. Similar to the adoption drivers, factors that determine the adoption rate by farmers are technical characteristics and farmers' social and economic conditions.

***First*, Hybrid Rice.** IAARD has released 19 new hybrid rice varieties; seven were licensed to private firms (Tempo, 2018). In addition, seven companies introduced imported hybrid rice varieties in Indonesia, among others from China and India. Hybrid rice was introduced for the first time to Indonesian farmers in 2002, but the planting acreage in the following years was insignificant. For example, in 2018, it was less than 1% out of 10.7 million harvested areas (Krishnamurti and Biru, 2019). In the following years, the progress was also slow. It was concluded that the reasons for the unsuccessful R&D outcome delivery were: (1) The gap between technology and farmers' technical and economic capacity; and (2) Failure to demonstrate the new technology in the field.

Hybrid rice has a yield potential of more than 25% higher than inbred rice. However, it has major drawbacks that discourage adoption among small-scale farmers, including: (1) Higher seed prices of around 7-10 times than inbred: (2) New seeds needed for every planting season (unlike inbred rice where seeds from harvest can be used up to three seasons); (3) More complicated than conventional cultivation practices; and 4) The rice quality (taste and aroma) is not accepted by all consumers, so the selling price is lower than inbred rice.

These downsides were intensified by crop failure when hybrid rice was first introduced to farmers. This bad experience posed challenges to extension workers in convincing farmers to adopt hybrid rice. Therefore, in 2021, the Indonesian Seed Association (Asbenindo) carried out several demonstration farms (demfarms) of hybrid rice, involving seven companies, a rice research institute, and farmers covering an area of approximately 19.5 hectares. This demfarms project aims to rectify the wrong impression about hybrid rice among farmers (Tabloid Sinartani, 2021).

***Second*, the Rice Cropping Index 400 (IP Padi 400)**[20]. IAARD designed the IP Padi 400 technology package to increase rice production and accelerate the achievement of national rice self-sufficiency. The design is built upon, among others, the existing high-yielding rice varieties with short harvesting times. Specifically, four technological components in IP Padi 400 are the use of: (1) Early maturing rice varieties (90-104 days); (2) More integrated pest and disease management (IPM); (3) integrated and site-specific

[20] IP Padi 400 (Rice Cropping Index 400) is a cropping system whereby farmers can plant and harvest rice four times a year on the same stretch of land.

nutrient management; and (4) Efficient planting and harvesting time, with annual farming plan clearly formulated, and implemented by strictly following schedules (IIRR of IAARD, 2009). Combining technology components in an integrated package like this is expected to optimize productivity and efficiency. In the case of IP Padi 400, it means farmers can cultivate and harvest rice four times a year on the same adjacent areas of about 25 hectares.

However, the implementation of IP Padi 400 in rice fields was not as straightforward as expected because: (1) Farmers were not ready to work on a tight schedule; and (2) There was no irrigation management system that provides water throughout the year. Supriatna (2012) and Sudana (2010) identified that the necessary condition should be met in terms of technical, economic, and institutional aspects before IP Padi 400 can be implemented. Meanwhile, Sudianto (2019) found that the main reason for the low adoption is farmers' low capacity to implement the technology, such as making mobile canals and wormholes, composting straws in the field, planting, and providing organic fertilizers. On a social aspect, the new farming system under IP Padi 400 was also new as it allows very little break time between planting seasons.

In brief, this promising technology package was not widely adopted by farmers because it is too complicated. Farmers ignored potential production and income increase due to technical or practical reasons. IP Padi 400 was expected to intensify harvested areas of 1.5 million hectares in irrigated rice fields as an alternative to opening new rice fields. However, within three years of launching, no official report for the total area of irrigated rice fields being dedicated to the IP Padi 400 program.

4.1.3. Impacts of Technology and Innovation on Productivity and Income

4.1.3.1. Trends of Food Crops' Yields and Livestock Production

R&D activities and technologies mentioned thus far are designed and directed to increase productivity, efficiency, and income. However, in the fields, productivity is not only determined by improved seeds, breeds, and farming system technology alone but also by the environment surrounding farming fields, technically, economically, and socially. Aside from that, productivity also depends on the capacity and capability of farmers to adopt and apply new technologies and government policy on agriculture, such as investment in infrastructure, R&D, farmer empowerment, and input subsidy or output price certainty.

Table 4.12 presents rice, maize, and soybean productivity in the last 15 years (2005-2020). Growth of rice productivity in 2005-2010 was 1.92% per year; in 2010-2015, declining to 1.14% per year; and in 2015-2020, remaining stagnant at -0.02% per year. The highest productivity level was in 2015 at 5.36 tons/hectare, while in 2020 was slightly lower at 5.07 tons per hectare. Likewise, maize and soybean yield trends also decreased to different degrees. The growth of maize yield in 2015-2020 was 2.35% per year, while soybean in the same period was -0.20%. The different trends were likely due to the different levels of profitability.

In 2020, rice, maize, and soybean productivity were 5.13, 5.69, and 1.51 tons per hectare, respectively. These yield levels were higher than 15 years ago at 4.57, 3.45, and 1.30 tons per hectare, respectively. However, compared to the potential yield estimated by IAARD, the actual yield was much lower for all three food crops. The potential yield of new superior rice varieties was around 6 to 10 tons per hectare, maize varieties 8.5 to 13.7 tons per hectare, and soybean varieties 1.4 to 4.4 tons per hectare.

Table 4.12. Productivity of rice, maize, and soybean, Indonesia, 2005-2020

Year	Rice	Maize	Soybean
Productivity (ton/ha):			
2005	4.57	3.45	1.30
2006	4.62	3.47	1.29
2007	4.65	3.66	1.29
2008	4.92	4.08	1.31
2009	5.01	4.24	1.35
2010	5.03	4.44	1.37
2011	5.00	4.57	1.37
2012	5.15	4.90	1.49
2013	5.17	4.84	1.42
2014	5.15	4.95	1.55
2015	5.36	5.18	1.57
2016	5.10	5.31	1.49
2017	5.07	5.23	1.51
2018	5.20	5.33	1.32
2019	5.11	5.44	1.46
2020	5.13	5.69	1.51
Growth (%):			
2005-2010	1.92	5.19	1.09
2010-2015	1.14	3.43	2.68
2015-2020	-0.02	2.35	-0.20
2005-2020	0.79	3.43	1.16

Source: FAO, 2022

These facts confirm that productivity was not only determined by the availability of high-yielding variety seeds and improved farming technology but also by the capability of farmers to implement a farming technology package as recommended. Based on interviews with IAARD officials, the wide gap between potential and actual yields was attributable to intensity and means of technology dissemination and farmers' capacity to acquire improved technology.

Similarly, there were gaps between potential and actual yields in the production of chili and shallot (horticulture) and coffee and cocoa (mostly small-scale farmers). In the 2015-2020 period, shallot and chili productivity growth were 3.68% and -0.66% per year, respectively. In 2020, the yield for chili was 8.87 tons per hectare, and shallot was 9.72 tons per hectare (Table 4.13). Meanwhile, the yield potential for chili was 8-12 tons per hectare, and shallot was 17-19 tons per hectare (Table 4.6). Likewise, the gaps between actual and estimated yields for coffee and cocoa were wide. During the period, the average production per hectare for coffee was 0.57 tons, and for cocoa was 0.42 tons (Table 4.13), which was lower than its yield potential at 2.5-3.0 tons per hectare for coffee and 1.8-2.8 tons per hectare for cacao (Table 4.6). Using improved seeds does not directly optimize productivity. Other factors also play significant roles, such as planting at suitability of land, applying recommended farming practices, overcoming extreme climate change, managing pest and disease attacks, and obtaining the right product selling prices.

Table 4.13. Productivity of selected horticulture and estate crops, Indonesia, 2015-2020

Year	Chili	Shallot	Coffee	Cocoa
Productivity (ton/ha):				
2015	7.49	10.06	0.52	0.35
2016	7.54	9.67	0.52	0.39
2017	7.61	9.29	0.58	0.36
2018	8.19	9.59	0.60	0.48
2019	8.62	9.93	0.60	0.49
2020	8.81	9.72	0.61	0.47
Growth (%):				
2015-2020	3.66	-0.68	2.72	2.95

Table 4.13. Continued...

Source: FAO, 2022

Data on livestock productivity was not available, so the impacts of R&D and other factors on livestock products were measured by production growth. During 2015-2020, the growth of chicken meat and egg production was 2.10% and 2.76%, respectively, which were above population growth. This means that the domestic needs for poultry products can be fulfilled domestically. In 2020, chicken meat and egg productions were 3.43 and 5.16 million tons, respectively. Meanwhile, beef production was 453 thousand tons, less than the domestic demand. Therefore, Indonesia imported around 223 thousand tons of beef or 33% of domestic needs. In 2015-2020, beef production growth was -2.43% per year (Table 4.14). The negative growth was due to the low adoption rate of technology, small-scale farmers' low capacity, and unfavorable market dynamics. For chicken meat and eggs, the dynamics in feed and product market prices also influenced poultry farmers' business decisions.

Table 4.14. Production of chicken meat, eggs, and beef, Indonesia, 2017-2021

Year	Chicken meat	Eggs	Beef
Productivity (000 tons):			
2017	3,176	4,633	486
2018	3,410	4,688	498
2019	3,495	4,753	505
2020	3,219	5,142	453
2021	3,426	5,156	438
Growth (%):			
2017-2021	2,10	2,76	-2,43

Source: BPS, 2022c; BPS, 2022d; BPS, 2022e

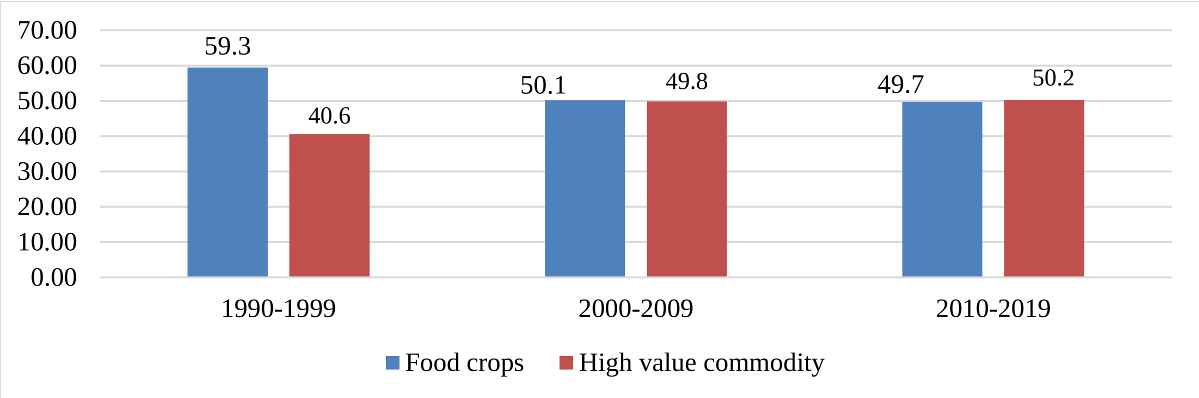
4.1.3.2. Agriculture Production Shifts toward High-Value Commodities

The shares of high-value commodities in the total value of agricultural production can be used as an indicator of rural transformation (Huang and Shi, 2021). The trends of these commodities (food crops, horticulture, perennial crops, and livestock) increased significantly between the 1990-1999 and 2000-2009 periods, from 40.6% to 49.2%. However, the share was almost stagnant from 2000-2009 to 2010-2019, at just around 50% (Figure 4.1).

This indicates that in the 1990s and 2020s, the composition of agricultural production has moved from staple food and low-value agriculture toward high-value and more commercialized commodities (horticulture, perennial crops, and livestock). This transformation also indicates changes in farmers' orientation from subsistence toward market-driven. Meanwhile, the nearly stagnant trends of commercial products in the 2010s reflect the government priorities on food crops production (Sudaryanto *et al.*, 2021), which is also reflected in the IAARD allocation of the R&D budget, as discussed in Chapter Three, to gear toward rice self-sufficiency and food security.

Agricultural transformation usually involves land consolidation, resulting in a larger average farm size (Huang, 2018). However, as discussed in the above section, the average land holding size (rice fields and highlands or drylands) decreased from 0.89 hectares in 2013 to 0.79 hectares in 2018. Furthermore, the proportion of farmers occupying less than 2.0 hectares was 89.1%. The data in Table 4.1 indicate that agricultural transformation indeed stagnated in the last decade, compared to the two earlier decades.

Figure 4.1. Change on the share of high-value commodities production value (%), 1990/1999-2010/2019



Source: Sudaryanto *et al.* (2021)

4.1.3.3. Farmers' Productivity and Agriculture Sustainability

One of the drivers of productivity and income in the agriculture sector is the optimal use of agriculture technology and innovation. However, the effectiveness the technology adoption depends on farmers' ability and capacity to follow the recommendation in the implementation. The Government of Indonesia (GoI) has made efforts to accelerate the adoption through extension services and demonstration farms and provided incentives to small-scale farmers, input subsidies, and output price guarantees. However, the productivity has not met the expected potential.

Referring to United Nations Statistics (UN Stat) SDG indicators, small-scale farmers' productivity is measured by indicator 2.3.1 (volume of production per labor unit by farming classes) and indicator 2.3.2 (average income of small-scale food producers)[21]. Definition of small-scale agriculture producers used in this calculation is different from the term stated in Law No. 19/ 2013. According to the Law, as discussed above, small-scale farmer operates lands less than 2.0 hectares. Meanwhile, the definition from the UN Stat, small-scale agriculture producers are those structurally independent of fixed-wage labor and mainly

[21] (https://unstats.un.org/sdgs/metadata)

manage their production activities using family labor. The agriculture covers activities of food crops, horticulture, plantations, and livestock sub-sectors.

In the 2020 Integrated Agriculture Survey (SITASI) conducted by BPS in three provinces (West Java, East Java, and West Nusa Tenggara, as a pilot project), referring to UN Stat method, BPS used the two criteria of small-scale farmers namely the physical size and economic size of the agricultural business (BPS 2021a). Small-scale agriculture producer (farmer) defined as a producer who is structurally independent of fixed-wage labor and who manage his/her production activities mainly using family labor. Small-scale farming in the three provinces in Indonesia was characterized that within one year they managed (the threshold) less than 0.16 hectares of land, raised less than 0.61 units of tropical livestock, and earned less than USD1,044.17 PPP (BPS, 2021). Based on this definition, in 2020 the proportion of small-scale farmers in West Java, East Java West Nusa Tenggara was 35.82%, 21.15%, and 23.0% respectively. The average proportion for the three provinces in aggregate term was 28.77%

Based on the 2020 SITASI data, the productivity of small-scale farmers per working day (indicator 2.3.1) was USD36.30 PPP meanwhile, the productivity of small-scale farmers in West Java, East Java and East Nusa Tenggara were USD43.58 PPP, USD28.52 PPP, and USD20.15 PPP, respectively. The aggregate net income of small-scale farmers (indicator 2.3.2) in the three provinces was USD641.97 PPP as stated above. The average net income of small-scale agriculture producers in the Provinces of West Java, Central Java and West Nusa Tenggara was USD683.37 PPP, USD573.83 PPP and USD466.73 PPP, respectively. (The conversion rate of the World Bank for 2020: 1 USD = IDR4,743,337 PPP). Using data as presented above, with the average income of small-scale farmers in 2020 was USD 641.97 PPP, hence their average daily income was about USD1.76 PPP. This figure was lower than the value used by the World Bank to calculate poverty headcount in Indonesia for 2021, which was USD 2.15 (2017 PPP).

Agriculture labor productivity is the agricultural value-added divided by the number of agricultural laborers. During the 2015 to 2019 period, the trend in agriculture labor productivity increased by 8.5% per year. The labor productivity in 2015 was IDR41.20 million and rose to IDR56.78 million in 2019. However, productivity dropped to IDR55.33 million in 2020 due to the COVID-19 pandemic. As discussed earlier, agricultural labor productivity does not only result from the use of agricultural technology and innovation but is also influenced by the following factors: (1) The trend of agricultural markets; (2) The balance between workforce availability and employment opportunity in agriculture; (3) Employment opportunities in the non-agricultural sector; and (4) Shocks from external factors such as international market dynamics, pandemics, and international conflicts.

Agricultural R&D also considers SDGs as guidance, such as optimum use of inputs and minimal chemical discharge to soil and water, adaptation and mitigation to climate change, and resilient and sustainable design of farming practices. An indicator of SDG #2 (Zero Hunger) is 2.4.1: the proportion of the sustainable and productive agricultural area. This indicator measures the implementation of a productive and sustainable food production system, consisting of three dimensions, 11 themes, and 11 sub-indicators (one sub-indicator is assigned for each theme). The three dimensions of sustainability are: (1) Economic dimension with the themes of land productivity, profitability, and resilience; (2)

Environmental dimensions with the themes of soil health, water use, fertilizers pollution risk, pesticides risk, and biodiversity; and (3) Social dimension with the themes of decent employment, food security, and land tenure. The sustainability assessment for each sub-indicator is categorized into three: (1) Desirable, i.e., according to the principle of sustainability; (2) Acceptable; and (3) Unsustainable. Based on the 2.4.1 indicator calculation formula, the level of productivity and sustainability of an agricultural area are determined by the lowest percentage of one of the 11 sub-indicators that fall into the criteria ‘desirable’ and ‘acceptable’[22].

Based on a BPS report (2021a), the proportion of productive and sustainable agricultural areas in Indonesia in 2021 (average from three provinces: West Java, East Java, and West Nusa Tenggara) was low, at 10.28%. From the calculation result of the 11 sub-indicators, eight showed high percentages in the ‘desirable’ and ‘acceptable’ categories, which meet the sustainability principle by more than 90%. Based on the dimension, the economic dimension had two sub-indicators with high percentages, i.e., profitability (97.13%) and resilience (91.84%); the environmental dimension had four, i.e., soil fertility (95.35%), water use (91.40%), biodiversity (99.45%), and the use of pesticides (98.49%), and the social dimension had two, i.e., food security (99.79%) and land ownership (98.06%). Two themes achieving lower than 50% in the sustainable category were land productivity at 10.28% and fertilizer pollution risk at 39.83% (Table 4.15).

In general, IAARD, as a public R&D institution, has contributed to improving the performance of several themes in sustainable agricultural land, such as farming productivity, soil health, water use, and biodiversity, through improved technology and innovation. As highlighted across sections in this report, sustainability is considered one of the essential components of designed agricultural technology. The acceleration of technology adoption by AIATs has contributed to this improvement to a large degree, along with the contribution from other research institutions and universities.

The GoI has issued a policy that encourages regional governments to dedicate a certain proportion of agricultural land for sustainable food production. This area of agricultural land is to be determined, protected, and developed consistently to produce staple food for national food self-reliance, security, and sovereignty (The Law Number 41/2009 about the Protection of Sustainable Food Agricultural Land). With this policy, each district/city government must stipulate sustainable agricultural land for food production through regional government regulation. Since rice is the most important staple food in Indonesia, with social, economic, environmental, and political values, the MoA is currently prioritizing rice field areas for sustainable agricultural land for food production.

Table 4.15 The proportion of productive and sustainable agricultural land in Indonesia (average from three provinces of West Java, East Java, and West Nusa Tenggara), 2020

Dimensions and themes	The proportion of agricultural land based on the sustainability category			
	Desirable	Acceptable	Sustainable*)	Unsustainable
Economic dimensions:				
Land productivity	8,12	2,16	10,28	89,72
Profitability	32,05	65,08	97,13	2,87
Resilience	90,33	1,52	91,84	8,16

22 https://unstats.un.org › files › Metadata-02-04-01.

Table 4.15. Continued…

Dimensions and themes	The proportion of agricultural land based on the sustainability category			
	Desirable	Acceptable	Sustainable*]	Unsustainable
Environmental dimensions:				
Soil health	91,37	3,98	95,35	4,65
Water Use	87,24	4,16	91,40	8,60
Fertilizer pollution risk	30,37	9,46	39,83	60,17
Pesticide risk	36,21	62,28	98,49	1,51
Biodiversity	77,43	22,02	99,45	0,55
Social dimensions:				
Decent employment	65,44	0,00	65,44	34,56
Food security	99,66	0,13	99,79	0,21
Land tenure	82,52	15,55	98,06	1,94

Note: *] Sustainable = Desirable + Acceptable
Source: BPS, 2020

It notes that resilient theme has one sub-indicator, namely "risk mitigation" mechanism. A desirable or sustainable according to resilient theme is access to or availed at least two of three mitigation mechanisms, while unsustainable if no access to the three mitigation mechanisms. Sub-indicator risk mitigation mechanism measures the implementation of mitigation mechanisms against risks that arise in the implementation of agricultural activities. A farm holding is considered resilient if it has availed or has the means to access the risk mitigation mechanisms. This calculation method or formula is from UN Stat related to SDGs (UN Stats, 2022) According to the Risk Mitigation Mechanism sub-indicator, in the provinces of West Java, East Java, and West Nusa Tenggara in 2020, only 8.16% of agricultural land was unsustainable. Therefore, 91.85% of agricultural land in these three provinces was categorized as sustainable (for each category: desirable 90.33% and acceptable 1.52%).

Based on information from the DG of Agricultural Infrastructure of the MoA, from 2012 to 2019, 109 districts and cities (out of 535) issued the district/city government regulation on the stipulation of sustainable food agricultural land, especially for rice fields. The cumulative designated rice fields as sustainable land as of 2019 amounted to 1.97 million hectares, with most categorized as technical, semi-technical, simple, and rural irrigated; reclaimed land, tidal and non-tidal swamps; and rainfed land. Based on the Ministry of Agrarian and Spatial Planning information, the total area of rice fields was 7.46 million hectares as of 2019. Using this rice field area as a denominator, the proportion of sustainable agricultural land for food production in the country in 2019 was around 25.6%, which was only half of the national target of 50%.

4.1.4. Problems Faced by Small-scale Farmers in Increasing Productivity and Competitiveness

To identify a person or household' ability to meet basic needs, BPS determines the poverty line. In March 2022, the poverty line was at IDR505,469/capita/month (BPS, 2022) or USD35 per month (USD1.17 per day, with exchange rate of IDR14,436/IDR, as of 30 March 2022). Meanwhile, the near-poor are those with monthly expenditures slightly above (1.2 times) the poverty line (Nurrahamah *et al.*, 2017). These people are vulnerable to falling into poverty and are sensitive to turbulences in the economy, finance, and government policies. Small-scale farmers are mostly belonging to this poor and near-poor segment of population. With such a low income, small-scale farmers have limited capacity to finance their farming. This widens the gap between the existence of agricultural technology for productivity and efficiency and farmers' adoption. Most small-scale farmers are categorized as poor or near-poor. The poor means their monthly per capita expenditure is below the poverty line (BPS, 2022).

The four main problems or challeIgeI in implementing technologies and innovations for higher crop productivity, farming efficiency, and product competitiveness faced by small-scale farmers include:

1. Limited ownership and control over productive resources such as land, water, and infrastructures, that could increase farming productivity and incomes;
2. Limited technical skill and financial capacity to access, acquire and implement improved agricultural technologies and innovation;
3. Limited access to agricultural input and output markets because as an individual farmer, he/she may not have the physical and economic capacity, then obtaining a reasonable input and output prices is challenging. In addition, with the pressing need to cash the harvests, farmers' bargaining power is low; and
4. Limited capacity to scale: Due to the principle of economies of scale, small-scale farmers cannot take benefit from certain improved technologies that require a certain acreage of land or business scale to be effective, such as agricultural machinery and agriculture processing activities.

Based on this assessment, it can be concluded that improved agriculture technology is a prerequisite to increase farming productivity and efficiency, but it is social engineering that will allow the economy of scale principle to be put into practice. Social engineering is needed to organize farmers in a certain area that meets the economies of scale to develop their farming business jointly (further details of these issues are presented in Chapter Five). In addition, technology dissemination and farmers' empowerment need to be accelerated, which includes knowledge and upskilling, access to technology, financial sources, information, and input and output markets.

4.2. Issues Faced by Food Consumers

4.2.1. Dynamics changes in food consumption patterns

The proportion of food to total household expenditures during the ten-year period (2010-2020) was, on average, around 50%. During this period, the proportion of expenditure on cereals decreased, but there was an increase in expenditure on: (1) Prepared food and beverages; and (2) Cigarettes and tobacco. Expenditure percentages for other food items are relatively constant. However, since the real household expenditure in 2020 was higher than that in 2010, the real value of these food expenditures increased (Table 4.16). From these figures, it can be concluded that households' food preferences have shifted toward more balanced food (carbohydrates versus protein, vitamin, and mineral sources) and prepared food products.

Table 4.16. The proportion of household expenditure by food groups, 2010, 2015, and 2020 (%)

Household Expenditure	2010	2015	2020
Food group:			
Cereals	8.9	7.7	5.4
Tubers	0.5	0.5	0.5
Fish products	4.3	3.7	3.8
Livestock products	5.3	5.4	5.0
Vegetables	3.8	3.1	3.7
Fruits	2.5	2.3	2.5
Pulses	1.5	1.2	1.0
Prepared food and beverages	12.8	12.7	16.9
Other food and beverages items	6.5	5.2	4.4
Cigarettes and tobacco	5.3	5.9	6.0
Total Food	51.4	47.5	49.2
Total non-food	48.6	52.6	50.8
Total expenditure	100.0	100.0	100.0
Total Expenditure (IDR000)	255	869	1,226

Sources: BPS, 2022

The increase in household consumption and expenditure for prepared food and beverages was due to the rapid urbanization. Small towns in rural regions are becoming more urbanized, including their economic activities and social facilities. Also, more women have entered the labor markets, so they have less time to prepare food at home for themselves and their families.

However, based on balanced nutrition, household consumption also changed, as shown in Table 4.17. From 2015 to 2020, in both rural and urban areas, rice consumption decreased, while consumption of imported wheat flour products rose significantly. Consumption of animal protein sources, such as meats, eggs, and fish, increased, while consumption of vegetables and fruits decreased. Based on expenditure patterns (Table 4.16) and consumption volumes (Table 4.17), the consumption of fruits and vegetables was changing toward more high-quality products with higher prices. From these figures, it can be concluded that households' food preferences were changing toward more balanced food (carbohydrates versus protein, vitamin, and mineral sources) and prepared food.

Table 4.17. Average per capita consumption of selected food, Indonesia, 2015 and 2020 (kg)

Food	National		Rural		Urban	
	2015	2020	2015	2020	2015	2020
Rice	96.9	94.0	101.0	97.9	92.8	91.0
Roots	11.0	12.5	15.8	15.5	8.6	10.1
Wheat flour	13.8	17.1	12.6	15.4	15.0	19.2
Beef	2.6	3.8.	1.3	3.0	3.9	4.5
Poultry meat	6.7	7.8	5.0	6.0	8.6	9.2
Eggs	7.1	7.3	5.9	6.3	8.2	8.0
Fish	20.8	21.3	20.9	21.6	20.8	21.1
Vegetables	60.0	52.3	58.9	54.6	61.0	50.5
Fruits	37.7	32.3	35.1	31.0	40.3	33.4

Source: Agency for Food Security, MoA, 2021

Average energy consumption per capita in 2015-2020 was above the standard of adequate energy consumption (2,100 kcal per day) recommended by the Ministry of Health (Minister of Health Regulation Number 20/2019). During this period, the average per capita energy consumption was 2,143 kcal per day. Energy consumption in rural areas was higher than in urban, but the quality of food consumed in urban areas was better. Measured by *Pola Pangan Harapan* or Desirable Dietary Patterns (DDP) score, the urban population score was 87.6, while the rural population score was 84.3. These figures indicated that the composition of food consumption of the urban population was better than that of the rural population. The average DDP score for Indonesian was 87.2 (Table 4.18).

Table 4.18. Average energy consumption per capita per day and the score of Desirable Dietary Pattern (DDP), Indonesia, 2015-2020

Year	Energy consumption (kcal/cap/day)			Desirable Dietary Pattern (score, max = 100)		
	National	Urban	Rural	National	Urban	Rural
2015	2,147	2,143	2,151	82.3	87.4	76.5
2016	2,128	2,092	2,169	86.3	88.0	83.7
2017	2,165	2,158	2,172	87.0	89.6	82.5
2018	2,138	2,137	2,138	87.9	89.2	83.7
2019	2,112	2,109	2,117	86.3	86.9	82.7
2020	2,143	2,137	2,156	87.2	87.6	84.3

Note: Energy sufficiency level is 2,100 kcal per capita per day
Source: Agency for Food Security (2021)

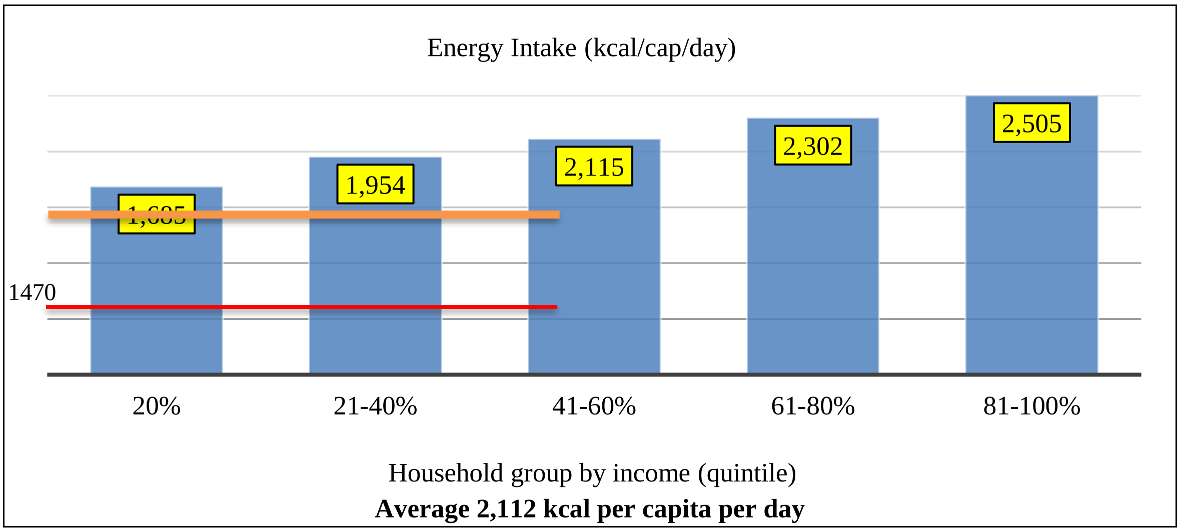
However, when household income is grouped by quintile, the first two lower quintiles consumed energy and protein less than the adequacy standard (Figure 4.2). This 40% population segment consumed less food and nutrition than a healthy, active, productive life standard. In addition, more than 10% population consumed energy less than 70% of the standard adequacy of 1,470 kcal per capita per day (NFA, 2021).

Unfortunately, most small-scale farmers belong to this segment of the population. As food producers, they could not fulfill their food needs due to limited access to productive endowments and employment opportunities. Improved technology generated by public R&D alone cannot solve this problem. This improved technology should be combined with: (1) Social engineering on farmer/farming institutions to increase the economy of scale; and (2) Government facilitation for access to financial sources, farm input, and food supply chains.

MoA has continuously implemented a program to increase domestic food production to fulfill the ever-increasing demand for more diversified food, especially for primary and essential food commodities. However, the country also imports some food commodities to fill the gap between domestic production and consumption needs. As shown in Table 4.19, food commodities with large importation volumes in 2010 and 2020 were wheat, maize, soybeans (including soybean cake), and white sugar.

Indonesia imported wheat and wheat flour to meet domestic needs. The wheat import volume increased from 4.8 million tons in 2010 to 10.3 million tons in 2020. As a result, the per capita import ratio increased from 20.2 kilograms to 35.2 kilograms. These figures indicate that the position of wheat-based food products has become more prominent in the Indonesian diet. Sugar imports also increased during the ten-year period. In 2020, the country imported 5.3 million tons of sugarcane or 19.5 kilograms per capita, a considerable rise compared to the per capita import ratio in 2010, at around 5.3 kilograms. The sugar importation increased because Indonesia experienced stagnant domestic production while its demand constantly increased yearly. Similarly, soybean imports increased due to the continuous drop in national soybean production. Meanwhile, the demand for tempeh and tofu (using soybean as raw material) as vegetable protein increased continuously.

Figure 4.2. Energy consumption per capita by household income, Indonesia, 2019



Source: Ariani *et al.*, 2021 from BPS, 2020

The country also imported maize and soybean cake as feed raw materials, mainly for poultry. The feed industry demands this importation for cattle and poultry. However, the volume of maize importation fluctuated, following the domestic production pattern. In contrast, soybean cake importation increased because domestic production dropped. In addition, Indonesia has always imported beef, fruits, and vegetables to meet growing demand.

Table 4.19. The volume of several food imports in Indonesia in 2010 and 2020

Food item	HS Code	Import volume (000 tons)		Import/capita (kg)	
		2010	2020	2010	2020
Rice	1006	688	356	2.89	1.32
Wheat	1101	4,811	10,300	20.24	35,22
Maize	1005	1,528	866	6.43	3.20
Soybean	1201	1,741	2,475	7.32	9.16
Soybean cake	2304	2,869	4,988	12.07	18.46
Sugarcane	170111 + 170114	1,191	5,263	5.01	19.48
Beef	0201 + 0202	91	167	0.38	0.62
Fruits	08	667	639	2.81	2.36
Vegetables	07	660	920	2.78	3.40
Oranges	080510	31	9	0.13	0.03
Apple	080810 + 081330	198	149	0.83	0.55
Shallot	070310	126	135	0.53	0.50
Potatoes	0701	27	40	0.11	0.15

Source: UN Comtrade, 2022; BPS, 2022a; and BPS, 2022b

4.2.2. Poverty and Food Insecurity

Quantity and quality of food consumption are closely related to purchasing power or income, which BPS estimates using the national poverty line. Determining this line means measuring people's ability to meet their basic needs. Falling below the line means an inability to meet basic food and non-food needs. The poverty line consists of two components: the food poverty line and the non-food poverty line. The former is the minimum spending on the equivalent of 2,100 kcal per capita per day of basic foods (totaling 52 items, such as grains, tubers, fish, meat, eggs and milk, vegetables, nuts, fruits, oils, and fats). The latter is the minimum spending for housing, clothing, education, and health. Packages of essential non-food commodities in urban and rural are represented by 51 and 47 commodity items (BPS, Berita Resmi Statistik, Number 7, 17 January 2022). BPS poverty line data are published twice per year, in March and September. For example, the poverty line in March 2021 was IDR427,525 (USD28) per month or USD1,05 per day (1USD = IDR14,664).

Measured by the national poverty line, the general poverty trend has been decreasing in the last eight years (2015-2022). However, the percentage of the poor increased due to the COVID-19 pandemic in 2020 and 2021. In 2022, the proportion of the poor was 9.54%, or about 25,8 million people. The proportion of the poor in rural areas was higher than that in urban areas, 12.29% and 7.50%, respectively (March data), as presented in Table 4.20.

Table 4.20. The proportion of the population under the poverty line, Indonesia, 2015-2020

Year	National (%)	Urban	Rural
2015	11.22	8.29	14.21
2016	10.86	7.79	14.11
2017	10.64	7.72	13.93
2018	9.82	7.70	13.20
2019	9.41	6.69	12.85
2020	9.78	7.38	12.82
2021	10.14	7.98	13.10
2022	9.54	7.50	12.29

Note: March figure
Source: BPS

The declining trend of poverty rate in the ten-year period was in line with the improvement of household food security, which can be measured by SDG Goal #2 indicators: (1) the prevalence of undernourishment (PoU); and (2) the prevalence of moderate or severe food insecurity in the population, based on the Food Insecurity Experience Scale (FIES). PoU is an estimate of the proportion of the population whose habitual food consumption is insufficient to provide the dietary energy levels required to maintain a normal, active, and healthy life[23]. The indicator is in percentages (%). For Indonesia, the sufficient requirement is measured by the daily energy consumption of 2,100 kcal per capita per day. Meanwhile, FIES measures the percentage of individuals in the population who have experienced food insecurity at moderate or severe levels during the reference period. The severity of food insecurity is measured on the FIES global reference scale, a standard established by FAO and used in more than 140 countries worldwide, starting in 2014[24].

Measured by the POU and FIES, food security in Indonesia has improved. As presented in Table 4.21, during 2017-2019 value of PoU decreased (improved). However, the COVID-19 pandemic disrupted the trend, so in 2020 and 2021, PoU rose again. On the other hand, the prevalence of FIES during 2017-2021 had been continuously declining, from 8.6% in 2017 to 5.42% in 2019, reaching 4.97% in 2021. This positive trend resulted from the government's responsive efforts to overcome the impact of the COVID-19 pandemic on the poor and those affected by layoffs. The government expands food assistance recipients for poor households and distributes cash transfers to workers who lost jobs due to a sharp decline in demand for goods and services.

[23] https://unstats.un.org/sdgs/metadata/02-01-01
[24] https://unstats.un.org/sdgs/metadata/02-01-02

Table 4.21. Prevalence of PoU and FIES, Indonesia, 2017-2021 (%)

Year	PoU	FIES
2017	8.26	8.66
2018	7.92	6.86
2019	7.63	5.42
2020	8.34	5.12
2021	8.49	4.97

Source: Bappenas, 2021, from BPS

Another critical issue in the effort to achieve food security and nutrition is the high prevalence of stunting of children below five years of age. For example, in 2013, the prevalence of stunting was 37.2% (Riskesdas from Ministry of Health), which dropped to 24.7% in 2020 (SSGI/Survey Status Gizi Indonesia, Ministry of Health and BPS). The government considers stunting a priority to be handled seriously and immediately because it determines the future of Indonesian human resources. Therefore, the President of Indonesia has set a target to reduce the stunting rate to 14% by 2024[25]. To achieve this target, the government issues Presidential Regulation Number 72/2021 about the Acceleration of Stunting Reduction.

4.2.3. Perspective of Future Food Consumption Patterns

As described above, the dynamic trends of household food consumption patterns are predicted to continue along with the growth in per capita income and households' awareness of food quality and safety. In addition, the government policy on developing the national food systems and food security and nutrition will affect the community and households' food consumption patterns. Elaboration of these two factors is as follows.

First, from the description presented in the previous section, the change in food consumption patterns over the ten-year period (2010-2020) has been towards more diverse food sources, processed food, balanced nutrition, and safe food. These trends will continue for the following reasons.

1. Rice is still the main carbohydrate source and staple food, and the decrease in per capita consumption is low. In addition, the demand for quality rice will increase (refined taste, aroma, and color). Consumption per capita of processed flour-based food products, such as noodles, cakes, or snacks, will continue to increase. The development of flour-based local food sources will be slower than expected. The proportion of local flour as raw material will increase but may not overtake the dominant role of wheat flour due to, among others, technical characteristics and price competitiveness.
2. Per capita consumption of protein sources from livestock and fish products will increase at a moderate rate, and horticultural products will increase slowly. These are concluded from the increasing trends during the ten-year period (2010-2020). Demand for imported horticultural products will continue to grow.
3. Demand for processed products (ready-to-eat) and dining trends will keep increasing rapidly. This increase is due to the continuing urbanization and the increasing proportion of women entering labor markets.

[25] https://setkab.go.id/inilah-efforts-the-government-achievement-target-prevalence-stunting-14-di-tahun-2024

4. The community awareness of food safety and quality will increase continuously, which influences the head of households in choosing food.

Second, changes in community food consumption behavior are influenced by income per capita, knowledge of food nutrition and health, the availability of variety foods, and the dynamics of food prices. The first three aspects are predicted to increase, aligned with the trend toward a more balanced nutritional composition. However, the dynamics of food prices will also affect the choice of food products purchased by household heads. These aspects influence households' spending patterns on food, namely toward more high-value commodities, including safety and health considerations.

Third, the government policy in developing the national food system determines the availability of various foods, the dynamics of food prices, and the community food consumption patterns. For example, in the RPJMN 2020-2024, GoI established economic development as a national priority, namely strengthening economic resilience for quality growth. One of the priority programs to achieve this is increasing availability, accessibility, and quality of food consumption.

GoI also established the National Food Agency (NFA) in July 2021, aiming to coordinate, formulate, and determine policy for food availability, food supply and price stabilization, food insecurity and nutrition, diversification of food consumption, and food safety. Related to food availability and price stabilization, NFA, along with related ministries, has succeeded in drafting a regulation about Management of Government Food Reserves (Presidential Decree No. 125/2022, issued 24 October 2022). NFA is also in the process of drafting a guideline for accelerating food diversification based on local resources and culture.

Local food sources in this food diversification program, include cassava, sweet potatoes, sago, bananas, and breadfruit, as substitutes for wheat flour. In addition, increasing the consumption of livestock and fish products as protein sources and horticultural products is promoted. The indicator for this effort is the Desirable Dietary Pattern (DDP) score. The target DDP score in 2024 and 2030 is 95.2 and close to 100 (ideal). However, the DDP score in 2020 was only 87,2, about seven points below the target.

4.2.4. Problems Faced by Food Consumers

On average, in 2020, food consumption per capita per year achieved or was above the standard adequacy requirement of 2,100 kcal per capita per day and 57 grams of protein (Ministry of Health Regulation Number 20/2019) and changed toward more balanced nutrition. However, problems emerged in the 40% lowest income class, who consumed less than the standard energy and protein requirement adequacy, and the lowest 10%, who consumed less than 70% of the standard adequacy.

One of the government's priorities in economic development is to strengthen economic resilience for quality growth, among others, through increasing the availability, accessibility, and quality of food consumption. The challenges and opportunities are as follows:

1. The low purchasing power of the lowest 40% of households does not allow them to buy enough food to meet the food consumption standard adequacy in terms of quantity and quality, as well as nutrition, to have a healthy, active, and productive life.

2. Adequate food supply, especially for carbohydrate staple food, is not a problem. The government declared the achievement of rice food self-sufficiency in the last three years (2019-2021). Furthermore, the government policy indicates that the shortage of particular food could be met by importation following the national interest. However, food price instability for certain commodities is still an issue due to seasonal harvesting time, logistical and distribution problems, and international food market dynamics.
3. Lower-income households display imbalanced food and nutrition consumption patterns. Due to the high prices, they consume more carbohydrate food sources (rice and wheat-based food products) and less protein, vitamins, and minerals (meat, vegetables, and fruits).
4. Demand for prepared food and eating out has been increasing steadily. However, food safety is an issue with this consumption habit, especially for a lower-income population who buys prepared food from small food stalls and street vendors.
5. The proportion of food loss and waste in Indonesia is relatively high. Results of a study on food loss and waste in Indonesia reported that over the twenty years (2009-2019), food loss and waste was 115–184 kcal per capita per day, 55% in the form of food loss along the supply chain up to retail, and 45% food waste from retail to consumers (Bappenas, 2021a). Reducing food loss and waste will increase food availability and have positive impacts on environment and sustainability.

The government has taken action to overcome these food problems and has given special attention to low-income households through the distribution of food assistance. As discussed above, through several ministries and institutions, the government has launched programs to increase domestic food production and maintain food availability and price stability. IAARD has done R&D to support these efforts by providing technologies and inventions to improve crop productivity, farming efficiency, and food product competitiveness. However, dissemination of improved technology and innovation and farmers' capacity to implement the latest technologies and innovations are still problems to be handled promptly. These issues are discussed in more detail in Chapter Five.

Chapter Summary

- For the last three cycles of the five-year development plans, the primary agriculture development issues remain the same: improving farmers' welfare, providing sufficient food for the entire population, supporting national economic growth, and reducing rural poverty. As a public institution, IAARD research policies and programs are directed to enhance agricultural technology to support the achievement of these objectives. Since agriculture actors are mainly small-scale farmers, most technology and innovation are designed for small-scale farming. Therefore, IAARD designed and created components or packages of agriculture technologies to increase the productivity, efficiency, and competitiveness of food products in small-scale farming systems. Technology and innovation are designed to improve crop varieties, farming system methods, cultivation practices, sub-optimal land use, livestock rearing, feed composition formula, and food value-adding from post-harvest technology.

- Dissemination of agriculture technology and innovation is one of IAARD's essential tasks as a public R&D institution. AIATs carry out this function in 34 provinces. For the last five years, budget allocation for all AIATs was one-third of IAARD's budget allocation. However, small-scale farmers do not always have the capacity to adopt agricultural technology. Therefore, the effectiveness of technology dissemination is as important as the creation of enhanced technology. Many factors determine the adoption rate, namely potential profitability, technical suitability to farmer preferences and local conditions, and farmers' capacity and capability to implement the introduced technology both technically and economically. In addition, government support plays a vital role, such as providing agriculture and rural infrastructures, extension systems, input subsidies, and output support prices.
- During the ten-year period (2010-2020), household food consumption changed toward more balanced nutrition. As a result, average energy and protein consumption were above the standard requirement for a healthy, active, and productive life. However, the lowest 40% of income households consumed food less than the energy adequacy standard. Most small-scale farmers belong to this segment of the population. In addition, the COVID-19 pandemic disrupted the improvement trend.
- Problems faced by small-scale farmers in adopting improved technology to increase crop productivity, farming efficiency, and product competitiveness are: (1) Limited ownership and control over productive resources; (2) Lack of ability and capacity to access and implement improved agricultural technologies and innovation; (3) Limited farmers' financial capacity to acquire and apply new, improved technology; (4) Limited accessibility to agricultural input and output markets; and (5) Inability to benefit from economies of scale principle.
- Problems and challenges for food consumers in acquiring balanced food and nutrition to have healthy, active, and productive lives are: (1) Low purchasing power, especially for the lowest 40% income household group; (2) Food availability and price instability for certain commodities; and (3) Lack of awareness of the importance of balanced, nutritious, and safe food consumption. Problems for food consumers can be solved, in part, through domestic food production increase. Technology and innovation from public research institutions can contribute significantly to this achievement.

CHAPTER FIVE

IDENTIFYING THE GAPS AND RECOMMENDATIONS FOR FUTURE R&D AGENDA REORIENTATION

CHAPTER FIVE

IDENTIFYING THE GAPS AND RECOMMENDATIONS FOR FUTURE R&D AGENDA REORIENTATION

This chapter outlines the gaps and key recommendations to strengthen research ecosystems in Indonesia. The country has experienced disruptive transformation and dynamic changes that reshaped the R&D management and strategy, including in the agriculture sector. Previous chapters have elaborated on the state of agriculture R&D before and after the transformation. This chapter demonstrates how reorienting future R&D becomes the way forward, organized in two sections: (1) Gap identification; and (2) Recommendation proposal covering the systemic shifts and their impacts on investments and policies. Before identifying the gaps, the drivers of change in agriculture R&D management and structural systems are summarized as follows.

1. **A massive institutional transformation**
   In 2019, agriculture R&D in Indonesia experienced a massive structural transformation. The leading institution of public agriculture R&D, the Indonesian Agency for Agricultural Research and Development of the Ministry of Agriculture (IAARD-MoA), was transformed into *Badan Riset dan Inovasi Nasional*(BRIN) or National Research and Innovation Agency. IAARD was established in 1974 under the coordination of the MoA. Forty-five years into its establishment, in 2019, the Indonesian government implemented the Law Number 11/2019 on the National Systems of Science and Technology, followed by Presidential Regulation Number 78/2021 on the establishment of the National Research and Innovation Agency (BRIN). The consequence was that: (1) All R&D activities under the coordination of the ministries were transferred to the new institution, including the agriculture R&D; (2) Researchers from IAARD were assigned to different research organizations: (a) Agriculture and food; (b) Biotechnology and life sciences; (c) Earth science and maritime; (d) Health; and (e) Governance, economy, and community welfare. Meanwhile, IAARD was transformed into a new institution under the name of the Agency for Agriculture Standardized Instruments (*Badan Standardisasi Instrumen Pertanian/* BSIP) as stipulated through The Presidential Regulation Number 117/2022, which has the task of coordinating, formulating, implementing, maintaining and harmonizing agricultural instrument standards. Agricultural instruments cover these following: materials, equipment, method, documents, infrastructures and facilities that are used in agriculture sector. For example, this includes seeds/seedlings, fertilizers, pesticides, land/soil, water, farmer's institutions and others, including standard operating procedures.

2. **Limited budget and spending on agriculture R&D**
   As discussed in Chapter Three, a large portion (81.6%) of the agriculture R&D budget originates from the national government. Other sources contribute marginally: private

sectors including manufacturing industries at 11.04%, university at 5.21%, and others at 2.15%. Over a decade (2010-2020), average annual R&D spending by IAARD was only 0.135% of agriculture GDP or 0.014% of the national GDP. This was equivalent to USD148.17 million per year. During this period, agriculture R&D spending decreased by 3.66% annually. Between 2015 and 2020, almost 90% of this spending was sourced from the national government budget and non-tax state revenue, while the remaining was sourced from overseas funding (grants and loans). Since 2019, the contribution of overseas funding was only 2% of the total R&D spending.

3. **Multi-Channel Dissemination Spectrum (SDMC)**
   IAARD not only conducts R&D but also delivers the output to farmers and evaluates stakeholders' feedback for improvement and future development. This process is managed using Multi-Channel Dissemination Spectrum (SDMC) in three stages: (1) **Generating systems**: research centers under IAARD develop technology and produce innovation for farmers as the end-users; (2) **Delivering systems**: technology and innovation are delivered by optimizing stakeholders (assessment institutes, MoA technical units, and extension agencies; and (3) **Receiving systems**: technology and innovation are received by farmer groups as the R&D receiving units by involving local governments, state-owned enterprises, national/ regional decision-makers, extension officers, entrepreneurs/private sectors/industries, and researchers.

4. **Role of technology and innovation**
   R&D policies and programs developed by IAARD aim to improve agricultural technology and support small-scale farmers. The design is suited to the needs of small-scale farming by implementing agricultural technology packages to increase productivity, efficiency, and competitiveness. These technology and innovation are biased toward improving crop varieties (breeding), particularly food crops.

5. **Dissemination of agriculture technology and innovation**
   This is an essential task IAARD carries out as a public R&D institution through its arms: AIATs across 34 provinces in Indonesia. In the last five years, budget allocation for all AIATs was one-third of the IAARD total budget. However, small-scale farmers do not always have the capacity to adopt agricultural technology introduced or promoted. Therefore, the effectiveness of technology dissemination is as important as the availability of new, improved technology. Given that IAARD is no longer exist within MoA, to speed up the dissemination processes of agriculture technology from BRIN and other sources such as universities to end users (farmers), a bridging institution within MoA should be established. BSIP, along with its task and functions, may be considered as the bridging institution. It is expected after the BSIP full operation, the former AIATs can be transformed into work units of BSIP at the provincial level and take over the function of former AIATs in technology dissemination.

6. **Food consumption transformation**
   Over a decade (2010-2020), household food consumption has shifted toward more balanced nutrition. Changes in consumption patterns are influenced by income per capita, knowledge of food nutrition and health, the availability of food variety, and the dynamics

of food prices. The government needs to develop a food policy that addresses the food systems transformation in line with food consumption behavior.

These drivers explain the current situation of agriculture R&D management and structure in Indonesia. Table 5.1 summarizes the gaps and recommendations to improve the R&D ecosystem, including the research priorities to reorient future agricultural R&D agendas in Indonesia. It is structured into three parts: (1) Identified gaps in the current R&D system; (2) Recommendations to create a more robust R&D ecosystem; and (3) Gaps faced by smallholder farmers in adopting innovation.

Table 5.1. Summary of gaps and recommendations for agriculture and food R&D in Indonesia

Gaps and Recommendations	Description
1. Identified gaps in the current R&D system	A. Inadequate research funding, with the main source coming from the government budget and small amounts from donor agencies and private sectors; B. Disproportionate budget allocation across commodities and thematic areas guided by central government policies; C. Barriers to the adoption of innovation by small-scale farmers; D. Gaps in food consumption patterns that hinder the achievement of food security and nutrition fulfillment; E. Unestablished R&D dissemination mechanism across working units in BRIN; and F. Tenuous connection and coordination between BRIN and line ministries as partners in formulating agriculture R&D strategies and delivering agricultural R&D results
2. Recommendations for strengthening the agriculture and food research ecosystem: *A. Inadequate research funding, with the main source coming from the government budget and small amounts from donor agencies and private sectors;*	(1) Increasing research funding gradually to at least 0.56% of agriculture GDP by 2030 with an annual growth of about 4.99%/year to strengthen the R&D ecosystem and promote evidence-based policy-making (2) Diversifying funding sources for R&D programs: (a) Formulating policies to implement levy systems for selected commercial agricultural commodities; (b) Developing multi-stakeholder partnerships, including with the private sector, to generate market-based innovation; and (c) Enhancing networking with international funding sources (donors, philanthropists, and international agricultural research centers).
B. Disproportionate budget allocation across commodities and thematic areas guided by central government policies;	(3) Increasing share of public agriculture R&D spending across commodities and thematic areas to achieve sustainable, nutritious, and climate-resilient food systems: (a) Increasing share of public agriculture R&D spending across commodities; and (b) Increasing share of public agriculture R&D spending across thematic areas.
C. *Barriers to the adoption of innovation by small-scale farmers*;	(4) Strengthening the delivery system of public R&D to farmers, including the mechanism of agricultural technology transfer from BRIN to users/small-scale farmers by: (a) Generating agricultural technology suitable for small-scale farmers' needs and preferences; (b) Strengthening the delivery system of public R&D to small-scale farmers based on specific locations; (c) Empowering farmers' agriculture technology adoption capacity, both technically and financially; and

Table 5.1. Continued…

Gaps and Recommendations	Description
	(d) Establishing a bridging institution within the MoA to facilitate and accelerate the dissemination of agricultural technology from BRIN and other sources such as universities to end users (farmers). The new established BSIP may be considered as the bridging institution.
D. Gaps in food consumption patterns that hinder the achievement of food security and nutrition fulfillment;	(5) Strengthening the impact of R&D results for farmers to achieve food security and nutrition fulfillment (a) Designing agriculture R&D programs to support the achievement of food security and nutrition, strengthen the food supply chain, and provide food and nutrition for all; and (b) Increasing consumers' awareness and capacity to access and consume nutritious food.
E. Unestablished R&D dissemination mechanism across working units in BRIN;	(6) Developing new agricultural R&D strategies, coordination, and communication platforms within BRIN.
F. Tenuous connection and coordination between BRIN and line ministries as partners in formulating agriculture R&D strategies and delivering agricultural R&D results.	(7) Strengthening the connection and coordination between BRIN and line ministries/agencies to formulate agriculture R&D strategies and delivering agricultural R&D results by: (a) Establishing a governance system and advisory board for the research organization to provide advice on research and management issues; (b) Finalizing the completion of research systems transformation from line ministries/agencies to BRIN; and (c) Developing the partnership strategies and communication platforms to deliver the agricultural technologies and innovations from BRIN to MoA technical units.
3. Recommendations for future research priority areas	(1) Prioritizing R&D on climate resilience, environment, and nutrition, as well as responding to the emerging challenges in food and agriculture; and (2) Prioritizing R&D on commodities that can accelerate agriculture transformation, focusing on high-value and commercial commodities.

5.1. Identifying Gaps for Strengthening the Research Ecosystem

The reorientation of future agricultural R&D agendas in Indonesia is faced with gaps that could hinder the growth in innovation, dissemination, and adoption of research results. It includes the following aspects:

1. **Inadequate research funding**

   Over the last decade, Indonesia's public R&D spending on food and agriculture declined from USD196.95 million in 2011 to USD89.30 million in 2021. On average, from 2010 to 2021, budget spending for food and agriculture R&D was about USD148.17 million. This amount was equivalent to 0.135% of agricultural GDP. Compared to other countries, R&D spending in Indonesia ranked sixth among ASEAN countries and lower than other Asian countries. The agricultural R&D in Indonesia is predominantly government-funded, with minimal contribution from overseas funding, private sectors. Interestingly, foreign funds' contribution (grants and loans) aligned with the budget trend between 2015 to 2020, declining from around 8% (USD12 million) in 2015 to less than 1% (USD0.7 million) in 2020. This shows that the budget spending for agricultural R&D is too small for a country with over 275.77 million populations. Nin-Pratt (2021) confirmed this condition by measuring the intensity ratio (IR) (agriculture R&D spending/agriculture GDP) in some countries using the 2018 data from Agricultural Science and Technology Indicators (ASTI). On average, the IR was at 3.2% in high-income countries such as North America, Western Europe, Japan, Australia, and New Zealand; 1.1% in Latin America and Caribbean (LAC) countries; 0.5% in Sub-Saharan African (SSA) countries and only 0.4% in Asia-Pacific (APAC) countries.

2. **Disproportionate budget allocation across commodities and thematic areas guided by central government policy**
   The four major priority areas of public agriculture R&D are: (1) Breeding technology; (2) Cultivation and sub-optimal land use technologies; (3) Post-harvest technology; and (4) Technologies to support food security and self-sufficiency. For food security and self-sufficiency, the R&D spending focused on: (1) Food crops (rice, maize, soybeans) and estate crops; (2) Livestock such as beef cattle; (3) Fisheries; and (4) Value-chain efficiency in all the above-mentioned research areas. The focus of agricultural R&D by the public sector from 2015 to 2020 had been directed more toward activities to increase productivity. IAARD was organized by commodity and thematic research centers. Over the six years (2015-2020), spending on commodity-based R&D was allocated for food crops research centers, i.e., the Indonesian Center for Food Crops Research and Development (ICFCRD) and Indonesian Center for Rice Research (ICRR), at about USD7.1 million per year and USD4.4 million per year on average, respectively. This was followed by estate crops (Indonesian Center for Estate Crops Research and Development/ICECRD), around USD9.7 million per year. Among food crops commodities, around 62.3% were allocated to rice. Rice is a staple food; thus, achieving self-sufficiency is necessary. Nevertheless, across commodities, budget spending for R&D was majority allocated to the breeding program (62.36%). Another hurdle researchers face is that the R&D budget allocationn was designed annually; ideally, the budget for R&D should be allocated for multi-years; for example, R&D spending for breeding should be allocated in long-term scenarios (multi-years).

   It is noteworthy that every government administration prioritizes rice self-sufficiency as its ultimate goal.

3. **Barriers to the adoption of innovation for small-scale farmers**
   IAARD has played a key role in providing research-based technology and disseminating the technology for small-scale farmers through Assessment Institutes for Agricultural Technology (AIATs). There was 34 AIATs across Indonesia located in the provincial capitals. The technology is tested, adapted, and utilized following a transformation process at the MoA working units. During the dissemination process, researchers and extension workers collaborate to achieve the best possible outcome of the technology/innovation usage. Over six years (2015-2020), the majority of R&D spending (on average around 39.23% per year or around USD51.59 million) was allocated for dissemination. Despite the maximum effort, small-scale farmers do not always adopt technology or innovation. The determinants of the adoption rate include: (1) Potential profitability generated by the technology; (2) Technical suitability of the technology with farmers' preferences and local conditions; and (3) The capability of

farmers to implement the introduced technology both technically and economically. On a side note, it is also important to manage and follow the administrative procedure for acknowledging intellectual property rights for every innovation produced by BRIN researchers.

4. **Gaps in food consumption patterns**

   The gaps in food consumption patterns are rooted in low income, which affects consumers' purchasing power. In 2020, food consumption per capita per day exceeded the standard adequacy requirement of 2100 kcal energy and 57 grams of protein. However, the population in the lowest 40% of the income class consumed less than the adequacy standard of energy and protein. Furthermore, the population in the lowest 10% of income class consumed less than 70% of the adequacy standard. Inadequate food and nutrition consumption patterns occurred in lower-income households. They consumed high carbohydrates and low protein, vitamins, and minerals sourced from meat, eggs, dairy products, fruits, and vegetables. The high costs were likely to become the reason.

5. **Unestablished R&D dissemination mechanism across working units in BRIN**

   The launch of Law Number 11/2019 prompted structural changes in the R&D ecosystems, including agriculture. Researchers from IAARD were transferred to five research organizations. BRIN management consists of deputies, executive secretary, and a supervisory board. There are seven deputies in BRIN: (1) Development Policy; (2) Research and Innovation Policy; (3) Science, Technology and Human Resources; (4) Research and Innovation Infrastructure, (5) Research and Innovation Facilitation; (6) Utilization for Research and Innovation; and (7) Regional Research and Innovation. The deputies are mandated to create an enabling environment for research and innovation activities. Despite the structure establishment, mechanisms and standard operating procedures have not been settled, especially the technology dissemination. In the past, IAARD maximized the role of AIATs as the institution tasked with technology/Innovation dissemination. However, under the new management, the dissemination process has not been clearly formulated. This is one factor that has limited the knowledge and innovation transfer from BRIN to farmers. Therefore, it is imperative to mitigate the impact of the massive structural changes by establishing and streamlining the dissemination mechanism. To date, the R&D mechanism is still an ongoing process, including agriculture R&D inside BRIN.

6. **Tenuous connection and coordination between BRIN and line ministries**

   The implementation of public R&D in agriculture involves integration and support from relevant institutions, including ministries/agencies and universities. IAARD applied end-to-end management, from agriculture research systems to farmers. The establishment of BRIN in 2019 has created massive changes, not only in R&D strategies but also management, budget, working environment, and human resources, including the dissemination process. The recent transformation is massive, disruptive, and volatile. In the past, end-to-end research management was consolidated under the Ministry of Agriculture. Under this transformation, research strategies need to be set up to connect technology/innovation developers and users.

5.2. Reorienting the Agriculture R&D Agenda to Serve Future Needs

5.2.1. Increasing research funding to strengthen the R&D ecosystem and promote evidence-based policy-making

Rationale

There is good evidence that the return on investment from public R&D tends to be higher than from other interventions such as input subsidies or output price support. Compared to other countries, the public agricultural R&D spending between 2010 and 2020 in Indonesia was relatively small, only 0.135% of agriculture GDP annually or around USD148.17 million per year, with a trend decreasing by about 3.66% annually. During the COVID-19 pandemic, the spending was even smaller, only about USD71.38 million in 2020 and USD89.30 million in 2021. Based on 2019 budget data as a base line, it is reasonable to increase the agriculture R&D spending at 0.56% by 2030. This number still lower than the average intensity of 1% around the globe and 2% in developed countries (OECD, 2018). To strengthen the role of R&D in development, it is necessary to allocate a sufficient budget across all strategic research themes. Under the new transformation of R&D management from IAARD to BRIN, the Head of BRIN has announced that the government budget for R&D (across disciplines) is only 20%, and the remaining 80% needs to be sourced from different sources. The R&D reduction has created pressure in the agriculture R&D sector.

Recommended Actions

The effectiveness and advantages of R&D spending for agricultural development need to be promoted because farmers require enhanced agriculture technology to improve their income and welfare. The R&D budget can be increased by government. It is also important to create an enabling ecosystem for researchers to design innovative technologies based on farmers' needs. Meanwhile, the researchers need to communicate and to promote the technologies to different stakeholders in order to get funding supports from government, the private sector or international research agencies/donors.

Possible time frame

Long-term (5-10 years).

Leading ministries/agencies and implementing partners

Table 5.2. Leading ministries/agencies and implementing partners in increasing research funding

Leading Ministries/Agencies	Implementing Partners
Executive Secretary, BRIN: ▪ Advocating the urgency to increase public agriculture R&D spending at 0.56% from agriculture GDP by 2030 to Bappenas, Ministry of Finance and the Parliaments ▪ Identifying the R&D budget requirement from RO that is actively involved in agriculture R&D ▪ Using the agriculture R&D Strategic Plan as a reference during the disbursement process	**Bappenas:** ▪ Incorporating agriculture R&D budget design and monitoring the effectiveness of its spending ▪ Monitoring the dissemination process and assisting BRIN in measuring the impact **Ministry of Finance** ▪ Supporting BRIN in preparing the budget design and providing recommendations if necessary **Parliaments** ▪ Supporting the urgency to increase public agriculture R&D spending

Potential Risks

The bureaucratic procedure and difficulties in setting priorities may slower the process.

5.2.2. Diversifying funding sources for R&D programs

Rationale

The agriculture R&D in Indonesia has limited access to funding sources. Almost 90% of R&D spending for agriculture is funded by the government and distributed to respective ministries/agencies (81.60%), local governments (2.15%), and universities (5.21%). Contributions from private sectors (including manufacturing industries) at about 11.04% respectively. Indonesia's R&D also has limited support from overseas funding, with spending from grants and loans decreasing significantly from 2015 to 2020.

Recommended actions

a. **Formulating policies to apply a levy system to selected commercial commodities**

The levy system has been a model of research fund sourcing in research centers in developed countries. Indonesia has started collecting commodity development budgets for oil palm from the export levy based on export value. The institution is called the Indonesian Palm Oil Plantation Fund Management Agency, managing and disbursing funds for programs that support the achievement of palm oil sustainability, including R&D. This concept could be expanded and adjusted to include other commercial commodities such as rubber, coffee, and cocoa so that the R&D can be strengthened.

Possible implementation time frame

Long-term (5-10 years).

Leading ministries/agencies and implementing partners

Table 5.3. Leading ministries/agencies and implementing partners in implementing the levy system

Leading Ministries/Agencies	Implementing Partners
Ministry of Finance: ▪ Coordinating the initiative on formulating the policy framework	**Ministry of State-Owned Enterprises:** ▪ Providing technical inputs ▪ Coordinating state-owned enterprises impacted by the policies **Ministry of Agriculture:** ▪ Providing technical inputs **BRIN (RO on Food and Agriculture and related rOs):** ▪ Developing research programs with commercial prospects ▪ Building a network and collaboration with the private sector agreeing to apply the levy to their businesses **Universities or research centers:** ▪ Providing substantive advice

Potential risks

Unsupportive response from the private sector that may be impacted by the new policy.

7. **Developing multi-stakeholder partnerships, including the private sector, to generate market-based innovation**

In the past, most agriculture researchers developed their research under public funding and targeted farmers as the end users of their innovation or technology. There was no competition to obtain a research fund. Few researchers have experience working with overseas or domestic partners or applying for competitive research to secure funding. Meanwhile, BRIN has pressured all researchers to build collaborative research culture with third parties (including universities and private sectors). The research funding is also competitive with a certain selection process. Therefore, researchers need to expand their network and balance between developing commercial-based research and open-access research targeting farmers as their main users. Many leading universities in Europe established a spin-off company as one of the dissemination models with a business orientation scheme. This model has been implemented and has demonstrated to: (1) accelerate the utilization of the innovation; and (2) generate profit to fund research expansion or generate new research ideas.

Possible implementation time frame

Long-term (5-10 years).

Leading ministries/agencies and implementing partners

Table 5.3. Leading ministries/agencies and implementing partners in developing multi-stakeholder partnership

Leading Ministries/Agencies	Implementing Partners
Deputy for Facilitation of Research and Innovation in BRIN: ▪ Developing modules and training to increase awareness, understanding, and capacity to develop commercial-based research;	**Private sectors (industries, associations, chamber of commerce):** ▪ Advocating members to participate in agriculture R&D of their interests; and ▪ Providing input on activities related to this initiative.
▪ Implementing training programs and monitoring outcomes; and ▪ Coordinating with related units within and outside of BRIN	**ROs at BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; and (4) Health:** ▪ Encouraging researchers to participate in the training; ▪ Creating incentive systems for researchers to attract external funding.

Potential risks

Lower interest among researchers in joining this initiative; requiring a new paradigm and higher awareness at the agriculture researchers' level to develop commercial research.

8. Expanding networks with international funding sources (donors, philanthropists, and international agricultural research centers)

International funding institutions have demonstrated their priorities to conduct agriculture research in Indonesia. BRIN needs to mobilize its research organizations (ROs) to establish and expand research networks and upskill its researchers so that they can devise appealing proposals to attract funding from international sources. It is also important to set up research priorities, impact multipliers, and dissemination mechanisms and center research around smallholder farmers to optimize their benefits from agriculture R&D.

Possible implementation time frame

Long-term (5-10 years).

Leading ministries/agencies and implementing partners

Table 5.4. Leading ministries/agencies and implementing partners in expanding networks with international funding sources

Leading Ministries/Agencies	Implementing Partners
Deputy for Facilitation of Research and Innovation in BRIN ▪ Developing modules and training to increase researchers' capacity to devise appealing proposals; ▪ Streamlining communication process (network establishment and project collaboration); ▪ Implementing training programs and monitoring outcomes; ▪ Coordinating with related units within and outside of BRIN	**ROs at BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; and (4) Health:** ▪ Determining research priorities, impacts, and benefits, hence, establishing a research advisory board; ▪ Streamlining communication process from idea pitching, proposal development, and project execution, evaluation, and monitoring, to dissemination and reporting; ▪ Encouraging researchers to participate in training ▪ Providing incentives for researchers who can attract external funding

Potential risks

Lower interest from researchers in joining this initiative; requiring courage and skill to develop a research network, communicate research ideas, and execute the project.

5.2.3. Increasing share of public agriculture R&D spending across commodities and thematic areas to achieve sustainable, equitable, and climate-resilient food systems

Rationale

The most urgent national food and agriculture R&D policies and programs aim to increase the production of staple foods, such as rice, maize, and soybeans. Thus, the budget allocation for public agriculture R&D is biased toward breeding technology and food crops. The only commodity with a more proportionate budget allocation across research themes is rice, such as for post-harvest and cultivation. There has also been a shift in agriculture production from low-value staple food commodities to high-value commodities (horticulture, estate crops, and livestock). Therefore, research budget allocations must consider these changes in production structure.

Recommended action

a. Increasing share of public agriculture R&D spending across commodities

Food security remains an important goal for the Indonesian government, especially since the new breeding technology cannot match population growth. Thus, the first government's priority is to fulfill basic needs. However, as the nation is becoming more developed, the quality of human resources needs to be improved. One way to do this is by diversifying consumption towards healthier diets and increasing protein intake. Therefore, agriculture production needs to shift toward high-value commodities (horticulture, estate crops and livestock). In addition to achieve resilient food systems, public agriculture R&D spending should be dedicated also to local food sources development. Research topics should match with the dynamic changes in the food and agriculture sectors, including trends in nutrition and consumption patterns globally, including prioritizing research programs toward high-value commodities.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.5. Leading ministries/agencies and implementing partners to increase share of public agriculture R&D spending across commodities

Leading Ministries/Agencies	Implementing Partners
Bureau of Planning and Finance, BRIN: ▪ Developing research programs based on agriculture research strategic plans; and	**Ministry of Finance:** ▪ Assisting in the budgeting process **Bappenas:** ▪ Assisting in the program planning
▪ Formulating a budget (output-based), including the additional budget for the dissemination process.	**ROs at BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; and (4) Health:** ▪ Establishing an advisory team in each RO to recommend and advise on research priorities that match with trends in the agricultural sectors on the global and national levels; ▪ Proposing a list of priority commodities and research themes and topics, and consult with the Bureau of Planning and Finance at BRIN; and ▪ Encouraging agriculture researchers to submit proposals that address global or national concerns.

Potential risks

Conflicting interests in research themes and budget availability.

b. Increasing share of public agriculture R&D spending across thematic areas

Agriculture R&D spending has to suit not only domestic needs but also global trends. The majority of the public R&D budget thus far has been allocated for food crops, aiming to improve productivity. As a result, the major thematic R&D area at that time was breeding. This is because Indonesia needs to strengthen food security and nutrition fulfillment. As the nation grows, there is a pressing need to align agriculture R&D strategies with global concerns such as climate resilience, sustainability, and improved nutrition intake. As such, it becomes imperative to match research topics with the dynamic changes in agriculture on a global level.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.6. Leading ministries/agencies and implementing partners to increase share of public agriculture R&D spending across thematic areas

Leading Ministries/Agencies	Implementing Partners
Bureau of Planning and Finance, BRIN: ▪ Advocating Bappenas, Ministry of Finance and Parliaments regarding the importance to shift from food crops-based to high-value commodities;	**Bappenas:** ▪ Assisting in the program planning **Ministry of Finance:** ▪ Assisting in the budgeting process
	Parliaments: ▪ Supporting the shift of public agriculture R&D spending from food crops-based to high-value commodities

Table 5.6. Continued…

Leading Ministries/Agencies	Implementing Partners
▪ Developing research programs based on agriculture research strategic plans; and ▪ Formulating a budget (output-based), including an additional budget for the dissemination process.	**ROs at BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; and (4) Health:** ▪ Establishing an advisory team in each RO to recommend and advise on research priorities that match with trends in the agricultural sectors on the global and national levels; ▪ Proposing a list of research themes and topics and consulting with the Bureau of Planning and Finance at BRIN; and ▪ Encouraging agriculture researchers to devise research proposals that address global or national concerns.

Potential risks

Conflicting interests in research themes and budget availability.

5.2.4. Strengthening the delivery system of public R&D, including the mechanism of agricultural technology transfer from BRIN to users/small-scale farmers

Rationale

IAARD managed the end-to-end R&D agricultural research systems from researchers to farmers, involving national research centers, regional/local assessment institutes, and extension workers. IAARD procured and delivered R&D to farmers and gauged feedback from related stakeholders to improve and develop future R&D. This was completed through AIATs in each province utilizing the Multi-Channel Dissemination Spectrum (MCDS) according to the characteristics of stakeholders. Maintaining and improving the dissemination process means building upon the existing delivery systems managed by the new national research system (BRIN) and working on the 'demand side' of agriculture technology or innovation.

Recommended action

a. Creating agricultural technology that suits the needs and preferences of small-scale farmers

In 2018, the number of Indonesian farmers reached 27.7 million. More than 60% completed or dropped out of primary school, and more than 35% were over 55 years old. The average land holding size was 0.18 hectares of lowland and 0.55 hectares of dryland. As such, 89.1% of Indonesian farmers are categorized small-scale. In general, the technologies that suit the needs and preferences of small-scale farmers aim to improve quality and conserve nature. Quality is needed to support the achievement of food security and nutrition. This includes high-quality seeds and breeds (higher productivity, product quality, and nutrition content), which are adaptive to climate change (tolerant to drought and inundation, and salinity and acidity) and sustainable (suitable to local agro-ecosystems such as various land types and locations). Meanwhile, nature conservation means that the components or packages of agriculture technologies aim to improve efficiency in natural resources use (land, water) and input use (mainly fertilizers and pesticides). Additionally, the technologies must also help farmers increase income and promote sustainable agriculture.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.7. Leading ministries/agencies and implementing partners to create agricultural technology that suits the needs and preferences of small-scale farmers

Leading Ministries/Agencies	Implementing Partners
BRIN: ▪ Designing national agriculture and food R&D strategic plans with the main objective of increasing small-scale farming efficiency and small-scale farmers' income	**National Food Agency (NFA):** ▪ Formulating national food and nutrition strategic plans based on local resources and culture **Ministry of Agriculture:** ▪ Leading the dissemination and adoption of agricultural and food technologies that suit farmers' preferences

Potential risks

Bureaucracy in utilizing research results from BRIN to MoA potentially hinders the process of down streaming research results to small-scale farmers. At the moment, the transformation from IAARD to BRIN is still an on-going process and to date the MoU between BRIN and MoA has not yet been developed to discuss the technology transfer mechanism.

b. Strengthening public R&D delivery systems to small-scale farmers based on specific locations

The delivery system implemented in the past, e.g., Multi-Channel Dissemination Spectrum, was applied based on specific locations. For delivery to be effective, bridging institutions are needed to downstream agriculture technology from its sources (BRIN or universities) to small-scale end users. This 'bridge' is where interactions and exchanges of ideas occur to understand the need and availability of technologies for small-scale farmers. It can also function as a platform that can shorten the distance between extension workers and technology producers or innovators. However, bridging alone will not suffice. The capacity of the extension workers should also be increased continuously through training. The IAARD research and extension linkages (REL) become a model adopted by the MoA. In the past AIATs were the main institution who communicate the research results to small-scale farmers, initiated technology transfers activities (dissemination) and measured the adoption level. By the most recent research transformation, the role of AIATs was no longer exist. Under the new national research and innovation institutional system, it is still important to set-up the platform or bridging institution to accelerate the dissemination of contextualized technology for small-scale farmers. In this case, the BSIP at central government may be considered as the bridging institution and coordinates the process and there is a need to function the subsidiaries of BSIP at provincial level (former AIATs) as bridging unit for technology and innovation dissemination.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.8. Leading ministries/agencies and implementing partners to strengthen the public R&D delivery system

Leading Ministries/Agencies	Implementing Partners
BRIN: ▪ Deputy for Utilization of Research and relevant ROs together with MoA create a bridging system of transfer and dissemination of agriculture technologies for end user/small-scale farmers. The ROs involved in this activity are Food and Agriculture, Earth Science and Maritime; Life Science and Environment; and Health. ▪ Ensuring that the research results suit the farmer's needs	**Ministry of Agriculture:** ▪ Setting up a bridging institution to provide better accessibility of the need and availability of agriculture technology for small-scale farmers. The new institution BSIP may be considered as a bridging institution within MoA for facilitating the dissemination of agricultural technology.
	Ministry of Agriculture: ▪ Setting up a bridging institution to provide better accessibility of the need and availability of agriculture technology for small-scale farmers. The new institution BSIP may be considered as a bridging institution within MoA for facilitating the dissemination of agricultural technology. ▪ Setting up a system on agriculture technology dissemination and extension, together with BRIN and universities and MoA, including test plots adapted to the local ecosystem; and ▪ Providing facilities for agriculture extension workers to assist farmers in assessing, designing technology for a specific ecosystem, and implementing the introduced technology. ▪ Coordinating and communicating with relevant stakeholders to enhance the effectiveness of extension workers' and researchers' linkage.
	Local government (provinces and districts/cities): ▪ Actively coordinating with regional BRIN and local universities to monitor and evaluate research results disseminated to farmers; ▪ Taking the lead in promoting linkages between extension workers and researchers; and ▪ Supporting with the necessary budget and facilities.

Potential risks

- Hindering bureaucratic procedures; difficulty in obtaining valid data on the extension workers' resource capacity; and the limited budget to support the dissemination process; and
- Conflicting interests that may slow down the process and hinder the implementation of the recommendations.

c. Enhancing farmers' technical and financial capacity to adopt agriculture technology

In the current system, farmers adopt technologies disseminated by the government through extension specialists, usually implemented as part of a major program, such as food self-sufficiency. In the future, along with this current scheme, farmers should be facilitated so that they can actively search for and provide information related to technological needs. Therefore, it is necessary to improve farmers' capacity in this area. Of particular importance is farmers' capacity to use digital technology. In terms of finance, farmers need to empower themselves in technology adaptation. Their purchasing power is determined by their net farm income increase and the affordability of the technology adaptation process. The government needs to be actively involved in facilitating this.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.9. Leading ministries/agencies and implementing partners to strengthen farmers' technical and financial capacity in technology adoption

Leading Ministries/Agencies	Implementing Partners
Ministry of Agriculture: ▪ Increasing farmers' capacity to access agriculture technology information using digital technology through training and extensions ▪ Providing digital infrastructure in rural areas to increase farmers' access to technology information sources ▪ Promoting farming efficiency and lowering the cost of technology adaptation ▪ Designing a content provider system offering easily accessible technology information	**Local government (provinces, districts/cities):** ▪ Taking the lead in improving the farmers' capacity for technology transfer **Universities:** ▪ Facilitating training to improve farmers' capacity **Private sectors:** ▪ Facilitating farmers in increasing technology transfer capacity

Potential risks

Slow adoption and transfer of technology as they depend on farmers' experiences.

d. Establishing a bridging institution within the MoA to facilitate and accelerate the dissemination of agricultural technology

Currently, the Indonesian MoA establishes BSIP. This institution has a mandate in terms of coordinating, formulating, implementing, and maintaining, and harmonizing agricultural instrument standards. Agricultural instruments cover these following: materials, equipment, method, documents, infrastructures and facilities are used in agriculture sector. For examples, seeds/seedlings, fertilizers, pesticides, land/soil, water, farmer's institutions and others, including standard operating procedures. Therefore, the presence of BSIP is expected to play a role as the bridging institution to facilitate and accelerate the dissemination of agricultural technology from BRIN and other sources such as private sectors and universities to end users (farmers).

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.10. Leading ministries/agencies and implementing partners to strengthen farmers' technical and financial capacity in technology adoption

Leading Ministries/Agencies	Implementing Partners
Ministry of Agriculture (BSIP and IAAEHRD): ▪ BSIP carries-out collaboration with BRIN regarding the conceptualized agricultural instrument standards including the dissemination processes ▪ BSIP follows-up the implementation of agricultural instrument standards including	**BRIN:** ▪ Supporting the implementation of agricultural agreement standards in line with disseminating platform ▪ Accelerating technology transfer to farmers through Ministry of Agriculture

Table 5.9. Continued…

Leading Ministries/Agencies	Implementing Partners
dissemination methods with BRIN to other relevant institutions such as private sectors and universities to end users (farmers) ▪ IAAEHRD increases farmers' capacity to adopt agriculture technology and innovation through training and extension.	**Private Sectors:** ▪ Increasing farmers income by opening -up business opportunity through partnership with private sectors. **Universities:** ▪ Facilitating training on agricultural instrument standards based-dissemination

* IAAEHRD: Indonesian Agency for Agricultural Extension and Human Resources Development, MoA

Potential risks

Slow adoption since BSIP is a new established institution.

5.2.5. Strengthening food security and nutrition fulfillment by optimizing the impacts of R&D results for consumers

Rationale

The trends of food consumption patterns in Indonesia show that people eat more diverse, balanced, and safe foods. These trends may lead to: (1) A decrease in per capita consumption of rice and an increase in the demand for high-quality rice; (2) A steady increase in per capita consumption of flour-based (mostly wheat) processed food; (3) A slight increase in per capita consumption of protein from livestock and fishery products, as well as horticultural product albeit at a slower rate; (4) A significant increase in demand for processed ready-to-eat products and dining out; and (5) An increase in awareness among communities toward consumption of food with better quality and safety. With this perspective, R&D support is needed to keep up with the changing food consumption patterns, focusing on diversification based on local sources and more balanced and nutritious food.

Recommended action

a. Designing agriculture R&D to support the achievement of food security and nutrition fulfillment

Research budgets need to be reoriented toward the creation of technologies and innovations that not only aim to increase main staple food production but also diversify food sources based on local resources. In addition, budget planning also needs to prioritize high-value commodities. Plant variety nutrient enhancement (bio-fortification) should also be accelerated at a large scale, such as the Inpari IR Nutri Zinc and Inpago 13 Fortiz for rice and Biosoy 1 for soybeans. This bio-fortification is important in providing nutritious food for all, especially for lower-income households with low purchasing power, so they can afford more diversified and quality food.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.11. Leading ministries/agencies and implementing partners to design agriculture R&D to support the achievement of food security and nutrition fulfillment

Leading Ministries/Agencies	Implementing Partners
National Food Agency: ▪ Formulating policies that support the achievement of national food security and nutrition fulfillment based on local resources and culture **Ministry of Agriculture:** ▪ Formulating policies on locality-based food production and diversification to provide nutrients (carbohydrates, protein, vitamins, and minerals) and support the national food security plan **BRIN:** ▪ Design and implement food R&D to support the achievement of food security and nutrition based on local resources and culture	**ROs in BRIN:** ▪ Research on: (1) Identification and enhancement of food and nutrition of local food sources potential; (2) Bio-fortification of food pants and fortification of food materials produced and consumed by a significant part of the population or local community; (3) Food post-harvest and processing techniques to support food diversification based on local sources and balanced nutrition; and (4) Consumer preference on food consumption and nutrition intake

Potential risks

Insufficient budget support leading to failure in providing suitable highly-nutritious varieties across agroecosystems.

b. Increasing consumers' awareness and capacity to purchase nutritious food

Consumer preferences have shifted to high-quality commodities. Campaigns could be intensified to raise awareness through infographics in print and electronic media, as well as through extensions in communities, especially in rural areas. Rural consumers have limited knowledge and access to information compared to urban consumers, so they should be the first target. Rural consumers in the lowest 40% income class need to be assisted through programs to access safe and nutritious food. Consumers in this income class do not have the capacity to access safe and nutritious food. Finally, R&D in this area needs to be promoted to make balanced and nutritious food more accessible.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.12. Leading ministries/agencies and implementing partners to increase consumers' capacity to access nutritious foods

Leading Ministries/Agencies	Implementing Partners
Deputy for Food Insecurity and Nutrition, NFA: ▪ Planning an orchestrated campaign and community extension along with MoA, Ministry of Health, regional offices for food and agriculture, and NGO/CSO to increase the awareness of communities/ households, on the need to have balance and nutritious food consumption patterns.	**Directorate General of Agro-Industry:** ▪ Empowering and assisting SMEs in food processing to use nutritious raw materials **Directorate General for Handling the Poor, Ministry of Social Affairs:** ▪ Formulating and implementing safe and nutritious non-cash food assistance programs (BPNT) **Local governments:** ▪ Creating employment opportunities and economic activities to increase households' purchasing power.

Potential risks

Inadequate rural infrastructure potentially hindering the campaign for safe and nutritious food; inaccurate data on food assistance programs' beneficiaries that may reduce the success.

5.2.6. Developing new agriculture R&D strategies and streamlining coordination and communication within BRIN

Rationale

Indonesia is reforming its research management system towards a more integrated research and innovation system through BRIN. The aim is to address weak connections and coordination between research institutions across technical ministries, including agriculture. The transformation is necessary to avoid budget inefficiencies and overlapping R&D activities, resulting in four significant changes. ***First,*** the structure and institutional arrangement are disrupted on an unprecedented scale, so fine-tuning strategies and programs will take time. ***Second,*** the R&D management is shifting from creating enabling environment for research and innovation to orienting to results and promoting collaborative research schemes. ***Third,*** the agriculture research human capital is split into BRIN and BSIP. ***Fourth,*** the working climate is shifting from regular working hours in the office to co-working space, online basis, and digital environment.

Recommended action

Strengthening agricultural R&D strategies post-transformation of all research units to BRIN

The establishment of BRIN was regulated under Law Number 11/2019 of the National System of Science and Technology (NSST Law). This law regulates the national science and technology system as the basis for formulating development policies to strengthen the carrying capacity of science and technology in achieving the state's goals and increasing the nation's competitiveness and independence. The transformation massively occurred from 2021 to 2022. As a result of this transformation, 1,100 out of 1,600 researchers (73%) in IAARD were transferred to research organizations (ROs) in BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; (4) Health; and (5) Governance, Economic, and Community Welfare. Farmers remain the main target of agricultural technologies and innovations. Considering the low purchasing power among smallholder farmers, including in accessing technologies and research output. Under the new law, a clear strategy is required to establish the road map for generating research topics, dissemination, and publication.

Possible implementation time frame

Medium-term (3-5 years).

Leading ministries/agencies and implementing partners

Table 5.13. Leading ministries/agencies and implementing partners to strengthen new agricultural R&D strategies

Leading Ministries/Agencies	Implementing Partners
Deputy for Facilitation Research and Innovation, BRIN: ▪ Taking a leading role in designing agriculture research strategies at BRIN across related research organizations	**Ministry of Finance:** ▪ Advising on the budgeting issues **Bappenas:** ▪ Bridging the R&D policy and development programs **Bureau of Planning and Finance, BRIN:** ▪ Providing support systems in designing a strategic plan for agriculture R&D with a detailed time frame and milestones

Potential risks

Government bureaucracy that may slow down the process and hinder the implementation of the recommendation.

5.2.7. Finalizing the connection and coordination between BRIN and line ministries/agencies in formulating agriculture R&D strategies and R&D output utilization

Rationale

Public agriculture R&D in Indonesia has undergone transformative changes and improvements through organizational restructuring and transformation since its establishment in 1974. All changes did not impact the positioning of IAARD, as the institution remained under the Ministry of Agriculture. In 2019, before the establishment of BRIN, IAARD managed 12 research centers, 15 research institutes, 33 Assessment Institutes for Agricultural Technology (AIATs) at the provincial level, and under the coordinator of the Center for Agricultural Technology Assessment and Development and three Assessment Centers for Agricultural Technology. As prominent agriculture and food R&D institution, IAARD holds a first-echelon structural position in MoA. IAARD supports programs of the other first echelons to achieve the vision and mission of the MoA, especially in providing technological packages and policy recommendations. IAARD also assists in the planning, implementing, and monitoring of various MoA policies and programs, especially the strategic ones. The establishment of BRIN has transferred more than 1000 researchers from IAARD to BRIN, assigned across its research organizations. The assignment was based on their preference and research background. The disruptive transformation poses challenges, especially related to the role of IAARD in supporting programs at different ministerial working units.

Recommended actions

a. Strengthening the governance system by establishing an advisory board for the research organizations to deal with strategic research and management issues

Research priority in public agricultural R&D is usually a top-down approach based on the authorities' interests. Inputs from line ministries and related stakeholders are not incorporated systematically. Establishing an advisory board can tackle this issue with representations from related ministries, farmer organizations, the private sector, and academia. This structure is common in developed countries' international research centers and research agencies. Therefore, an advisory board should be established in every research organization.

Possible implementation time frame

Short-term (1-3 years).

Leading ministries/agencies and implementing partners

Table 5.14. Leading ministries/agencies and implementing partners in the establishment of an advisory board at the RO level

Leading Ministries/Agencies	Implementing Partners
Deputy for Facilitation Research and Innovation, BRIN: - Taking a leading role in designing agriculture research strategies at BRIN across related research organizations - Formulating the advisory board concept: functions, membership, business process, etc.	**Executive Secretariat in BRIN:** ▪ Providing backstopping on administrative and legal aspects in the establishment of the advisory board **ROs at BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; and (4) Health:** ▪ Identifying potential and interested candidates from relevant stakeholders

Potential risk

The bureaucratic procedure that may slow down the establishment of the board.

b. Finalizing the research system transformation from line ministries/agencies to BRIN

Under the new regulation, where agricultural research is centralized at BRIN, streamlined communications and mechanisms are needed to ensure that all partners and users of new technology are updated. BRIN has established a Communication Forum for Research and Innovation, with the main function of identifying needs for research and policy in all line ministries. This forum's business process should be strengthened to serve the need of line ministries and BRIN more effectively. Streamlining communications is a dynamic process, which needs continuous adjustment until finding a pattern that works best for each party. Hence, the completion of the R&D transformation system highly depends on the collaborative role and commitment of BRIN and other line ministries/agencies.

Possible implementation time frame

Short-term (1-3 years).

Leading ministries/agencies and implementing partners

Table 5.15. Potential leading agencies and implementing partners to finalize research systems transformation and streamlining communications with line ministries

Leading Ministries/Agencies	Partner Ministries/Agencies
Deputy for Development Policy, Deputy for Utilization of Research and Innovation, and Deputy for Facilitation of Research and Innovation, BRIN: • Communicating, coordinating, and facilitating processes between BRIN and line ministries; and • Creating a digital platform to facilitate communications	**ROs at BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; and (4) Health:** ▪ Strengthening the communication forum to stay connected to line ministries; ▪ Improving communication platforms or media that can facilitate communications; and ▪ Strengthening the network between researchers and their partners. **Line ministries:** • Participating as a member of the forum by providing input on technology and policy analysis needs; and • Establishing follow-up and deliverable mechanisms at the internal ministry or partner institution

Potential risks

Unestablished procedures and knowledge gaps, as well as bureaucratic processes that may hinder the recommendation implementation.

c. Developing partnership strategies and communication platforms to transmit agricultural technologies and innovations from BRIN to technical units at the MoA

Under the new R&D structure, BRIN and MoA have to build communication platforms upon the existing mechanism under IAARD that ran from 1974 to 2022 (almost 48 years). The tasks are, among others, reducing budget inefficiencies, scopes, qualities, and utilizations and strengthening research impacts for farmers or technical units. One critical success factor is establishing a bridging unit that facilitates communications across parties.

Possible implementation time frame

Short-term (1-3 years).

Leading ministries/agencies and implementing partners

Table 5.16.Leading ministries/agencies and implementing partners to develop partnership strategies and communication platforms to transmit the agricultural technologies and innovations from BRIN to technical units at the MoA

Leading Ministries/Agencies	Implementing Partners
ROs at BRIN: (1) Food and Agriculture; (2) Earth Science and Maritime; (3) Life Science and Environment; and (4) Health: ▪ Appointing a communication task force as the leading group to bridge the communication between agricultural researchers and their partners at the MoA; ▪ Establishing a communication platform or media that can facilitate the communication process; and ▪ Strengthening the network between researchers and their working units to share new technology or innovation that needs support from the MoA.	**MoA (BSIP):** ▪ Together with BRIN, establishing a communication task force to bridge the sharing of information, policies, and demand for new technology or innovation, as well as technology transfer

Potential risks

Bureaucracy procedures that may hinder the implementation.

5.3. Recommendations for Future Research Priority Areas

Based on the gaps and recommendations to strengthen the R&D ecosystem and contribute to respective experts and stakeholders, the research team proposes the following recommendations for future research priority areas in Indonesia.

Recommendation 1. Prioritizing R&D to address emerging challenges related to climate resilient, environmental sustainability and nutrition

The data analyses and the highlights from the in-depth interviews show that climate-resilient, environmentally sensitive, and nutrition-focused research has not been a priority across all commodities. This means that research focusing on climate resilience, sustainability, and nutrition enrichment should be supported through fund allocation. Research should be directed to create adaptable climate-smart innovations, improve nutrition, and identify climate-sensitive agricultural practices that will mitigate the impact of climate change on agricultural productivity in the various parts of Indonesia. This recommendation is in line with the current priority of BRIN to strengthen research on the green economy, blue economy, and digital technology. The BRIN's research priority also emphasizes the circular economy approach to optimize natural resource use and reduce waste.

Recommendation 2. Prioritizing R&D on commodities that can accelerate agriculture transformation, with a focus on high-value and commercial commodities

The structure of agricultural production is shifting from low-value commodities (food crops) to high-value commodities (horticulture, estate crops, and livestock). At the same time, rural employment is also changing from on-farm to off-farm and non-farm sectors. As the economy develops, household consumptions also move toward better and more balanced diets characterized by higher consumption of protein, vitamin, and mineral sources. Dynamic production and consumption changes required appropriate research and innovation support. The decision on what specific commodities to be prioritized should be based on appropriate foresight analysis providing information on the economic prospects. Thematic research areas related to the selected commodities should follow the priorities proposed in Recommendation 1.

CHAPTER SIX

CONCLUSION

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Considering the strategic role of agriculture in the Indonesian economy, the government budget allocated to finance agriculture R&D is minor compared to that in other Asian Countries. Governed by the Food Law of 2018 and the MoA Strategic Plan of 2015-2020, the focus of R&D in agriculture by the public sector was directed to activities related to increasing productivity and supporting food security. However, in practice, farmers have not optimally adopted the technology. There are still some gaps that hinder the performance of agriculture R&D in responding to the emerging needs of small-scale farmers and consumers.

Major gaps in agriculture R&D include: (1) Inadequate research funding; (2) Disproportionate budget allocation across commodities and thematic areas in responding to emerging challenges; (3) Barriers to the adoption of innovation by small-scale farmers; (4) gaps in food consumption patterns that hinder the achievement of food security and nutrition fulfillment; (5) Unestablished R&D dissemination mechanism across working units in BRIN; and (6) Tenuous connection and coordination between BRIN and line ministries as partners in formulating agriculture R&D strategies and delivering agricultural R&D results.

To address these gaps, the research team proposed seven major recommendations to strengthen the research ecosystem. ***First***, the Government of Indonesia needs to increase research funding to at least 0.56% of agriculture GDP in 2030 in order to strengthen agriculture R&D and promote evidence-based policy. Creating enabling ecosystems for researchers is imperative in order to advance agriculture technology and provide information for users (farmers and private sectors/industries). ***Second***, given that the dominant budget source is from the government, there is an urgency to diversify research funding sources from the private sector, philanthropists, and donor agencies. Recommended actions to promote this include: (1) Implementing the levy systems; (2) Developing multi-stakeholder partnerships involving the private sector to generate market-based innovation research; and (3) Enhancing networking with international funding sources. ***Third***, based on the current R&D budget structure, we propose to incerase budget share for public agriculture across thematic areas and commodities. ***Fourth***, the delivery system of public R&D to the farmers needs to be improved, including the mechanism of agricultural technology transfer from BRIN to small-scale farmers. ***Fifth***, it is of strategic importance to strengthen the delivery system of agricultural technology and innovation from its sources (such as BRIN, universities), channeling through ministries/agencies to end users, particularly farmers. ***Sixth***, to improve the research ecosystem, new strategies, coordination, and communication platform inside BRIN have to be developed fully. ***Seventh***, at the current phase of R&D system transformation, finalizing connection and coordination between the BRIN and line ministries/agencies is key to formulating agriculture R&D strategies and utilizing agricultural R&D results. Recommended actions include: (1) Strengthening the governance system by establishing an advisory board of the research organization; (2) Finalizing the research systems transformation from line ministries/agencies to BRIN; and (3) Developing a partnership strategy and communication platform to transmit technology and innovation from BRIN to technical units at MoA.

In response to the emerging issues on environment sustainability, climate resilient, nutrition, and agricultural transformation, it is advisable to prioritize future research agendas in the two areas. The first is thematic research on climate resilience, environment, and nutrition. This recommendation is in line with BRIN’s current priorities to strengthen research on the green economy, blue economy, and digital technology by utilizing the circular economy approach. The second is commodity research areas to support agricultural transformation on commodities, shifting from food crops to high-value commodities. The selection of prioritized commodities should be based on the foresight analysis providing sound information on the economic prospects of the corresponding commodities.

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APENDICES

Appendix 1. List of stakeholders of the study

No.	Name	Position	Institution	Address	Data and Information
1.	Laila Kadar, S.E., M.Si.	Coordinator of Program and Evaluation	Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture (IAARD)	Jakarta	Data and information of IAARD's research budget and topic
2.	Aulia, S.TP., MM.	Coordinator of Cooperation and Utilization of Research Results	Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture (IAARD)	Jakarta	Foreign cooperation, R&D perspectives, opportunities and constraints
3.	Nuning Nugrahaeni, S.Pt., M.Si.	Sub-Coordinator of Cooperation Research	Indonesian Agency for Agricultural Research and Development, Ministry of Agriculture (IAARD)	Jakarta	Research collaboration management at IAARD
4.	Ir. Anang Noegroho Setyo Moeljono, MEM	Director for Food and Agriculture	Ministry of National Development Planning/ National Development Planning Agency (Bappenas)	Jakarta	National policy and research and technology support on development of food and agricultural systems
5.	Mr. Midzon Johannis	Head of Business Sustainability	Syngenta Indonesia	Jakarta	Corporate research programs to improve product competitiveness to support food and nutrition development
6.	Mr Wakrimin	Senior Product Manager	PT EWINDO	Purwakarta, West Java	Research program in increasing product competitiveness, supporting development of food and nutrition
7.	Prof. Dr. Sjamsul Bahri	Animal Husbandary Expert	Indonesian Center for Animal Research and Development (ICARD)	Bogor, West Java	Utilization of R&D results related to Livestock
8.	Prof. Dr. Mat Syukur	Agricultural Finance Expert	Indonesian Center for Agricultural Socioeconomics and Policy Studies (ICASEPS)	Bogor, West Java	Adoption of R&D results by the industrial sector
9.	Dr. Setyo Adhie	Agricultural Planning Expert	Planning Bureau MoA	Jakarta	Increase in environmentally friendly agricultural production from the results of R&D for future planning

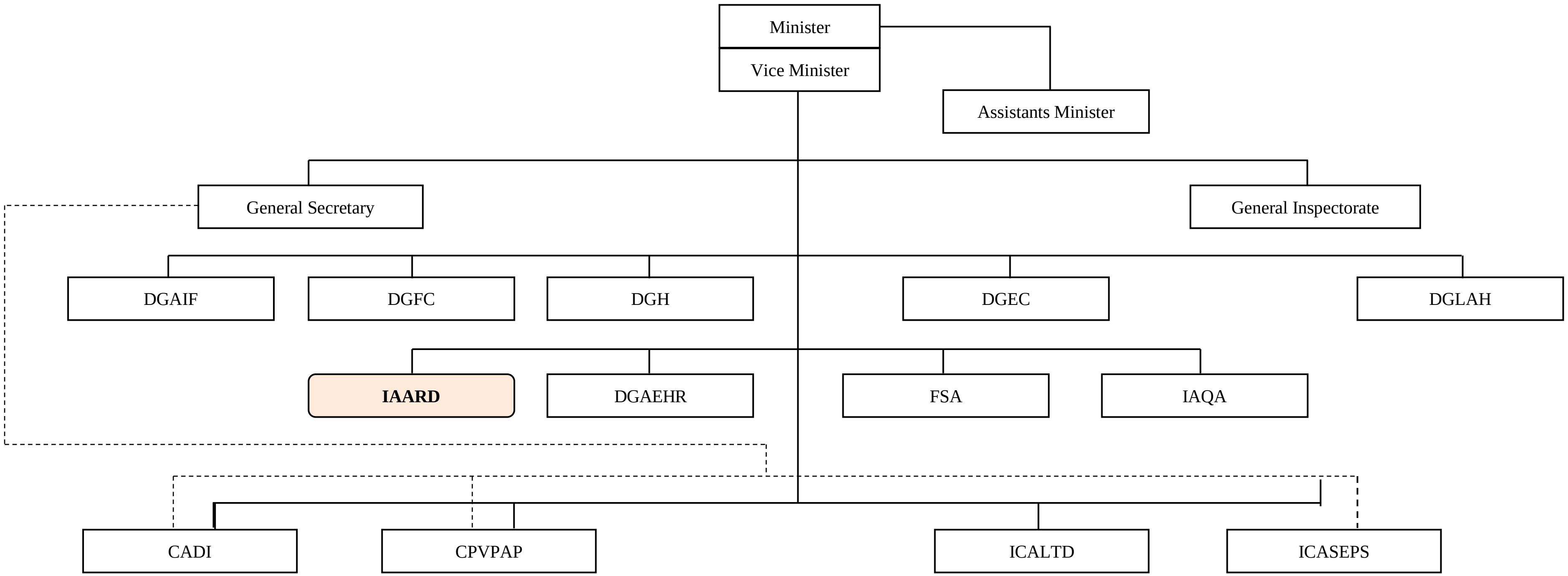
Appendix 1. Continued…

No.	Name	Position	Institution	Address	Data and Information
10.	Dr. Ernan Rustiadi	Head of Research and Community Service Institute	IPB Univeisity	Bogor, West Java	R&D budget data and information
11.	Prof. Dr. Atien Priyanti	Animal Husbandary Economist	Indonesian Center for Animal Research and Development (ICARD)	Bogor, West Java	An overview of research activities and related policies at ICARD
12.	Dr. Ir. Priatna Sasmita, M.Si.	Head of Indonesian Center for Food Crops Research and Development	Indonesian Center for Food Crops Research and Development (ICFORD)	Bogor, West Java	An overview of research activities and related policies at ICFORD
13.	Nanin Noorhajati	Head of Research and Development Syngenta Indonesia	Syngenta Indonesia	Via zoom meeting	An overview of research activities, research collaborations, and government policies that influence research topics conducted by Syngenta Indonesia
14.	Dr. Agung Wahyu Susilo	Head of Indonesian Coffee and Cocoa Research Institute	Indonesian Coffee and Cocoa Research Institute	Via zoom meeting	The dynamics of the development of research and dissemination activities at the ICCRI
15.	Agustin Sri Mulyatni, SP., MP.	Head of Sub Division Planning, Monitoring, Evaluation, and Functional Research Support	Research Institute for Estate Crops	Bogor, West Java	Data and information of Research Institute for Estate Crops' research budget and topic
16.	Prof. Muhammad Firdaus, SP, M.Si	Lecture of IPB University	IPB University	Bogor, West Java	Reorientation of Research and Development Program at IPB University in the future related to stunting, climate change, and food security, both at the consumer and farmer level.
17.	Dr. Bambang Susilo	Vice Chancellor for Research and Innovation	Brawijaya University	Malang, East Java	R&D spending data and information based on title and impact
18.	Prof. Dr. Alimuddin	Head of Research and Community Service Institute	Hasanuddin University	Makassar, South Sulawesi	An overview of research activities and related policies at Hasanuddin University
19.	Dr. Abdul Rasyid Cido	Secretary of Research and Community Service Institute	Hasanuddin University	Makassar, South Sulawesi	An overview of research activities and related policies at Hasanuddin University

Appendix 1. Continued…

No.	Name	Position	Institution	Address	Data and Information
20.	Firman Wahyu, SH, MH	Head of Data Sub Division of Research and Community Service Institute	Hasanuddin University	Makassar, South Sulawesi	Data and information of Research Institute for Hasanuddin University's research budget and topic
21.	Prof. Rizky Abdullah	Director of Research and Community Service	Padjajaran University	Bandung, West Java	An overview of research activities and related policies at Padjadjaran University

Appendix 2. Organizational Structure of the Indonesian Ministry of Agricultural

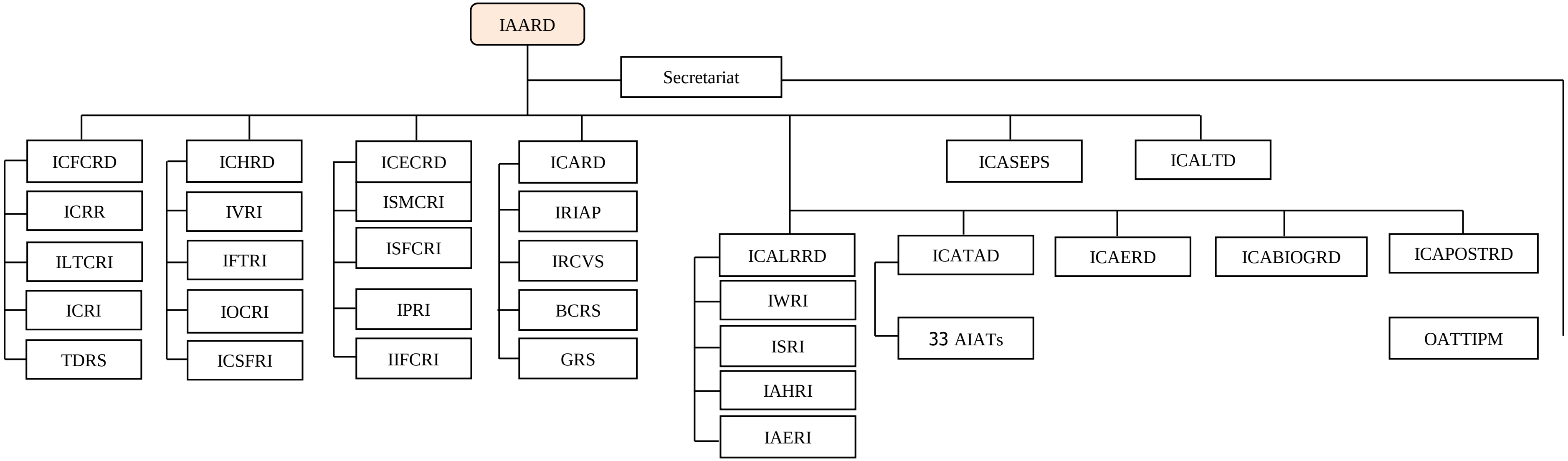


Note: Assistants Minister for Environment, Agricultural Development Policy, International Cooperation, Innovation and Technology, and Agricultural Investment
DGAIF (Director General of Agricultural Infrastructure and Facilities)
DGFC (Directorate General of Food Crops)
DGH (Directorate General of Horticulture)
DGEC (Directorate General of Estate Crops)
DGLAH (Directorate General of Livestock and Animal Health)

IAARD (Indonesian Agency for Agricultural Research and Development)
DGAEHR (Directorate General of Agricultural Extension and Human Resource)
FSA (Food Security Agency)
IAQA Indonesia Agricultural Quarantine Agency
CADI (Center for Agricultural Data and Information)
CPVPAP (Center for Plant Variety Protection and Agriculture Permit)
ICALTD (Indonesian Center for Agricultural Library and Technology Dissemination (ICALTD)
ICASEPS (Indonesian Center for Agricultural Social Economic and Policy Studies

Source: MoA, 2021

Appendix 3. Organizational Structure of the Indonesian Agency for Agricultural Research and Development



Note:
IAARD (Indonesian Agency for Agricultural Research and Development)
ICFCRD (Indonesian Center for Food Crops Research and Development)
ICRR (Indonesian Center for Rice Research)
ILTCRI (Indonesian Legumes and Tuber Crops Research Institute)
ICRI (Indonesian Cereals Research Institute)
TDRS (Tungro Diseases Research Station)
ICHRD (Indonesian Center for Horticulture Research and Development)
IVRI (Indonesian Vegetables Research Institute)
ITFRI (Indonesian Tropical Fruit Research Institute)
IOCRI (Indonesian Ornamental Crops Research Institute)
ICSFRI (Indonesian Citrus and Sub-tropical Fruits Research Institute)
ICECRD (Indonesian Center for Estate Crops Research and Development)
ISMCI (Indonesian Spice and Medicinal Crops Research Institute)
ISFCRI (Indonesian Sweetener and Fiber Crops Research Institute)
IIFCRI (Indonesian Industry and Freshener Crops Research Institute)
ICARD (Indonesian Center for Animal Research and Development)
IRIAP (Indonesian Research Institute for Animal Production)
IRCVS (Indonesian Research Center for Veterinary Sciences)
BCRS (Beef Cattle Research Station)
GRS (Goats Research Station)
ICASEPS (Indonesian Center for Agricultural Socio Economic and Policy Studies)
ICALTD (Indonesian Center for Agricultural Library and Technology Dissemination)
ICALRRD (Indonesian Center for Agricultural Land Resources Research and Development)
IWRI (Indonesian Wetland Research Institute)
ISRI (Indonesian Soil Research Institute)
IAHRI (Indonesian Agro-climate and Hydrology Research Institute)
IAERI (Indonesian Agricultural Environment Research Institute)
ICATAD (Indonesian Center for Agricultural Technology Assessment and Development)
AIAT (Assessment Institute for Agricultural Technology)
ICAERD (Indonesian Center for Agricultural Engineering Research and Development)
ICABIOGRD (Indonesian Center for Agricultural Biotechnology and Genetic Resource Research and Development)
ICAPOSTRD (Indonesian Center for Agricultural Post Harvest Research and Development)
OATTIPM (Office for Agricultural Technology Transfer and Intellectual Property Management

Source: IAARD, 2020

Appendix 4. Description of IAARD's work units

No.	Name of Institution		Abbreviation		Year of Establishment	Official Mandate	Location
	Indonesian	English	Indonesian	English			
1.	Badan Penelitian dan Pengembangan Pertanian	Indonesian Agency for Research and Development	Balitbangtan	IAARD	1974	Conducting research, development and innovation in agriculture.	Jakarta
2.	Sekretariat Badan Penelitian dan Pengembangan Pertanian	Indonesian Agency for Research and Development Secretariat	Sekba Litbangtan	IAARD Secretariat	1974	Providing technical and administrative services to all work units within the IAARD	Jakarta
3	Pusat Penelitian dan Pengembangan Tanaman Pangan	Indonesian Center for Food Crops Research and Development	Puslitbangtan	ICFORD	1918	Formulate technical policies, plans and programs for research, development and innovation in the field of food crops, as well as monitoring, evaluating and reporting on the implementation of activities	Bogor, West Java
4.	Balai Besar Penelitian Tanaman Padi	Indonesian Center for Rice Research	BB Padi	ICRR	1972	Conducting research on rice plants	Subang, West Java
5.	Balai Penelitian Tanaman Aneka Kacang dan Umbi	Indonesian Legumes and Tuber Crops Research Institute	Balitkabi	ILTCRI	1968	Conducting research on various nuts and tubers	Malang, East Java
6.	Balai Penelitian Tanaman Serealia	Indonesian Cereals Research Institute	Balit Sereal	ICRI	1929	Conducting research on cereal crops	Maros, South Sulawesi
7.	Loka Penelitian Penyakit Tungro	Tungro Diseases Research Station	Lolit Tungro	TDRS	2002	Conducting research and produce a tungro disease control technology package.	Sidenreng Rappang, South Sulawesi
8.	Pusat Penelitian dan Pengembangan Tanaman Hortikultura	Indonesian Center for Horticulture Research and Development	Puslibanghorti	ICHORD	1983	Develop technical policies, plans and programs, horticulture research and development, as well as monitoring, evaluating and reporting on the implementation of activities	Bogor, West Java
9.	Balai Penelitian Tanaman Sayuran	Indonesian Vegetables Research Institute	Balitsa	IVRS	1940	Conducting research on various vegetables	Lembang, West Java
10.	Balai Penelitian Tanaman Buah Tropika	Indonesian Tropical Fruit Research Institute	Balitbu	ITFRI	1984	Conducting research on tropical fruit plants	Solok, West Sumatra

Appendix 4. Continued…

No.	Name of Institution		Abbreviation		Year of Establishment	Official Mandate	Location
	Indonesian	English	Indonesian	English			
11.	Pusat Penelitian dan Pengembangan Tanaman Perkebunan	Indonesian Center for Estate Crops Research and Development	Puslitbangbun	ICESCD	1879	Develop technical policies, plans and programs for research, development and innovation in the plantation sector, as well as monitoring, evaluating and reporting on the implementation of activities.	Bogor, West Java
12.	Pusat Penelitian dan Pengembangan Peternakan	Indonesian Center for Animal Research and Development	Puslitbangnak	ICARD	1950	Develop technical policies, plans and programs, research, development and innovation in the field of animal husbandry and animal health, as well as monitoring, evaluating and reporting on the implementation of activities	Bogor, West Java
13.	Balai Penelitian Ternak	Indonesian Research Institute for Animal Production	Balitnak	IRIAP	1981	Conducting livestock research and development including poultry, dairy and dual-purpose cattle, buffalo, sheep, dairy goats and various livestock.	Bogor, West Java
14.	Balai Besar Penelitian Veteriner	Indonesian Research Centre for Veterinary Science	BB Litvet	IRCVS	1908	Conducting research on veterinary	Bogor, West Java
15.	Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian	Indonesian Center for Agricultural Land Resources Research and Development	BBSDLP	ICALRRD	1905	Conducting research and development of agricultural land resources	Bogor, West Java
16.	Balai Penelitian Agroklimat dan Hidrologi	Indonesian Agro-climate and Hydrology Research Institute	Balitklimat	IAHRI	1974	Conducting research on agroclimate and hydrology	Bogor, West Java
17.	Loka Penelitian Sapi Potong	Beef Cattle Research Station	Lolit Sapi	BCRS			Grati, East Java
18.	Balai Besar Penelitian dan Pengembangan Pascapanen Pertanian	Agricultural Post Harvest Research and Development	BB Pascapanen	ICAPHRD	2001	Conducting research and development of agricultural postharvest technology	Bogor, West Java

Appendix 4. Continued…

No.	Name of Institution		Abbreviation		Year of Establishment	Official Mandate	Location
	Indonesian	English	Indonesian	English			
19.	Balai Besar Pengembangan Mekanisasi Pertanian	Indonesian Center for Agricultural Engineering Research and Development	BBP Mektan	ICAERD	1953	Conducting research, engineering and development of agricultural mechanization	Serpong, Banten
20.	Balai Besar Pengkajian dan Pengembangan Teknologi Pertanian	Indonesian Center for Agricultural Technology Assessment and Development	BBP2TP	ICATAD	2002	Conducting assessment and development of agricultural technology	Bogor, West Java
21.	Pusat Sosial Ekonomi dan Kebijakan Pertanian	Indonesian Center for Agricultural Socio Economic and Policy Studies	PSE-KP	ICASEPS	1974	Conducting analysis and assessment of socio-economic and agricultural policies	Bogor, West Java

Note: [*] see provincial map of Indonesia
Source: IAARD, 2021

Provincial map of Indonesia, 2021

Appendix 5. R&D spending based-study title of **rice**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Rice	Availability of new high yielding varieties of rice	4,346.66
2.	2015	Rice	Availability and distribution of BS, FS, and SS grade rice seeds	2,143.30
3.	2015	Rice	Monitoring the development of population dynamics of green leafhoppers and green leafhoppers and the presence of tungro	549.21
4.	2015	Rice	Improvement of rejuvination, characterization and evaluation of rice genetic resources against biotic and abiotic stresses supports the program of assembling new varieties	42.00
5.	2015	Rice	Monitoring the factors causing the shift in the location of the tungro hot spot	62.68
6.	2015	Rice	Integrated bio-intensive control of tungro disease	58.00
7.	2015	Rice	Pesticide management in tungro control	75.00
8.	2015	Rice	Control of tungro based on virulence and pathogenicity of tungro virus in endemic areas	81.50
9.	2015	Rice	Collection of rejuvenation, characterization, and evaluation of tungro-resistant rice germplasm	35.50
10.	2015	Rice	Selection of markers related to rice resistance to tungro virus	40.00
11.	2015	Rice	Formation of a new gene pool for tungro disease-resistant rice genotypes	30.00
12.	2015	Rice	Genetic and phenotypic selection of rice lines against several tungro virus isolates and green leafhoppers	155.00
13.	2015	Rice	Yield test of tungro-resistant lines	104.00
14.	2015	Rice	Availability of seed sources resistant to tungro disease	209.03
15.	2015	Rice	Small rice mill revitalization model, post-harvest handling of corn and soybeans to reduce yield losses	2,500.00
16.	2015	Rice	Functional rice processing technology and utilization of by-products	200.00
17.	2015	Rice	Characterization of physicochemical properties of new high yielding rice varieties	100.00
18.	2015	Rice	Policy to increase rice production on non-paddy agricultural land	177.89
19.	2015	Rice	Communication system for the use of new superior varieties of soaking tolerant rice in supporting sustainable food self-sufficiency	162.19
20.	2015	Rice	Economic valuation of Indonesia's agricultural genetic resources: a case study of rice	166.49
21.	2015	Rice	Institutional strengthening of seed breeders to support the independence of rice and soybean seeds	400.00
22.	2015	Rice	Formation of superior rice lines through the application of molecular markers	1,446.44
23.	2016	Rice	Availability of new high yielding varieties of rice	2,830.04
24.	2016	Rice	Availability and distribution of BS, FS, and SS grade rice seeds	397.71
25.	2016	Rice	Monitoring the development of population dynamics of green leafhoppers and green leafhoppers and the presence of tungro	397.71
26.	2016	Rice	Improvement of rejuvination, characterization and evaluation of rice genetic resources against biotic and abiotic stresses supports the program of assembling new varieties	397.71
27.	2016	Rice	Monitoring the factors causing the shift in the location of the tungro hot spot	397.71

Appendix 5. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
28.	2016	Rice	Integrated bio-intensive control of tungro disease	397.71
29.	2016	Rice	Pesticide management in tungro control	397.71
30.	2016	Rice	Control of tungro based on virulence and pathogenicity of tungro virus in endemic areas	397.71
31.	2016	Rice	Collection of rejuvenation, characterization, and evaluation of tungro-resistant rice germplasm	290.77
32.	2016	Rice	Selection of markers related to rice resistance to tungro virus	2.54
33.	2016	Rice	Formation of a new gene pool for tungro disease-resistant rice genotypes	1.47
34.	2016	Rice	Genetic and phenotypic selection of rice lines against several tungro virus isolates and green leafhoppers	0.90
35.	2016	Rice	Yield test of tungro-resistant lines	0.29
36.	2016	Rice	Availability of seed sources resistant to tungro disease	0.40
37.	2016	Rice	Small rice mill revitalization model, post-harvest handling of corn and soybeans to reduce yield losses	450.00
38.	2016	Rice	Functional rice processing technology and utilization of by-products	374.98
39.	2016	Rice	Characterization of physicochemical properties of new high yielding rice varieties	200.00
40.	2016	Rice	Policy to increase rice production on non-paddy agricultural land	299.95
41.	2016	Rice	Communication system for the use of new superior varieties of soaking tolerant rice in supporting sustainable food self-sufficiency	410.00
42.	2016	Rice	Economic valuation of Indonesia's agricultural genetic resources: a case study of rice	450.00
43.	2016	Rice	Institutional strengthening of seed breeders to support the independence of rice and soybean seeds	247.44
44.	2016	Rice	Formation of superior rice lines through the application of molecular markers	357.32
45.	2016	Rice	Assembling new high yielding varieties of rice	344.90
46.	2016	Rice	jajar legowo super technology	396.17
47.	2016	Rice	Phosphorus nutrient management technology for irrigated paddy fields	1,620.06
48.	2016	Rice	Technology for adding organic fertilizers and biological fertilizers to upland rice	2,830.04
49.	2016	Rice	Technology for controlling grubs or uret in upland rice plantations with seed treatment techniques	397.71
50.	2016	Rice	Potential use of brown rice in wet food products	397.71
51.	2016	Rice	Integrated bio-intensive control technology for tungro disease	397.71
52.	2016	Rice	Pesticide management technology in tungro control	397.71
53.	2016	Rice	Management of rice genetic resources through collection, characterization, and rejuvination to improve the characteristics of rice varieties	397.71
54.	2016	Rice	Availability of new superior varieties of rice, adaptive and competitive by utilizing advanced technology and bio-science	397.71
55.	2016	Rice	Availability and distribution of seed products from rice sources	397.71

Appendix 5. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
56.	2016	Rice	The implementation of a food sovereignty field school that integrates 1,000 seed independent villages to support rice self-sufficiency	290.77
57.	2016	Rice	Availability of information on genetic resources of rice plants	2.54
58.	2016	Rice	Availability of rice technology information and feedback	1.47
59.	2016	Rice	Development of integrated tungro control techniques in tungro endemic areas	0.90
60.	2016	Rice	Increased resistance of rice varieties to specific tungro virus variants	0.29
61.	2016	Rice	Dissemination of information on tungro control technology	0.40
62.	2016	Rice	Rice seed production	450.00
63. 64.	2016	Rice	Auto-pneumatic husking system grain stripping process technology increases the yield and quality of rice as well as the utilization of husks for the production of liquid smoke	374.98
65.	2016	Rice	Production of nanobiosilica and bio-pesticide materials from rice husk waste to increase rice crop productivity	200.00
66.	2016	Rice	Research on the effectiveness of isotope technology for improving land management technology for rice, corn and soybean commodities	299.95
67.	2016	Rice	Research on optimizing soil biological resources to support increased productivity of rice, corn, soybeans, and shallots adaptive to climate change	410.00
68.	2016	Rice	Research on paddy field management supports increased productivity of rice, corn, and soybeans	450.00
69.	2016	Rice	Research on technological improvements to increase rice and chili productivity	247.44
70.	2016	Rice	Formation of superior rice lines through the application of molecular markers	357.32
71.	2017	Rice	Assembling new high yielding varieties of rice	2,830.04
72.	2017	Rice	jajar legowo super technology	397.71
73.	2017	Rice	Phosphorus nutrient management technology for irrigated paddy fields	397.71
74.	2017	Rice	Technology for adding organic fertilizers and biological fertilizers to upland rice	397.71
75.	2017	Rice	Technology for controlling grubs or uret in upland rice plantations with seed treatment techniques	397.71
76.	2017	Rice	Potential use of brown rice in wet food products	397.71
77.	2017	Rice	Integrated bio-intensive control technology for tungro disease	397.71
78.	2017	Rice	Pesticide management technology in tungro control	397.71
79.	2017	Rice	Management of rice genetic resources through collection, characterization, and rejuvination to improve the characteristics of rice varieties	290.77
80.	2017	Rice	Availability of new superior varieties of rice, adaptive and competitive by utilizing advanced technology and bio-science	2.54
81.	2017	Rice	Availability and distribution of seed products from rice sources	1.47

Appendix 5. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
82.	2017	Rice	The implementation of a food sovereignty field school that integrates 1,000 seed independent villages to support rice self-sufficiency	0.90
83.	2017	Rice	Availability of information on genetic resources of rice plants	0.29
84.	2017	Rice	Availability of rice technology information and feedback	0.40
85.	2017	Rice	Development of integrated tungro control techniques in tungro endemic areas	450.00
86.	2017	Rice	Increased resistance of rice varieties to specific tungro virus variants	374.98
87.	2017	Rice	Dissemination of information on tungro control technology	200.00
88.	2017	Rice	Rice seed production	299.95
89.	2017	Rice	Auto-pneumatic husking system grain stripping process technology increases the yield and quality of rice as well as the utilization of husks for the production of liquid smoke	410.00
90.	2017	Rice	Production of nanobiosilica and bio-pesticide materials from rice husk waste to increase rice crop productivity	450.00
91.	2017	Rice	Research on the effectiveness of isotope technology for improving land management technology for rice, corn and soybean	247.44
92.	2017	Rice	Research on optimizing soil biological resources to support increased productivity of rice, corn, soybeans, and shallots adaptive to climate change	357.32
93.	2017	Rice	Research on paddy field management supports increased productivity of rice, corn, and soybeans	344.90
94.	2017	Rice	Research on technological improvements to increase rice and chili productivity	396.17
95.	2017	Rice	Formation of superior rice lines through the application of molecular markers	1,620.06
96.	2018	Rice	Rice source seed production	1,004.67
97.	2018	Rice	Dissemination of technological innovations for rice commodities	522.10
98.	2018	Rice	Superior varieties of rice	2,176.13
99.	2018	Rice	Rice production technology	1,664.73
100.	2018	Rice	Denfarm seed innovation for rice VUB development	28,773.32
101.	2018	Rice	Rice plant seeds	300.00
102.	2018	Rice	Assembling technology and innovation to increase rice production	800.00
103.	2018	Rice	Rice storage and packaging technology and portable rice blind test device	550.00
104.	2018	Rice	Development of a rice bioindustry model in tidal paddy fields	1,500.00
105.	2018	Rice	Development of biosilica production model from rice husk for industry	500.00
106.	2018	Rice	Review the policy on seed and subsidized rice and corn seeds	369.96
107.	2018	Rice	Anticipatory strategies for managing surplus rice and corn production	347.16
108.	2018	Rice	Analysis and mapping of impact under climate change for adaptation and food security through (AMICAF-SSC)	264.41
109.	2018	Rice	Formation of superior rice lines through the application of molecular markers	1,265.58

Appendix 5. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
110.	2019	Rice	Dissemination of technological innovations for rice commodities	3,500.00
111.	2019	Rice	Superior varieties of rice	2,313.80
112.	2019	Rice	Rice production technology	1,600.00
113.	2019	Rice	Rice seeds	2,937.63
114.	2019	Rice	Optimization of pheromone dose to manage yellow rice stem borer, scirpophaga incertulas, in rice by mating disruption	405.55
115.	2019	Rice	Comparison of sheet-pipe technology installation and farmers practice on rice growth, yield and prospect to increase the planting index	150.15
116.	2019	Rice	Test the effectiveness of dynamic inorganic fertilizers on rice growth and yield	42.44
117.	2019	Rice	Resistance test of PT Dupont Indonesia's hybrid rice lines against blast disease in the greenhouse	17.62
118.	2019	Rice	Test the effectiveness of frensoil soil improver on rice plants	48.46
119.	2019	Rice	Testing of pest resistance, yield quality and adaptation of rice plants	133.05
120.	2019	Rice	Testing of rice lines from the Banyuwangi district agriculture office against brown planthoppers and bacterial leaf blight	38.42
121.	2019	Rice	Adaptation test, evaluation of resistance to pests and diseases, evaluation of the quality of grain, rice and organoleptic tests, as well as preparation of proposals for the release of varieties	566.90
122.	2019	Rice	Technology of iron coated seed to improve direct sowing (broadcasting) of rice planting in Indonesia	112.77
123.	2019	Rice	Efficacy of polly 4 as Kmgs fertilizer on rice growth and production	114.60
124.	2019	Rice	Loading the calibration curve of moisture content, protein content and amylose content in the AN-920 . rice composition analyzer	105.83
125.	2019	Rice	Testing the resistance of black rice rice lines to tungro disease	19.38
126.	2019	Rice	Testing of disease resistance of tungro and blast viruses on rice lines resulting from mutations of local varieties of lampai kuniang from Sijunjung district	42.29
127.	2019	Rice	Testing the resistance of rice lines to brown planthopper (Nilavarpata lugens stal), bacterial leaf blight, tungro, and blast	94.63
128.	2019	Rice	Management of yellow rice stem borer, scrirphopaga incertulas iin rice by mating disruption	10,603.34
129.	2019	Rice	Rice production technology	850.00
130.	2019	Rice	Rice seeds	300.00
131.	2019	Rice	Development of packaging technology, storage, and rapid detection of rice quality Support the implementation of national rice regulations	671.89
132.	2019	Rice	Development of biosilica production technology from rice husks and the utilization of their waste for industrial and agricultural applications	982.16

Appendix 5. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
133.	2019	Rice	Small-scale rice milling process technology improvement	434.79
134.	2019	Rice	Co-development and transfer of rice technology)	1,478.25
135.	2019	Rice	Development of digital object identifiers for access to rice genetic resources (SDGs) as a supporter of the multilateral system	1,835.66
136.	2020	Rice	Test the effectiveness of sulfur coated urea (SCU) fertilizer "HARACOAT SCU39" on rice growth and yield, rainy season 2020	44.06
137.	2020	Rice	Testing of disease resistance of tungro and blast viruses on genetically engineered adi payo lines from Kerinci district	42.29
138.	2020	Rice	Test plan for direct seeding and land preparation using D21PL-8 to increase yield of rice (oryza sativa)	177.40
139.	2020	Rice	Technology of iron coated seed to improve direct sowing (broadcasting) of rice planting in Indonesia	160.51
140.	2020	Rice	Rice development with guaranteed varieties and premium quality	23.42
141.	2020	Rice	HIPA 19 and HIPA 21 elder seed production to support licensing collaboration	995.21
142.	2020	Rice	High Zn rice for Indonesia, harvest plus program	370.06
143.	2020	Rice	Adaptation test, pest resistance test, and quality of rice yield of PT Agri Makmur Pertiwi	132.43
144.	2020	Rice	Rice production technology	268.78
145.	2020	Rice	Rice Seeds	122.32
146.	2020	Rice	Rice seed coating technology supports modernization of planting methods using drones	300.00
147.	2020	Rice	Nanoemulsion-based nanobiopesticide production technology and its application for the control of the main crop pests of rice in the field	450.00
148.	2020	Rice	Implementation of RMU revitalization to improve the quality and yield of milled rice and its derivative products	300.00
149.	2020	Rice	The implementation of artificial intelligence-based rice quality rapid detection technology supports the managemer of national rice reserves	550.00
150.	2020	Rice	Development of rice bioindustry and the application of its derivative products in swampland production centers	600.00

Source: IAARD, ICFORD, ICRR, TDRS, 2015-2020

Appendix 6. R&D spending based-study title of **maize**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Maize	Genotypic analysis based on molecular markers (maize, wheat, and sorghum) supports the assembly of high-yielding varieties	670.69
2.	2015	Maize	Assembling competitive maize hybrid varieties to support sustainable agricultural bio-industry	800.00
3.	2015	Maize	Assembling free pollinated maize varieties supports national food security for sub-optimal land	250.00
4.	2015	Maize	Assembling corn production technology supports bio-industrial agriculture and sustainable productivity improvements	523.89
5.	2015	Maize	Utilization of purple corn as a functional food ingredient	95.00
6.	2015	Maize	UPBS management and strengthening of corn seed breeders	360.00
7.	2015	Maize	Development of source seed distribution system (BS) for VUB corn and other cereals by implementing a quality management	988.54
8.	2015	Maize	Increased seed production (FS) and strengthening of corn seed breeders	35.00
9.	2015	Maize	Doubling the scale of corn waste-based bioethanol production	287.20
10.	2015	Maize	Corn bio-industry farming model	301.50
11.	2015	Maize	Assembling new high yielding varieties of corn and other cereals	2,002.06
12.	2016	Maize	Method technology for determining recommendations for Phosphorus fertilization on corn plants based on soil nutrient availability and crop yield potential	133.57
13.	2016	Maize	Recommendations for site-specific maize fertilization on dry land in Bantaeng district	133.57
14.	2016	Maize	Collection, rejuvenation, characterization and evaluation of genetic resources of maize, sweet sorghum, tropical wheat, and millet	313.05
15.	2016	Maize	Molecular marker-based genotyping analysis (maize, wheat, and sorghum) to support the assembly of high-yielding varieties	365.92
16.	2016	Maize	Assembling sub-optimal land tolerant maize varieties to support sustainable food self-sufficiency	977.20
17.	2016	Maize	Assembling corn varieties supports national food security for optimal land	352.85
18.	2016	Maize	Assembling corn production technology supports sustainable productivity improvements	517.40
19.	2016	Maize	Development of production and distribution systems for seed sources of new high-yielding varieties of maize and other cereals with the application of quality management	870.00
20.	2016	Maize	Integration of upstream and downstream technologies for staple food and feed in the corn bio-industry	303.58
21.	2016	Maize	Analysis of growth sources and policies to accelerate corn and soybean production	246.21
22.	2016	Maize	Analysis of the performance and potential of the warehouse receipt system for financing sources, increasing farm prices and income of corn and soybean farmers	238.21
23.	2016	Maize	Decision support system for maize fertilization	239.79
24.	2017	Maize	Assembling new high yielding varieties of corn and other cereals	1,744.61

Appendix 6. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
26.	2017	Maize	Recommendations for site-specific maize fertilization on dry land in Bantaeng district	56.39
27.	2017	Maize	Collection, rejuvenation, characterization and evaluation of genetic resources of maize, sweet sorghum, tropical wheat, and millet	446.47
28.	2017	Maize	Characterization of maize, sorghum and wheat genotypes based on molecular markers	250.00
29.	2017	Maize	Assembling sub-optimal land adaptive maize varieties to support sustainable food self-sufficiency	750.00
30.	2017	Maize	Assembling corn varieties for optimal land supports national food security	300.00
31.	2017	Maize	Improvements in corn and other cereal production technologies support sustainable productivity improvements	400.00
32.	2017	Maize	Development of production and distribution systems for seed sources of new high-yielding varieties of maize and other cereals by implementing a quality management system	620.69
33.	2017	Maize	Technology for rapid detection of aflatoxin contamination in corn at farm leve	205.00
34.	2018	Maize	New superior varieties of corn	1,262.52
35.	2018	Maize	Cultivation, harvest and post-harvest technology for corn and other cereals	494.11
36.	2018	Maize	Production of seed sources for corn and other cereals	819.45
37.	2018	Maize	Development of test equipment for aflatoxin detection technology in corn and nutmeg at farm level	300.00
38.	2019	Maize	New superior varieties of corn	1,114.09
39.	2019	Maize	Cultivation, harvest and post-harvest technology for corn and other cereals	946.14
40.	2019	Maize	Production of seed sources for corn and other cereals	2,977.46
41.	2020	Maize	Warehousing technology (rapid detection, handling, and control of aflatoxins) on IoT (Internet of Things) based corn	600.00

Source: IAARD, ICFORD, IRICC, 2015-2020

Appendix 7. R&D spending based-study title of **soybean**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Soybean	Accelerating the release of national soybean varieties through consortia	564.35
2.	2015	Soybean	Assembling soybean varieties for high yields, tolerance to biotic and abiotic stresses supports bio-industry	253.60
3.	2015	Soybean	Increasing soybean productivity on suboptimal land supports bio-industry	232.50
4.	2015	Soybean	Improvements in the technology components of various nuts cultivation have the potential to increase productivity and yield quality in several agro-ecologists to support bio-industry raw materials	246.80
5.	2015	Soybean	Integration of control of major pests and diseases of various nuts and tubers to reduce yield loss and improve yield quality to support bio-industry	283.64
6.	2015	Soybean	Identification of physico-chemical properties and bioactive components of various nuts and tubers supports the release of high-yielding varieties	122.70
7.	2015	Soybean	Management and empowerment of plant genetic resources supports the assembly of various varieties of nuts and tubers for bio-industry	221.20
8.	2015	Soybean	Dissemination of various bean and tuber crop technologies to support bio-industrial farming systems	932.11
9.	2015	Soybean	Prospects of developing various nuts and tubers for bio-industry agriculture	83.00
10.	2015	Soybean	Production of seeds from various sources of nuts and tubers with a quality management system (QMS) based on ISO 9001-2008	1,000.40
11.	2015	Soybean	Increasing soybean seed production and strengthening breeders	938.45
12.	2016	Soybean	Assembling new high yielding varieties of various beans and sweet potatoes	1,800.65
13.	2016	Soybean	Soybean cultivation in tidal land under oil palm	193.32
14.	2016	Soybean	Integration of neem seed powder and nuclear polyhedrosis virus for pest control on soybean plants in tidal land	193.32
15.	2016	Soybean	Management and empowerment of plant genetic resources of various beans and sweet potatoes	297.02
16.	2016	Soybean	Sub-optimal land soybean variety assembly consortium	495.00
17.	2016	Soybean	Assembling soybean varieties for optimal land	315.00
18.	2016	Soybean	Improvement of cultivation technology components to increase soybean productivity in sub-optimal land	315.00
19.	2016	Soybean	Distribution and development prospects of soybean and cassava farming to support food sovereignty	110.00
20.	2016	Soybean	Management of plant genetic resources supports the assembly of high-yielding varieties of various beans and sweet potatoes	300.00
21.	2016	Soybean	Seeds of various plant sources, beans and sweet potatoes	1,871.00
22.	2016	Soybean	Integrated control of major pests and diseases of soybean and mung bean to reduce yield loss and improve yield quality	250.00
23.	2017	Soybean	Assembling new high yielding varieties of various beans and sweet potatoes	1,339.93
24.	2017	Soybean	Soybean cultivation in tidal land under oil palm	126.59
25.	2017	Soybean	Integration of neem seed powder and nuclear polyhedrosis virus for pest control on soybean plants in tidal land	126.59

Appendix 7. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
26.	2017	Soybean	Management and empowerment of plant genetic resources of various beans and sweet potatoes.	399.68
27.	2017	Soybean	Sub-optimal land soybean variety assembly consortium	250.00
28.	2017	Soybean	Assembling soybean varieties for optimal land	250.00
29.	2017	Soybean	Improvement of cultivation technology components to increase soybean productivity on sub-optimal land (tidal, dry, dry climate, and saline)	225.00
30.	2017	Soybean	Distribution and development prospects of soybean and cassava farming to support food sovereignty	40.00
31.	2017	Soybean	Assistance, coordination, guidance, technology support for soybean UPSUS community-based	400.00
32.	2017	Soybean	Management of plant genetic resources supports the assembly of high-yielding varieties of various nuts and tubers	400.00
33.	2017	Soybean	Seeds of various plant sources, nuts and tubers	1,700.00
34.	2017	Soybean	Assembly and development of technology components for controlling major pests and diseases of soybean and mung bean	100.00
35.	2017	Soybean	Development of nanotechnology to increase shelf life and maintain soybean seed quality	148.55
36.	2018	Soybean	Seed sources of soybeans and other nuts	850.76
37.	2018	Soybean	Assembling adaptive and productive soybean varieties on acid dry land (>3 t/ha) and resistant to pod breaking	113.92
38.	2018	Soybean	Testing the population resistance of the varieties of Anjasmoro essential derivatives tolerant of whitefly and pod break-resistant Grobogan	98.00
39.	2018	Soybean	Testing of resistance to leaf rust and pod sucking pests of mutant strains of hope for soybeans	40.00
40.	2018	Soybean	Design and policy alternatives to achieve soybean self-sufficiency	356.54
41.	2019	Soybean	Technology and varieties of Akabi	2,044.97
42.	2019	Soybean	Seed sources of soybeans and other nuts	2,158.03
43.	2020	Soybean	Technology and varieties of Akabi	446.66
44.	2020	Soybean	Seed sources of soybeans and other nuts	1,159.22

Source: IAARD, ICFORD, ILTCRI, ICAPOSTRD, ICASEPS, 2015-2020

Appendix 8. R&D spending based-study title of **mango**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Mango	Minimum input and environmentally friendly cultivation technology for commercial mango development on sub optimal land	186.79
2.	2016	Mango	Efficient and environmentally friendly cultivation technology in commercial mango development on sub optimal land	242.97
3.	2016	Mango	Non-destructive evaluation system of mango and mangosteen fruit quality using image processing	338.12
4.	2017	Mango	Improvement of cultivars supports increased productivity and competitiveness of bananas and mangoes	81.89
5.	2017	Mango	Cultivation technology supports mango off season	182.87
6.	2017	Mango	Mango seed support	1,497.27
7.	2018	Mango	Cultivation technology supports mango off season	222.63
8.	2019	Mango	cultivation technology supports mango off season	222.08
9.	2020	Mango	Optimization of land use and cultivation technology to increase the production and quality of mangoes in a sustainable manner	108.02
10.	2020	Mango	Development of Area-Wide Management Approaches for Fruit Flies in mango for Indonesia, Philippines, Australia and the Asia Pacific Region (Indowarm)	142.87

Source: IAARD, ICHORD, ITFRI, 2015-2020

Appendix 9. R&D spending based-study title of **pineapple**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2018	Pineapple	True to type pineapple, snake fruit, and banana plant propagation technology by tissue culture	249.37
2.	2019	Pineapple	True to type pineapple and papaya hermaphrodite propagation technology by tissue culture	244.87

Source: IAARD, ICHORD, ITFRI, 2018-2019

Appendix 10. R&D spending based-study title of **shallot**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Shallot	Assistance for pioneering onion agribusiness models	83.49
2.	2015	Shallot	Production of seed sources of shallots and other vegetables	967.88
3.	2015	Shallot	Shallot cultivation technology in sub-optimal land, high quality with a nano-technology approach and environmentally friendly	275.74
4.	2015	Shallot	CV Sumenep onion bulblet production technology in vitro through somatic embryogenesis	199.57
5.	2015	Shallot	Assembling superior varieties of shallots adaptive to wet climates, tolerant of purple spot (alternariaporri) and anthracnose (Colletrichum gloeosporioides) disease	282.63
6.	2016	Shallot	Onion source seeds	1,078.00
7.	2016	Shallot	New superior varieties of shallots	368.61
8.	2016	Shallot	technology and innovation to increase onion production	303.37
9.	2016	Shallot	handling fresh chilies and processing shallots towards national self-sufficiency	539.61
10.	2017	Shallot	SMM-based shallot seed source (UPBS)	1,772.07
11.	2017	Shallot	Assembling shallot cultivation technology with a profit of 40 tons/ha	347.91
12.	2017	Shallot	Dissemination of technological innovations supports UPSUS self-sufficiency in shallots and chilies	289.95
13.	2017	Shallot	Implementation of commercial-scale shallot handling and processing technology	398.95
14.	2017	Shallot	A study of supply chain efficiency and the factors that influence the volatility of chili and shallot prices	361.29
15.	2017	Shallot	Research on technology improvements to increase peatland productivity for chili and shallot production	444.92
16.	2018	Shallot	Improvement of competitive TSS/true seed of shallot technology innovation to support shallot seedling	518.74
17.	2018	Shallot	Assembling shallots adaptive to the rainy season and for export preferences	474.32
18.	2018	Shallot	Production technology of double-fold (Proliga) shallot 40 tons/ha from true shallot seed (TSS) in lowland production centers	289.15
19.	2018	Shallot	SMM-based shallot seed production	2,426.79
20.	2018	Shallot	Dissemination of the results of assembling varieties of shallots and chilies	289.13
21.	2018	Shallot	Dissemination of technological improvements and innovations to increase the production of shallots and chilies	190.78
22.	2018	Shallot	Shallot seed production	3,463.02
23.	2018	Shallot	Strengthening the onion and chili bioindustry model	241.21
24.	2019	Shallot	Improvement of competitive TSS (true seed shallot) technology innovation to support shallot seed	544.25
25.	2019	Shallot	Dissemination of technological improvements and innovations to increase onion production	137.96
26.	2019	Shallot	Assembling rainy season adaptive shallots for export preferences	497.81
27.	2019	Shallot	Dissemination of the results of assembling varieties of shallots and chilies	199.61
28.	2019	Shallot	Production of onion seed sources	2,220.97
29.	2019	Shallot	Shallot seed production	424.68

Appendix 10. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
30.	2019	Shallot	Production technology of double-fold (Proliga) shallot 40 tons/ha from TSS (true shallot seed) in the lowlands	345.70
31.	2019	Shallot	Shallot track	796.52
32.	2020	Shallot	Improvement of TSS (true seed shallot) production technology to increase shallot productivity	188.90
33.	2020	Shallot	Assembling new high yielding varieties of shallots with high productivity and adaptive to environmental stresses to support self-sufficiency, export and meet industrial needs	60.27
34.	2020	Shallot	Production of shallot seed sources based on a quality management system	276.51
35.	2020	Shallot	Dissemination of technology and innovation to increase onion production	65.23

Source: IAARD, ICHORD, ISRI, ICAPOSTRD, 2017-2020

Appendix 11. R&D spending based-study title of **chili**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Chili	Chili cultivation technology that is adaptive to land and climate dynamics supports sustainable farming systems	399.89
2.	2015	Chili	Assembly of high yielding chili varieties tolerant of biotic stress (anthracnose and chimibv virus) through conventional and unconventional approaches	345.78
3.	2016	Chili	Chili seed source	57.64
4.	2016	Chili	New superior varieties of chili	378.60
5.	2016	Chili	Technology and innovation to increase chili production	373.25
6.	2016	Chili	Research on sub-optimal land management and degraded land to support increased productivity of red chilies and shallots	391.87
7.	2017	Chili	Production of chili seed sources based on SMM (UPBS)	998.64
8.	2017	Chili	Assembling hybrid chili varieties with productivity >20 tons/ha	199.89
9.	2017	Chili	Improvement of chili production technology with productivity > 20 tons/ha	343.16
10.	2017	Chili	Fresh chili handling technology through controlled atmosphere storage to maintain freshness	190.00
11.	2018	Chili	Assembling high yielding hybrid chili varieties	423.79
12.	2018	Chili	Improvement of chili production towards productivity >20 tons/ha	340.33
13.	2018	Chili	Production of source seeds and distributed seeds (F1) of chili based on a quality management system	734.01
14.	2018	Chili	Technology model for handling fresh chilies through controlled atmosphere storage at the farmer/collector level	400.00
15.	2019	Chili	Assembling high yielding hybrid chili varieties	545.29
16.	2019	Chili	Chili seed production	1,440.36
17.	2019	Chili	Chili Spread Seeds	224.60
18.	2019	Chili	Improvement of chili production technology towards productivity >20 tons/ha	99.69
19.	2019	Chili	Handling technology (preparation, temperature and humidity modification, packaging) of chili to maintain freshness and reduce damage in the field	391.87
20.	2020	Chili	Assembling hybrid chili varieties with high productivity and adaptive to environmental stresses and supporting bioindustry	133.06
21.	2020	Chili	Efficient red chili proliga technology	218.22
22.	2020	Chili	Production of chili source seeds based on quality management system	675.17
23.	2020	Chili	Dissemination of technology and innovation to increase red chili production	14.19

Source: IAARD, ICHORD, ISRI, ICAPOSTRD, 2017-2020

Appendix 12. R&D spending based-study title of **coffee**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Coffee	Exploration, conservation, characterization, evaluation, utilization, and documentation of coffee, cocoa, tea and rubber germplasm	100.50
2.	2015	Coffee	Selection of candidates for local high-yield varieties with special flavors of Arabica, Robusta and Excelsa coffee	129.20
3.	2015	Coffee	Increasing the efficiency of robusta coffee fertilization through the use of indigenous microbes	142.00
4.	2015	Coffee	production and distribution technology to maintain the viability of robusta coffee and rubber seeds	115.00
5.	2015	Coffee	coffee and rubber plant seeds	150.00
6.	2015	Coffee	Support for coffee technology innovation in the Pagaralam Agricultural Research and Development Agency Field laboratory	160.00
7.	2016	Coffee	Assembling superior varieties of robusta and arabica coffee	234.00
8.	2016	Coffee	exploration, conservation, characterization, evaluation, utilization, and documentation of coffee, cocoa, tea, and rubber germplasm	57.50
9.	2016	Coffee	Increasing the efficiency of robusta coffee fertilization through the use of indigenous microbes	140.00
10.	2016	Coffee	Assembling PBKo pest control technology and leaf rust disease on coffee plants	165.00
11.	2016	Coffee	Irrigation and fertilization technology to increase the productivity of coffee and cocoa tanaman	55.00
12.	2016	Coffee	Increasing the added value and competitiveness of cocoa and coffee commodities through technological improvements and product diversification	125.00
13.	2016	Coffee	Seedlings of coffee and rubber plants	138.00
14.	2018	Coffee	Assembling high-yielding coffee varieties	190.00
15.	2018	Coffee	Assembling technology for controlling coffee berry borer (PBKo) and leaf rust disease	160.00
16.	2018	Coffee	Improving the quality of coffee and cocoa tanaman	109.00
17.	2018	Coffee	Training on processed coffee, cocoa, biological fertilizers, biopesticides and vegetable pesticides	80.00
18.	2018	Coffee	Coffee seed production innovation	2,107.49
19.	2019	Coffee	Acceleration of superior varieties of coffee and cocoa	245.00
20.	2019	Coffee	Assembling high-yielding coffee varieties	140.00
21.	2019	Coffee	Assembling coffee root fungal disease control technology	100.00
22.	2019	Coffee	Increased coffee yield on tidal peatlands	110.00
23.	2019	Coffee	Exploration, conservation, characterization, evaluation, utilization, and documentation of coffee, cocoa, tea and rubber germplasm	90.00
24.	2019	Coffee	Coffee seed production innovation	3,136.07

Source: IAARD, ICECRD, ICCRI, 2015-2019

Appendix 13. R&D spending based-study title of **cocoa**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Cocoa	Increasing the added value of cocoa through the application of handling and processing technology in the cocoa bioindustry farming model	253.92
2.	2015	Cocoa	Exploration, conservation, characterization, evaluation, utilization, and documentation of coffee, cocoa, tea and rubber germplasm	100.50
3.	2015	Cocoa	Assembly of high-yielding cocoa varieties resistant to CPB pests, BBK disease and VSD	229.00
4.	2015	Cocoa	Assembling BBK and VSD disease control technology in cocoa	133.00
5.	2015	Cocoa	Increasing the added value and competitiveness of cocoa commodities through improved fermentation technology and product diversification	290.00
6.	2015	Cocoa	Cocoa plant seeds	144.00
7.	2015	Cocoa	Model of applying cultivation technology to increase productivity in cocoa	160.00
8.	2015	Cocoa	Dry fermentation starter production technology and instant granule chocolate formula for flavor enhancement and cocoa added value	356.10
9.	2015	Cocoa	Technology for handling and controlling mycotoxin contaminants in cocoa and nutmeg	256.01
10.	2015	Cocoa	Assembly of high-yielding cocoa varieties	180.00
11.	2015	Cocoa	Exploration, conservation, characterization, evaluation, utilization, and documentation of coffee, cocoa, tea and rubber germplasm	57.50
12.	2016	Cocoa	Assembling the main pest and disease control technology (PBK, BBK, and VSD) on cocoa plantations on a field scale	188.00
13.	2016	Cocoa	Irrigation and fertilization technology to increase the productivity of coffee and cocoa tanaman	55.00
14.	2016	Cocoa	Increasing the added value and competitiveness of cocoa and coffee commodities through technological improvements and product diversification	125.00
15.	2016	Cocoa	Analysis of the impact of the mandatory cocoa bean fermentation policy on the cocoa marketing system	75.00
16.	2016	Cocoa	Cocoa plant seeds	162.21
17.	2016	Cocoa	Assembling high yielding, pest-resistant cocoa varieties	145.00
18.	2016	Cocoa	Improving the quality and diversification of small-medium scale cocoa-based products	190.00
19.	2016	Cocoa	Improving the quality of coffee and cocoa tanaman	109.00
20.	2016	Cocoa	Training on processed coffee, cocoa, biological fertilizers, biopesticides and vegetable pesticides	80.00
21.	2018	Cocoa	Cocoa pest and disease control formula	145.00
22.	2018	Cocoa	Increasing community cocoa productivity through the application of biofertilizers and growth hormones	190.00
23.	2018	Cocoa	Cocoa seed production innovation	1,159.90
24.	2018	Cocoa	Evaluation of agricultural insurance program and implementation design of sugarcane and cocoa farming insurance	397.42
25.	2018	Cocoa	Acceleration of superior varieties of coffee and cocoa	245.00

Appendix 13. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
26.	2018	Cocoa	Assembling high yielding, pest-resistant cocoa varieties	140.00
27.	2018	Cocoa	Quality improvement and diversification of cocoa-based products	125.00
28.	2019	Cocoa	Increasing cocoa yield through the application of biofertilizers and ameliorants	110.00
29.	2019	Cocoa	Technology and control of cocoa pests and diseases	105.00
30.	2019	Cocoa	Exploration, conservation, characterization, evaluation, utilization, and documentation of coffee, cocoa, tea and rubber germplasm	90.00
31.	2019	Cocoa	Cocoa seed production innovation	289.18

Source: IAARD, ICECRD, ICCRI, 2015-2019

Appendix 14. R&D spending based-study title of **beef**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1.	2015	Beef	Conservation and Utilization of Local Cattle Genetic Resources	154.76
2.	2015	Beef	Beef Cattle Crosses for Optimization of Production and Reproductive Traits	84.46
3.	2015	Beef	Improving the Reproductive Efficiency of Ongole Cattle	179.61
4.	2015	Beef	Improving the Genetic Quality of Local Cattle Breeds (PO, Madura and Bali)	3,751.49
5.	2015	Beef	Low Protein - High Fiber Feed Technology for Multiple Physiological Status of Beef Cattle	303.06
6.	2015	Beef	Exploration, Collection, Characterization and Evaluation of Ruminant and Non-Ruminant Livestock Genetic Resources	328.36
7.	2015	Beef	Efficient Optimization of Animal Feed Crops Productivity in Sub-Optimal Land	537.40
8.	2015	Beef	Development of UPBS as a High Profile Seed and TPT Reproduction Unit	503.86
9.	2015	Beef	Improvement of Livestock Production System in Anticipating Climate Change	221.30
10.	2016	Beef	Formation and new breeds of local beef cattle	4,304.00
11.	2016	Beef	Strategic Disease-Resistant Local Beef Cattle Mapping	125.00
12.	2016	Beef	Management and Utilization of Beef Cattle Sources	270.00
13.	2016	Beef	Improved Beef Cattle Reproductive Efficiency	142.00
14.	2016	Beef	Low Protein - High Fiber Feed Technology for Multiple Physiological Status of Beef Cattle	285.00
15.	2016	Beef	Efficient Optimization of Animal Feed Crops Productivity in Sub-Optimal Land	508.65
16.	2016	Beef	Exploration, Collection, Characterization and Evaluation of Ruminant and Non-Ruminant Livestock Genetic Resources	328.65
17.	2016	Beef	Development of high-profile livestock and TPT seeds	150.00
18.	2016	Beef	Improvement of Livestock Production System in Anticipating Climate Change	233.64
19.	2017	Beef	Consolidation of Lines and Formation of New Breeds of Local Beef Cattle	1,485.71
20.	2017	Beef	Management and Utilization of Beef Cattle Sources	260.00
21.	2017	Beef	Exploration/ Collection/ Characterization and Evaluation of SDGs for Ruminants/Poultry and Animal Feed Plants	450.00
22.	2018	Beef	Consolidation of Lines and Formation of New Breeds of Local Beef Cattle	1,535.89
23.	2018	Beef	Strategic Disease-Resistant Local Beef Cattle Mapping	5.30
24.	2018	Beef	Management and Utilization of Beef Cattle Sources	210.00
25.	2018	Beef	Research Supports Superior Seed Production	535.00
26.	2018	Beef	Improved reproductive efficiency in supporting efforts to establish high-yielding seeds	500.00
27.	2018	Beef	Eco-Friendly Feed for Optimizing Growth and Quality of Beef Beef	420.25
28.	2018	Beef	Optimizing Efficient TPT Production in Sub Optomal Land	38.00
29.	2018	Beef	Exploration/ Collection/ Characterization and Evaluation of Ruminant Animal Genetic Resources	170.00
30.	2018	Beef	Assembling Livestock Breeding System Technology and Anticipating Climate Change	49.06

Appendix 14. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
31.	2018	Beef	Assembling Innovations in Ruminant and Non-Ruminant Feed Additive Tech to Support National Meat and Dairy Production	6.11
32.	2018	Beef	Mentoring, Counseling and Monitoring "Work" activities	500.00
33.	2018	Beef	Assistance, Coordination, Guidance and Technology UPSUS SIWAB	225.00
34.	2019	Beef	Consolidation of Lines and Formation of New Breeds of Local Beef Cattle	1,500.00
35.	2019	Beef	Management and Utilization of Beef Cattle Sources	3,120.00
36.	2019	Beef	Eco-Friendly Feed for Beef Cattle Breeding Production	700.00
37.	2019	Beef	Improved reproductive efficiency in supporting efforts to establish high-yielding seeds	625.00
38.	2019	Beef	Bioreproductive Technology Consolidation for Beef Cattle Population Propagation	675.00
39.	2019	Beef	SDG Beef Cattle	250.00
40.	2019	Beef	Efficiency Optimization of Animal Feed Crops Productivity in Sub-optimal Land	200.00
41.	2019	Beef	Assembling Innovations in Ruminant and Non-Ruminant Feed Additive Technology to Support National Meat and Dairy Production	225.00
42.	2019	Beef	Breeding Innovation Development for Belgian Blue Cattle Breeding Development	500.00
43.	2019	Beef	Assistance, Development, Coordination, Guidance and Support for Plant Livestock Integration (SITT)	100.00
44.	2019	Beef	Assistance, Coordination, Guidance and Technology UPSUS SIWAB	200.00
45.	2019	Beef	Exploration/ Collection/ Characterization and Evaluation of Ruminant Animal Genetic Resources	250.00
46.	2019	Beef	Veterinary Microbial Identification	3.18
47.	2019	Beef	Veterinary Microbial Conservation and Characterization	224.82
48.	2019	Beef	Molecular Identification of Trichophyton mentagrophytes and Treatment Efforts	130.00
49.	2019	Beef	Molecular Characterization of Bacteriophages as Salmonella Enteritidis biocontrol agents and for typing	180.00
50.	2019	Beef	Development of Infectious Bursal Disease (IBD) Vaccine Based on Local Isolates	230.00
51.	2019	Beef	Veterinary Policy Analysis Supports National Animal Health System Development	150.00
52.	2019	Beef	Anticipation of Explosions/Outbreaks of Animal Diseases and Their Spread in Relation to Climate Change	370.00
53.	2019	Beef	Animal Health Program to Increase Livestock Productivity.	250.99
54.	2019	Beef	Research and Application of Veterinary Technology at UPT Scope of Research and Development Center in producing sustainable disease-free livestock breeds	764.79
55.	2019	Beef	Development of technology for the detection of several types of gastrointestinal protozoan pathogens in livestock parasitologically and molecularly	160.00
56.	2019	Beef	Development of LAMP (Loop Mediated Isothermal Amplification) PCR Technique for Detection of Blood Parasites (T.evansi) in Cattle/Buffalo	160.00
57.	2019	Beef	Epidemiology and geographic distribution of pathogenic gastrointestinal protozoan infections in livestock	150.00

Appendix 14. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
58.	2019	Beef	Potential Study of SE Vaccine Developed from Strain Pasteurella multocida Local Isolate in Field-Scale Cattle	180.00
59.	2019	Beef	Efficacy of Trematophagus (Paecilomyces lilacinus local) in Reducing Worm Eggs Fasciola gigantica	120.00
60.	2019	Beef	Detection and Identification of BGC) with FAT and Multiplex PCR Methods	160.00
61.	2019	Beef	Development of immunochromatographic strips for the detection of aflatoxin B1 in cattle feed.	158.00
62.	2019	Beef	Livestock Crop Integration System (SITT)	50.00
63.	2019	Beef	Veterinary Technology Dissemination	200.00
64.	2019	Beef	Assistance, Coordination, Guidance and Technology Support UPSUS SIWAB	241.30
65.	2020	Beef	Development of Pogasi Agrinak Cattle for Achieving a Cattle Weight of 120 kg and a Body Weight of 24 Months of 400 kg	352.62
66.	2020	Beef	Dizziness	693.99
67.	2020	Beef	Conservation and Utilization of Local Cattle Genetic Resources	32.24
68.	2020	Beef	Beef Cattle Crosses for Optimization of Production and Reproductive Traits	262.49
69.	2020	Beef	Improving the Reproductive Efficiency of Ongole Cattle	678.95
70.	2020	Beef	Improving the Genetic Quality of Local Cattle Breeds (PO, Madura and Bali)	0.15
71.	2020	Beef	Low Protein - High Fiber Feed Technology for Multiple Physiological Status of Beef Cattle	12.25
72.	2020	Beef	Exploration, Collection, Characterization and Evaluation of Ruminant and Non-Ruminant Livestock Genetic Resources	0.51
73.	2020	Beef	Efficient Optimization of Animal Feed Crops Productivity in Sub-Optimal Land	91.47
74.	2020	Beef	Development of UPBS as a High Profile Seed and TPT Reproduction Unit	35.61
75.	2020	Beef	Improvement of Livestock Production System in Anticipating Climate Change	55.59
76.	2020	Beef	Formation and new breeds of local beef cattle	4.56
77.	2020	Beef	Strategic Disease-Resistant Local Beef Cattle Mapping	221.26
78.	2020	Beef	Management and Utilization of Beef Cattle Sources	50.00
79.	2020	Beef	Improved Beef Cattle Reproductive Efficiency	17.45
80.	2020	Beef	Low Protein - High Fiber Feed Technology for Multiple Physiological Status of Beef Cattle	155.11
81.	2020	Beef	Efficient Optimization of Animal Feed Crops Productivity in Sub-Optimal Land	3.18
82.	2020	Beef	Exploration, Collection, Characterization and Evaluation of Ruminant and Non-Ruminant Livestock Genetic Resources	226.99
83.	2020	Beef	Development of high-profile livestock and TPT seeds	330.00
84.	2020	Beef	Improvement of Livestock Production System in Anticipating Climate Change	300.00
85.	2020	Beef	Consolidation of Lines and Formation of New Breeds of Local Beef Cattle	500.00
86.	2020	Beef	Management and Utilization of Beef Cattle Sources	400.00
87.	2020	Beef	Exploration/ Collection/ Characterization and Evaluation of SDGs for Ruminants/Poultry and Animal Feed Plants	250.00
88.	2020	Beef	Consolidation of Lines and Formation of New Breeds of Local Beef Cattle	385.00
89.	2020	Beef	Strategic Disease-Resistant Local Beef Cattle Mapping	200.00

Appendix 14. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
90.	2020	Beef	Management and Utilization of Beef Cattle Sources	375.00
91.	2020	Beef	Research Supports Superior Seed Production	910.00
92.	2020	Beef	Improved reproductive efficiency in supporting efforts to establish high-yielding seeds	150.00
93.	2020	Beef	Eco-Friendly Feed for Optimizing Growth and Quality of Beef Beef	200.00
94.	2020	Beef	Optimizing Efficient TPT Production in Sub Optomal Land	95.00
95.	2020	Beef	Exploration/ Collection/ Characterization and Evaluation of Ruminant Animal Genetic Resources	250.00
96.	2020	Beef	Assembling Livestock Breeding System Technology and Anticipating Climate Change	50.00
97.	2020	Beef	Assembling Innovations in Ruminant and Non-Ruminant Feed Additive Technology to Support National Meat and Dairy	400.00

Source : IAARD, ICARD, IRIAP, IRCVS, 2015-2019

Appendix 15. R&D spending based-study title of **poultry**, 2015-2020

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
1	2015	Poultry	Collection and rejuvenation of duck genetic resources	99.44
2	2015	Poultry	Management of chicken genetic resources	62.01
3	2015	Poultry	Selection of sensi and gaosi male lines	490.86
4	2015	Poultry	Effect of various levels of protein (amino acids) and ration energy on carcass growth characteristics and economic value of Sentul-GS chicken	59.74
5	2015	Poultry	Selection of female KUB chicken lines for GP (grand parent) candidates	482.36
6	2015	Poultry	Molecular markers related to brooding properties in local chickens	133.79
7	2015	Poultry	Selection of Alabio and Mojosari ducks as GPS laying ducks	342.34
8	2015	Poultry	Increasing the efficiency of local broiler production through the use of probiotics and enzymes as feed additives	66.40
9	2015	Poultry	Selection of local entog as the oldest seed for the formation of fiber ducks	246.86
10	2016	Poultry	Selection of KUB chicken lines for GP (grant parent) candidates	387.70
11	2016	Poultry	Response Performance of the growth of chickens from crosses of selected male and brood lines on the quality of the ration	38.70
12	2016	Poultry	Selection of sentul chicken and gaok chicken as Male Line for local chickens	362.75
13	2016	Poultry	Prolactin gene is related to brooding properties with local chickens	79.50
14	2016	Poultry	Selection of Alabio and Mojosari ducks as GPS laying ducks	333.79
15	2016	Poultry	Selection of local entog as the oldest seed for the formation of fiber ducks	219.89
16	2016	Poultry	Improving the efficiency of local broiler production by using enzymes as feed additives	94.83
17	2016	Poultry	Management and development of chicken genetic resources	86.78
18	2016	Poultry	Mojosari Putuh and Peking duck genetic resources collection	89.39
19	2016	Poultry	KUB-1 chicken breeding superior	244.56
20	2016	Poultry	PMP duck breeding superior (600 heads)	357.93
21	2016	Poultry	The effectiveness of carbohydrase and protease enzymes as feed additives for broiler chickens	159.91
22	2017	Poultry	Establishment of GPS (grand parent stock) and PS (parent stock) for local chickens	652.36
23	2017	Poultry	GPS and PS establishment of local white ducks and mutton	549.95
24	2017	Poultry	Exploration/collection/characterization and evaluation of SDGs for ruminants/poultry and fodder crops	445.81
25	2017	Poultry	KUB-1 chicken breeding superior	195.75
26	2017	Poultry	Superior seeds for laying ducks	186.05
27	2017	Poultry	Development of KUB chicken breeding model (core)	195.84
28	2017	Poultry	Development of KUB Chicken Breeding Model (plasma)	86.56
29	2017	Poultry	Study of supply chain efficiency of broilers and layers in order to improve competitiveness and welfare of farmers	366.18
30	2018	Poultry	Establishment of GPS (grand parent stock) and PS (parent stock) for local chickens	489.23

Appendix 15. Continued…

No.	Year	Commodity	Study Title	Real R&D Spending (Million USD)
31	2018	Poultry	GPS and PS establishment of local white ducks and mutton	294.52
32	2018	Poultry	Exploration/collection/characterization and evaluation of animal genetic resources for poultry	151.38
33	2019	Poultry	Production of Rhizopus oligosporus powder and its efficacy for the prevention of aflatoxin contamination in chicken feed	115.00
34	2019	Poultry	Molecular characterization of antimicrobial resistance (AMR) of salmonella enteritidis isolated from laying hens	150.00
35	2019	Poultry	Epidemiological studies of antibiotic residues (fluoroquinolones and sulfonamides) in broiler eggs and consumption eggs in various locations	150.00
36	2019	Poultry	KUB-1 (DOC) chicken breeding superior	204.34
37	2019	Poultry	Superior breeds for laying ducks (DOD)	319.58
38	2019	Poultry	Establishment of GPS (grand parent stock) and PS (parent stock) for local chickens	974.08
39	2019	Poultry	GPS and PS establishment of local white ducks and mutton	415.64
40	2019	Poultry	Exploration/collection/characterization and evaluation with poultry	189.00
41	2019	Poultry	The independent model of chicken feed supports the availability of sustainable feed in the work program in Tasikmalaya district	424.80
42	2019	Poultry	Halal Gelatin Production Technology from Chicken Feet Raw Materials on a Pilot Scale	352.81
43	2020	Poultry	Vaccine technology innovation and veterinary medicine in order to improve poultry health	805.00
44	2020	Poultry	Superior livestock source seeds (baseline)	896.60
45	2020	Poultry	Poultry and various livestock sources	749.29
46	2020	Poultry	Technology dissemination	278.43
47	2020	Poultry	Animal SDG, fodder crops and livestock microbes	295.67
48	2020	Poultry	Egg handling technology to maintain freshness and extend shelf life	300.00
49	2020	Poultry	Implementation of halal gelatin production technology from livestock waste (chicken claws) in the field	400.00

Source: IAARD, ICARD, IRIAP, IRCVS, 2015-2019

Appendix 16. Description of selected universities

Name of University	Year of Establishment	Number of Faculty (unit)	Address
IPB University	1963	9 Faculties	Bogor, West Java province
Padjadjaran University	1957	16 Faculties	Bandung, West Java province
Brawijaya University	1963	18 Faculties	Malang, East Java province
Hasanuddin University	1956	15 Faculties	Makassar, South Sulawesi province

Source: IPB, Padjadjaran, Brawijaya, and Hasanuddin Universities, 2021

Appendix 17. R&D spending based on selected study title of Padjadjaran University, 2015-2020

No.	Year	Study Title	Real R&D Spending (Million USD)
1.	2016	Development of Unpad Corn Hybrids with High Nutrients as Pharmaceutical Excipients in Reducing Dependence on Imported Drugs in Indonesia	0.010
2.	2016	Application of Ketapang Badak (Ficus Lyrata Warb) Fruit Extract as a Natural Preservative in Chicken Carcass as a Promoter of Food Safety in Indonesia	0.010
3.	2016	Production of Xylitol, Bioethanol and Glucose Syrup in the Application of the Concept of a Hybrid Corn Commodity-Based Biomass Refinery Unpad	0.006
4.	2016	Productivity of Paddy Rice (Oryza Sativa L.) Under Weed Control, Planting Spacing In Different Land Preparations	0.006
5.	2016	Production of Basic Seeds for Four Genotypes of Red Chili Unpad and Launching of New Varieties of Seeds in Ciamis, West Java	0.006
6.	2016	Analysis of Actions on the Implementation of Labeling and Packaging on Gedong Gincu Mangoes to Improve the Welfare of Mango Farmers in Cirebon Regency	0.007
7.	2016	Efforts to Accelerate the Formation of Rice Lines Through Microspore Culture and Gene Pyramidization For Brown Planthopper Resistant Characters And High Quality Rice Through Molecular Markers	0.007
8.	2016	Phosphate Biological Fertilizer Formulation And Application To Improve Suboptimal Soil Quality, Increase Corn Crop Yield And Resistance To Disease	0.007
9.	2016	Assembling Sweet Corn Hybrids in Multiple-Cropping Cropping Patterns to Support Food Security in Indonesia	0.009
10.	2016	New Attractant Formulation and Innovation of Industrial-Scale Traps to Support Fruit Fly-Free Mango Exports	0.024
11.	2016	Assembly of Superior Rice Lines through Marker Assisted Gene Pyramiding and Involvement of Farmers in Participatory Plant Breeding	0.010
12.	2016	Investigating the Potential of Artificial Fruits, Vegetable Oil Formulations, and Their Combinations in Suppressing Oviposition of Fruit Flies Bactrocera Spp. On Chili Fruit	0.005
13.	2016	Detection of Genetic Variability of Peronosclerospora Spp. Causes of Downy mildew on Corn Plants in West Java	0.004
14.	2016	The Use of Biophosphates on the Productivity of Unpad's High Isoflavone Black Soybean Lines in West Java Production Centers	0.005
15.	2016	Soybean (Glycine Max L. Merill) Productivity and Weed Dominance Shifts in Different Control, Planting Distances and Soil Processing	0.004
16.	2016	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.010
17.	2017	Development of Drought Tolerant and Adaptive Corn to Global Climate Change and Analysis of Water Needs in Arjasari, West Java	0.009
18.	2017	Assembling Sweet Corn Hybrids in Multiple-Cropping Cropping Patterns to Support Food Security in Indonesia	0.008
19.	2017	Utilization of Biofertilizer And Azolla Technology Packages To Increase The Quantity And Quality Of Organic Rice	0.006
20.	2017	Assembly of Superior Soybean Varieties of High Productivity And Large Seed Size Through Hybridization And Mutation Induction	0.006

Appendix 17. Continued…

No.	Year	Study Title	Real R&D Spending (Million USD)
21.	2017	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.010
22.	2017	Optimization of Organic Biofertilizer and Ameliorant Formulas to Improve Sub-Optimal Soil Quality, Rice Yield and Inorganic Fertilizer Efficiency	0.006
23.	2017	Unpad Corn Selection Adaptive Various Cropping Patterns Based on Molecular Markings to Support National Corn Self-Sufficiency	0.008
24.	2017	Test the Effectiveness of Hydrogel Super Absorbent Polymer As Fertilizer Media To Increase Production Of Rice, Corn, In Dry Land	0.008
25.	2017	Selection Based on Corn Molecular Markers Tolerant Shade In Agroforestry With Albizia in Supporting Food Independence	0.008
26.	2017	Growth and Productivity of Oil Palm Plants in Intercropping Patterns Based on Pajale Cassava and Chili in Supporting Food Security in Indonesia	0.008
27.	2017	The Response of Deteriorated Soybean Seeds To The Application Of Seed Coating And Bokashi In Rice Fields	0.008
28.	2017	Study of Anti-microbial Peptide Zmes4 Gene from Corn Plants for Development of Recombinant DNA-Based Biological Products	0.009
29.	2017	New Attractant Formulation and Innovation of Industrial-Scale Traps to Support Fruit Fly-Free Mango Exports	0.036
30.	2017	The Role of Water Status and Soil Aeration in Root Areas on Flowering Ability of Mangifera Indica L. Gedong Gincu Plants	0.006
31.	2017	Potential and Development of Bio-Pesticides Binahong [Anredera Cordifolia (Ten.) Steenis] To Control Rice Plant Diseases	0.005
32.	2017	Systemic Induction of Resistance in Rice Plants With Plant Extracts Against Swollen Root Nematodes Meloidogyne Graminicola	0.006
33.	2017	Increased Production of Rice and Corn, on Sub-Optimal Land Through Fertilization Engineering in Order to Meet Food Security in West Java	0.018
34.	2017	Development of Unpad Hybrid Corn in an Intercropping Pattern in an Integrated Farming System with Sheep to Improve Farmers' Welfare in Arjasari, West Java	0.018
35.	2017	Potential Combination of Vegetable Oil and Artificial Fruit to Suppress Oviposition of Bactrocera Dorsalis Hendel Fruit Flies on Red Chili Fruit	0.005
36.	2017	Yeast as an inducer of plant resistance to control anthracnose and yellow curls in chili capsicum annuum L.	0.006
37.	2017	Halal Traceability Information System in Chicken Meat Distribution System in West Java	0.006
38.	2017	Application of Ketapang Badak (Ficus Lyrata Warb) Fruit Extract as a Natural Preservative in Chicken Carcass as a Promoter of Food Safety in Indonesia	0.007
39.	2017	Productivity of Paddy Rice (Oryza Sativa L.) Under Weed Control, Planting Spacing In Different Land Preparations	0.007
40.	2017	Design and Build a Structured Market Oriented Mango Agribusiness Supply Chain Financing Model in West Java	0.010
41.	2017	Analysis of Actions on the Implementation of Labeling and Packaging on Gedong Gincu Mangoes to Improve the Welfare of Mango Farmers in Cirebon Regency	0.031

Appendix 17. Continued…

No.	Year	Study Title	Real R&D Spending (Million USD)
42.	2017	Efforts to Accelerate the Formation of Rice Lines Through Microspore Culture and Gene Pyramidization For Brown Planthopper Resistant Characters And High Quality Rice Through Molecular Markers	0.011
43.	2017	Assembling Sweet Corn Hybrids in Multiple-Cropping Cropping Patterns to Support Food Security in Indonesia	0.004
44.	2017	New Attractant Formulation and Innovation of Industrial-Scale Traps to Support Fruit Fly-Free Mango Exports	0.008
45.	2017	Assembly of Superior Rice Lines through Marker Assisted Gene Pyramiding and Involvement of Farmers in Participatory Plant Breeding	0.031
46.	2017	Investigating the Potential of Artificial Fruits, Vegetable Oil Formulations, and Their Combinations in Suppressing Oviposition of Fruit Flies Bactrocera Spp. On Chili Fruit	0.005
47.	2018	Detection of Genetic Variability of Peronosclerospora Spp. Causes of Downy mildew on Corn Plants in West Java	0.008
48.	2018	The Use of Biophosphates on the Productivity of Unpad's High Isoflavone Black Soybean Lines in West Java Production Centers	0.003
49.	2018	Soybean (Glycine Max L. Merill) Productivity and Weed Dominance Shifts in Different Control, Planting Distances and Soil Processing	0.004
50.	2018	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.004
51.	2018	Development of Drought Tolerant and Adaptive Corn to Global Climate Change and Analysis of Water Needs in Arjasari, West Java	0.021
52.	2018	Utilization of Biofertilizer And Azolla Technology Packages To Increase The Quantity And Quality Of Organic Rice	0.007
53.	2018	Assembly of Superior Soybean Varieties of High Productivity And Large Seed Size Through Hybridization And Mutation Induction	0.007
54.	2018	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.008
55.	2018	Optimization of Organic Biofertilizer and Ameliorant Formulas to Improve Sub-Optimal Soil Quality, Rice Yield and Inorganic Fertilizer Efficiency	0.007
56.	2018	Unpad Corn Selection Adaptive Various Cropping Patterns Based on Molecular Markings to Support National Corn Self-Sufficiency	0.007
57.	2018	Test the Effectiveness of Hydrogel Super Absorbent Polymer As Fertilizer Media To Increase Production Of Rice, Corn, In Dry Land	0.007
58.	2018	Selection Based on Corn Molecular Markers Tolerant Shade In Agroforestry With Albizia in Supporting Food Independence	0.007
59.	2018	Growth and Productivity of Oil Palm Plants in Intercropping Patterns Based on Pajale Cassava and Chili in Supporting Food Security in Indonesia	0.014
60.	2018	The Response of Deteriorated Soybean Seeds To The Application Of Seed Coating And Bokashi In Rice Fields	0.015
61.	2018	Study of Anti-microbial Peptide Zmes4 Gene from Corn Plants for Development of Recombinant DNA-Based Biological Products	0.016
62.	2018	Potential and Development of Bio-Pesticides Binahong [Anredera Cordifolia (Ten.) Steenis] To Control Rice Plant Diseases	0.005

Appendix 17. Continued…

No.	Year	Study Title	Real R&D Spending (Million USD)
63.	2018	Systemic Induction of Resistance in Rice Plants With Plant Extracts Against Swollen Root Nematodes Meloidogyne Graminicola	0.005
64.	2018	Soybean Agribusiness Development	0.005
65.	2018	Increased Production of Rice and Corn, on Sub-Optimal Land Through Fertilization Engineering in Order to Meet Food Security in West Java	0.004
66.	2018	Development of Unpad Hybrid Corn in an Intercropping Pattern in an Integrated Farming System with Sheep to Improve Farmers' Welfare in Arjasari, West Java	0.004
67.	2018	Potential Combination of Vegetable Oil and Artificial Fruit to Suppress Oviposition of Bactrocera Dorsalis Hendel Fruit Flies on Red Chili	0.004
68.	2018	Yeast as an inducer of plant resistance to control anthracnose and yellow curls in chili capsicum annuum L.	0.005
69.	2018	The Social Impact of the Difference in Farmer Prices of Arjasa Red Cayenne Pepper	0.005
70.	2018	Halal Traceability Information System in Chicken Meat Distribution System in West Java	0.003
71.	2018	Application of Ketapang Badak (Ficus Lyrata Warb) Fruit Extract as a Natural Preservative in Chicken Carcass as a Promoter of Food Safety in Indonesia	0.003
72.	2018	Production of Xylitol, Bioethanol and Glucose Syrup in the Application of the Concept of a Hybrid Corn Commodity-Based Biomass Refinery Unpad	0.004
73.	2018	Productivity of Paddy Rice (Oryza Sativa L.) Under Weed Control, Planting Spacing In Different Land Preparations	0.004
74.	2018	Production of Basic Seeds for Four Genotypes of Red Chili Unpad and Launching of New Varieties of Seeds in Ciamis, West Java	0.007
75.	2018	Design and Build a Structured Market Oriented Mango Agribusiness Supply Chain Financing Model in West Java	0.025
76.	2018	Efforts to Accelerate the Formation of Rice Lines Through Microspore Culture and Gene Pyramidization For Brown Planthopper Resistant Characters And High Quality Rice Through Molecular Markers	0.009
77.	2018	Phosphate Biological Fertilizer Formulation And Application To Improve Suboptimal Soil Quality, Increase Corn Crop Yield And Resistance To Disease	0.004
78.	2018	Assembling Sweet Corn Hybrids in Multiple-Cropping Cropping Patterns to Support Food Security in Indonesia	0.022
79.	2019	Assembly of Superior Rice Lines through Marker Assisted Gene Pyramiding and Involvement of Farmers in Participatory Plant Breeding	0.008
80.	2019	Investigating the Potential of Artificial Fruits, Vegetable Oil Formulations, and Their Combinations in Suppressing Oviposition of Fruit Flies Bactrocera Spp. On Chili Fruit	0.005
81.	2019	Detection of Genetic Variability of Peronosclerospora Spp. Causes of Downy mildew on Corn Plants in West Java	0.004
82.	2019	The Use of Biophosphates on the Productivity of Unpad's High Isoflavone Black Soybean Lines in West Java Production Centers	0.005
83.	2019	Soybean (Glycine Max L. Merill) Productivity and Weed Dominance Shifts in Different Control, Planting Distances and Soil Processing	0.006

Appendix 17. Continued…

No.	Year	Study Title	Real R&D Spending (Million USD)
84.	2019	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.003
85.	2019	Development of Drought Tolerant and Adaptive Corn to Global Climate Change and Analysis of Water Needs in Arjasari, West Java	0.009
86.	2019	Utilization of Biofertilizer And Azolla Technology Packages To Increase The Quantity And Quality Of Organic Rice	0.008
87.	2019	Assembly of Superior Soybean Varieties of High Productivity And Large Seed Size Through Hybridization And Mutation Induction	0.021
88.	2019	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.010
89.	2019	Optimization of Organic Biofertilizer and Ameliorant Formulas to Improve Sub-Optimal Soil Quality, Rice Yield and Inorganic Fertilizer Efficiency	0.015
90.	2019	Unpad Corn Selection Adaptive Various Cropping Patterns Based on Molecular Markings to Support National Corn Self-Sufficiency	0.016
91.	2019	Selection Based on Corn Molecular Markers Tolerant Shade In Agroforestry With Albizia in Supporting Food Independence	0.003
92.	2019	Growth and Productivity of Oil Palm Plants in Intercropping Patterns Based on Pajale Cassava and Chili in Supporting Food Security in Indonesia	0.005
93.	2019	Globalization Era: Efforts to Increase the Capacity of Mango Farmers in the Modern Market Viewed from the Dynamics of Agribusiness and Land Tenure	0.008
94.	2019	The Response of Deteriorated Soybean Seeds To The Application Of Seed Coating And Bokashi In Rice Fields	0.006
95.	2019	Potential and Development of Bio-Pesticides Binahong [Anredera Cordifolia (Ten.) Steenis] To Control Rice Plant Diseases	0.004
96.	2019	Systemic Induction of Resistance in Rice Plants With Plant Extracts Against Swollen Root Nematodes Meloidogyne Graminicola	0.004
97.	2020	Soybean Agribusiness Development	0.003
98.	2020	Increased Production of Rice and Corn, on Sub-Optimal Land Through Fertilization Engineering in Order to Meet Food Security in West Java	0.003
99.	2020	Development of Unpad Hybrid Corn in an Intercropping Pattern in an Integrated Farming System with Sheep to Improve Farmers' Welfare in Arjasari, West Java	0.007
100.	2020	Yeast as an inducer of plant resistance to control anthracnose and yellow curls in chili capsicum annuum L.	0.007
101.	2020	The Social Impact of the Difference in Farmer Prices of Arjasa Red Cayenne Pepper	0.004
102.	2020	Development of Unpad Corn Hybrids with High Nutrients as Pharmaceutical Excipients in Reducing Dependence on Imported Drugs in Indonesia	0.003
103.	2020	Halal Traceability Information System in Chicken Meat Distribution System in West Java	0.004
104.	2020	Application of Ketapang Badak (Ficus Lyrata Warb) Fruit Extract as a Natural Preservative in Chicken Carcass as a Promoter of Food Safety in Indonesia	0.004

Appendix 17. Continued…

No.	Year	Study Title	Real R&D Spending (Million USD)
105.	2020	Production of Xylitol, Bioethanol and Glucose Syrup in the Application of the Concept of a Hybrid Corn Commodity-Based Biomass Refinery Unpad	0.007
106.	2020	Productivity of Paddy Rice (Oryza Sativa L.) Under Weed Control, Planting Spacing In Different Land Preparations	0.005
107.	2020	Production of Basic Seeds for Four Genotypes of Red Chili Unpad and Launching of New Varieties of Seeds in Ciamis, West Java	0.005
108.	2020	Design and Build a Structured Market Oriented Mango Agribusiness Supply Chain Financing Model in West Java	0.007
109.	2020	Analysis of Actions on the Implementation of Labeling and Packaging on Gedong Gincu Mangoes to Improve the Welfare of Mango Farmers in Cirebon Regency	0.015
110.	2020	Efforts to Accelerate the Formation of Rice Lines Through Microspore Culture and Gene Pyramidization For Brown Planthopper Resistant Characters And High Quality Rice Through Molecular Markers	0.006
111.	2020	Phosphate Biological Fertilizer Formulation And Application To Improve Suboptimal Soil Quality, Increase Corn Crop Yield And Resistance To Disease	0.004
112.	2020	New Attractant Formulation and Innovation of Industrial-Scale Traps to Support Fruit Fly-Free Mango Exports	0.006
113.	2020	Assembly of Superior Rice Lines through Marker Assisted Gene Pyramiding and Involvement of Farmers in Participatory Plant Breeding	0.003
114.	2020	Investigating the Potential of Artificial Fruits, Vegetable Oil Formulations, and Their Combinations in Suppressing Oviposition of Fruit Flies Bactrocera Spp. On Chili Fruit	0.004
115.	2020	Detection of Genetic Variability of Peronosclerospora Spp. Causes of Downy mildew on Corn Plants in West Java	0.004
116.	2020	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.004
117.	2020	Development of Drought Tolerant and Adaptive Corn to Global Climate Change and Analysis of Water Needs in Arjasari, West Java	0.004
118.	2020	Assembling Sweet Corn Hybrids in Multiple-Cropping Cropping Patterns to Support Food Security in Indonesia	0.004
119.	2020	Utilization of Biofertilizer And Azolla Technology Packages To Increase The Quantity And Quality Of Organic Rice	0.004
120.	2021	Participatory Plant Breeding (Ppb) Unpad Red Chili	0.008
121.	2021	Optimization of Organic Biofertilizer and Ameliorant Formulas to Improve Sub-Optimal Soil Quality, Rice Yield and Inorganic Fertilizer Efficiency	0.006
122.	2021	Unpad Corn Selection Adaptive Various Cropping Patterns Based on Molecular Markings to Support National Corn Self-Sufficiency	0.008
123.	2021	Test the Effectiveness of Hydrogel Super Absorbent Polymer As Fertilizer Media To Increase Production Of Rice, Corn, In Dry Land	0.004
124.	2021	Growth and Productivity of Oil Palm Plants in Intercropping Patterns Based on Pajale Cassava and Chili in Supporting Food Security	0.006

Appendix 17. Continued…

No.	Year	Study Title	Real R&D Spending (Million USD)
125.	2021	Globalization Era: Efforts to Increase the Capacity of Mango Farmers in the Modern Market Viewed from the Dynamics of Agribusiness and Land Tenure	0.007
126.	2021	The Response of Deteriorated Soybean Seeds To The Application Of Seed Coating And Bokashi In Rice Fields	0.007
127.	2021	New Attractant Formulation and Innovation of Industrial-Scale Traps to Support Fruit Fly-Free Mango Exports	0.007
128.	2021	The Role of Water Status and Soil Aeration in Root Areas on Flowering Ability of Mangifera Indica L. Gedong Gincu Plants	0.007
129.	2021	Potential and Development of Bio-Pesticides Binahong [Anredera Cordifolia (Ten.) Steenis] To Control Rice Plant Diseases	0.004
130.	2021	Systemic Induction of Resistance in Rice Plants With Plant Extracts Against Swollen Root Nematodes Meloidogyne Graminicola	0.004
131.	2021	Soybean Agribusiness Development	0.005
132.	2021	Increased Production of Rice and Corn, on Sub-Optimal Land Through Fertilization Engineering in Order to Meet Food Security in West Java	0.005
133.	2021	The Social Impact of the Difference in Farmer Prices of Arjasa Red Cayenne Pepper	0.002
134.	2021	Development of Unpad Corn Hybrids with High Nutrients as Pharmaceutical Excipients in Reducing Dependence on Imported Drugs in Indonesia	0.001
135.	2021	Halal Traceability Information System in Chicken Meat Distribution System in West Java	0.001
136.	2021	Application of Ketapang Badak (Ficus Lyrata Warb) Fruit Extract as a Natural Preservative in Chicken Carcass as a Promoter of Food Safety in Indonesia	0.003
137.	2021	Production of Xylitol, Bioethanol and Glucose Syrup in the Application of the Concept of a Hybrid Corn Commodity-Based Biomass Refinery Unpad	0.003
138.	2021	Productivity of Paddy Rice (Oryza Sativa L.) Under Weed Control, Planting Spacing In Different Land Preparations	0.004
139.	2021	Production of Basic Seeds for Four Genotypes of Red Chili Unpad and Launching of New Varieties of Seeds in Ciamis, West Java	0.005
140.	2021	Design and Build a Structured Market Oriented Mango Agribusiness Supply Chain Financing Model in West Java	0.004
141.	2021	Analysis of Actions on the Implementation of Labeling and Packaging on Gedong Gincu Mangoes to Improve the Welfare of Mango Farmers in Cirebon Regency	0.004
142.	2021	Efforts to Accelerate the Formation of Rice Lines Through Microspore Culture and Gene Pyramidization For Brown Planthopper Resistant Characters And High Quality Rice Through Molecular Markers	0.001
143.	2021	Phosphate Biological Fertilizer Formulation And Application To Improve Suboptimal Soil Quality, Increase Corn Crop Yield And Resistance To Disease	0.004

Source: Padjadjaran University, 2021

Appendix 18. R&D spending based on selected study title of Hasanuddin University, 2015-2020

No.	Year	Study Title	Real R&D Spending (Million USD)
1.	2016	A Study on Rumen Microbial Diversity of Buffalo and Cattle Livestock Using Biomolecular Techniques to Produce Biodecomposers to Optimize Agricultural Waste As a Source of Fiber for Ruminants	0.004
2.	2016	Development of biopesticide and seed industry with active ingredients of endophytic fungi plus sonic bloom on rice plants to support national food self-sufficiency	0.052
3.	2016	Increasing farmers' income through Mina Padi and integrated and sustainable development of maize with livestock.	0.013
4.	2016	Increasing farmers' income through technical improvements in cocoa cultivation and post-harvest in an integrated and sustainable manner	0.012
5.	2017	Impact of Climate Change on Reproductive Phenology and Productivity of Mangoes	0.004
6.	2017	Food Production from Cocoa and Soybean “Kokolai”	0.023
7.	2017	Farming Development of Rice-Based Integrated Agricultural Systems (Plants-Livestock) Through Climate Field Schools (SLI)	0.001
8.	2017	PBK Pest Trapping Pheromone Application, Cocoa Farmer Solution in Betao Riase Village, Pitu Riawa District, Sidrap Regency	0.001
9.	2018	Impact Analysis of Climate Change on Cocoa Productivity and Quality in South Sulawesi (Case Study in Bantaeng Regency)	0.003
10.	2018	Engineering and Application of Organic Fertilizer Applicators for Rice Plants	0.008
11.	2018	In Supporting Food Self-Sufficiency	0.015
12.	2018	PA'LOPIAN: The Gait of Makassar Bugis Seafarers in the Archipelago in the Distribution of Agricultural Products, Especially Rice	0.001
13.	2018	Application of Straw Baller and Complete Feed to Support the Utilization of Agricultural Waste as Cattle Feed in Maros Regency	0.004
14.	2018	Application of MDG's Scorecard and Priority Chart to Combat Poverty of Cocoa Farmers in the Sulawesi Economic Corridor as the Spearhead of National Cocoa Exports and Anticipation Facing the European Union Market	0.001
15.	2018	Culture Organic Farming (Farmers Character Building in Modern and Sustainable Rice Field Management)	0.001
16.	2019	IBM Designs a Corn Sheller Machine to Increase Production Capacity of Hybrid Corn Farmers in Suli Village, Suli District, Luwu	0.010
17.	2019	Development of Animal Functional Food Products Rich in Antioxidants through Fortification of Bioactive Compounds of Broiler Check Collagen Extract	0.013
18.	2019	Engineering and Application of Organic Fertilizer Applicators for Rice Plants in Supporting Food Self-Sufficiency	0.017
19.	2019	Development of the Supplement Food Product Industry from Cocoa Commodities	0.019
20.	2019	Pa'lopian (the Gait of Makassar Bugis Seafarers in the Distribution of Agricultural Products, Especially Rice from South Sulawesi)	0.006
21.	2019	Enrichment of Agricultural Waste Compost with Phosphate Solvent Microbes Applied with Natural Phytohormones to Increase Chili Growth	0.003
22.	2020	Impact Analysis of Contract Farming Partnership on Red Chili Farmers' Income (Study in Magelang Regency)	0.003
23.	2020	Pa'lopian (Idea of Rice Paddy Agricultural Development Policy Oriented to Archipelago Market)	0.002
24.	2020	PKM Application of Biodecomposer Technology to Increase the Utilization of Agricultural Waste as Beef Cattle Feed in Bulo Village, Panca Rijang District, Sidrap Regency	0.005

Source: Hasanuddin University, 2020

Appendix 19. List of selected rice varieties resulted by IAARD, 2015-2020

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
1.	Rice	Inpari 38 Rainfed Agritan	2015	8.16	Moderately tolerant to drought, suitable in irrigated low land rainfed ecosystems with the elevation to 600 meter above sea level (m asl), soft and tender texture with the amylose content of 20.9%.
2.	Rice	Inpari 39 Rainfed Agritan	2015	8.45	Moderately tolerant to drought, suitable in irrigated low land rainfed ecosystems with the elevation to 600 m asl, soft and tender texture with the amylose content of 20.2%.
3.	Rice	Inpari 40 Rainfed Agritan	2015	9.60	Soft and tender texture with the amylose content of 23.6% and moderately tolerant to drought.
4.	Rice	Inpari 41 Rainfed Agritan	2015	7.83	Suitable in irrigated low land rainfed ecosystems with the elevation to 600 m asl, soft and tender texture with the amylose content of 20.1%.
5.	Rice	Inpago 11 Agritan	2015	6.00	Moderately tolerant to drought during vegetative phase, hard and loose texture with the amylose content of 21.3%, optimal in low land ecosystems with the elevation to less than 700 m asl.
6.	Rice	Inpari 42 Agritan GSR	2016	10.58	Suitable in optimal and sub-optimal low land irrigated ecosystems with the elevation to 600 m asl. High yield productivity, soft and tender texture with the amylose content of 18.84%.
7.	Rice	Inpari 43 Agritan GSR	2016	9.02	Soft and tender texture with the amylose content of 18.99%, suitable in fertile and non-fertile paddy ecosystems with the elevation to 0-600 m asl.
8.	Rice	Inpari 44 Agritan	2016	9.25	Hard and loose texture with the amylose content of 22.55%, suitable in irrigated paddy ecosystems with the elevation to 600 m asl.
9.	Rice	Mustaban Agritan	2017	10.86	Soft and tender texture with the amylose content of 13.13%, suitable in low land paddy ecosystems with the elevation to 600 m asl.
10.	Rice	HIPA 18	2017	10.30	Hybrid paddy variety, with soft and tender texture with aromatic with the amylose content of 22.7%, suitable in paddy ecosystems area.
11.	Rice	Rindang 1 Agritan	2017	6.97	Hard and loose texture with the amylose content of 26,4%, tolerant to shade, moderately tolerant to drought and tolerant to Al contamination up to 40 ppm, adaptive to dry land in low land, suitable to be planted as intercropping with estate crops commodity and industrial commodities.
12.	Rice	Rindang 2 Agritan	2017	7.39	Soft and tender texture with the amylose content of 16.4%, tolerant to shade, moderately tolerant to drought and highly tolerant to Al contamination up to 40 ppm, adaptive to dry land on low land areas.

Appendix 19. Continued…

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
13.	Rice	Inpago 12 Agritan	2017	10.20	Brown rice with white color and medium size, having moderate texture with the amylose content of ±22.8%. Adaptive in fertile and acid dry land in low land paddy ecosystems with elevation up to 700 asl.
14.	Rice	Inpara 8 Agritan	2018	6.00	Hard and loose texture with the amylose content of 28.5%, suitable in tidal land, low and moderate swamp ecosystems. This variety has specific attribute especially the ability of stem elongation to be in level with water and tolerant to stagnant flooding between 60-80 cm until generative phase
15.	Rice	Inpago 10	2018	7.31	Moderately tolerant to drought and contamination, moderate taste with amylose content of 24.9%, suitable in dry land on low land with the elevation less than 700 m asl.
16.	Rice	Siliwangi Agritan	2018	10.70	Soft and tender texture with the amylose content of 21.2%. Suitable in low land irrigated land to medium with the elevation of 600 m asl.
17.	Rice	Inpara 10 BLB	2018	6.80	Medium texture with amylose content of 24.9%, tolerant to Fe contamination and suitable in freshwater swamp and tidal swamp land.
18.	Rice	Purwa	2018	6.70	Sticky rice texture with amylose content of 3.8%, moderately tolerant to Fe contaminant, suitable in tidal swamp and freshwater swamp land.
19.	Rice	Bio Patenggang Agritan	2019	6.00	Soft and tender texture with amylose content of 16.2%. Moderately tolerant to Al contaminant up to 40 ppm, and moderately tolerant to drought and vegetative phase.
20.	Rice	Inpari IR Nutri Zinc	2019	9.98	Potenital content of Zinc at 34.51 ppm with average level at 29.54 ppm, soft and tender with amylose content of ± 16,6 %, suitable in wetland areas with elevation of 600 m asl.
21.	Rice	HIPA 20	2019	12.08	Hybrid rice, soft and tender with amylose content of 22,89%, increase productivity 20% from non-hybrid, seed production testing up to 1.5 MT per ha, suitable in wetland areas with elevation of 300 m asl.
22.	Rice	Pamera	2019	11.33	Moderate texture with amylose content of 21.1%, suitable in irrigated wetland areas with elevation of 0-600 m asl.
23.	Rice	Biosalin 1 Agritan	2020	8.70	Suitable in wetland ecosystem with high salinity in coastal and intrusion sea water area, soft and tender texture with amylose content of 20,07%, tolerant to salinity during seedling process (score 3.33).

Appendix 19. Continued…

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
24.	Rice	Biosalin 2 Agritan	2020	9.06	Suitable in wetland ecosystems under high level of salinity in coastal and sea water intrusion area. Moderate texture with amylose content of 20.57%, tolerant to salinity during seedling process (score 3.0).
25.	Rice	Biobestari Agritan	2020	7.90	Soft and tender texture with amylose content that low from (21%) compare with IR64 (23%). Resistance toward pest (brown plant hopper) and diseases (rice blast disease, bacterial leaf blight, and tungro virus disease), tolerant to abiotic stress ecosystems such as aluminium contamination and drought then it could be expanded to other land ecosystems included dry-land acid land areas.
26.	Rice	Bioni 63 Ciherang Agritan	2020	7.00	Suitable during rainy season and dry season with the elevation less than 500 m asl.

Note: *] related to consumer's preference and agro-ecosystem suitability
Source: ICFCRD, 2021

Appendix 20. List of selected maize varieties resulted by IAARD, 2015-2020

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
1.	Maize	JH 27	2015	12.60	Lodge root and stem as well as highly adaptive in low land or up land. For food/feed consumption, it contains of 78.45% carbohydrates, 7.59% protein and 4.13% fat.
2.	Maize	JH 234	2015	12.60	Adaptive in low land with elevation of 5-1,000 m asl.
3.	Maize	Pulut URI 2	2016	9.20	Has a strong root, strong and big stems. It contained 52.3% carbohydrates, for food/feed consumption it contains of 11.7% protein, 7.1% fat, 9.4% amylose, dan 55.9% amylopectin.
4.	Maize	JH 36	2016	12.20	Resistant to lodged-root, stem and adaptive in low land areas.
5.	Maize	JH 45	2016	12.60	Resistant to lodging and adaptive in low land areas.
6.	Maize	Nakula Sadewa 29	2017	13.70	Adaptive in low to high-land ecosystems and prolific more than 30% in suitable ecosystems.
7.	Maize	JH 35	2017	12.90	Adaptive in low to high-land ecosystems with the elevation of 17–1024 m asl.
8.	Maize	JH 47	2017	12.80	Moderately tolerant to drought, suitable in low land areas.
9.	Maize	HJ 28 Agritan	2018	12.90	Adaptive in areas with the elevation of 5-650 m asl.
10.	Maize	Srikandi Ungu 1	2018	8.50	Adaptive and stable in sub-optimal low land areas.
11.	Maize	Jhana 1	2019	12.45	Drought tolerant and tolerant to shading with light less than 50%.
12.	Maize	JH 29	2019	13.60	Adaptive in low-land and high-land areas with the elevation of 17-1024 m asl. As for food and feed consumption, it consists of ± 70,02% carbohydrates, ± 10.02% protein and at 6.34% fat
13.	Maize	JH 30	2020	12.60	Highly adaptive in low-land to high-land areas with the elevation of 17-1024 m asl. For food/feed consumption, it consists of ± 67,35% carbohydrates ± 10,12%, protein and 9,03% fat.
14.	Maize	JH 31	2020	13.60	Highly adaptive in low-land to high-land areas with the elevation of 17–1024 m asl.
15.	Maize	JH 32	2020	13.60	Highly adaptive in low-land to high-land areas with the elevation of 17–1024 m asl.

Note: *] related to consumer's preference and agro-ecosystem suitability
Source: ICFCRD, 2021

Appendix 21. List of selected soybean varieties resulted by IAARD, 2015-2020

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
1.	Soybean	Devon 1	2015	3.09	Content of protein 34.8% dan fat 17.34%.
2.	Soybean	Dega 1	2016	3.82	Adaptive in wetland areas. Content of protein 37.78% dan fat 17.29%.
3.	Soybean	Deja 1	2017	2.87	Highly tolerant to saturated water stress from 14 days after planting until maturity phase.
4.	Soybean	Deja 2	2017	2.75	Tolerant to saturated water stress from 14 days after planting until maturity phase.
5.	Soybean	Devon 2	2017	2.89	Isoflavon (Genistein dan Daidzein) content 303,70 μg BK.
6.	Soybean	Derap 1	2018	3.16	Harvesting at 76 days.
7.	Soybean	Demas 2	2019	3.27	Harvesting at 77 days.
8.	Soybean	Biosoy 1	2019	3.30	As food, its content of (in dried-weight) 39.7% protein and 18.4% fat. This variety can be used as raw material for tempeh, tofu, soy milk, and other soy-based processed products.
9.	Soybean	Biosoy 2	2019	3.50	Its content of (in dried weight) 40,5% protein and 20,1% fat
10.	Soybean	Dering 2	2020	3.32	Highly tolerant to drought stress during germination period
11.	Soybean	Dering 3	2020	2.99	Highly tolerant to drought stress during germination period.

Note: *] related to consumer's preference and agro-ecosystem suitability
Source: ICFCRD, 2021

Appendix 22. List of selected shallot varieties resulted by IAARD, 2016-2020

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
1.	Shallot	Violetta 1 Agrihorti	2018	17.32–24.66	Harvesting period: 68-74 days after planting. Round bulb with length 2,93-3,36 cm diameter 1,65–2,26 cm. Bulb color: dark purple with weight per-bulb is 3.62-7.20 g, having shelf life at room temperature 25-30ºC for duration around 2-3 months after harvest. Suitable in high-land areas.
2.	Shallot	Violetta 2 Agrihorti	2018	23.12-29.07	Harvesting period:86 days after planting, round bulb with length 2.65 - 2.84 cm and diameter 2.01-2.10 cm. Bulb color: light pink, with average weight per bulb between 8.84 - 10.21 g. Suitable in high-land areas.
3.	Shallot	Ambassador 1 Agrihorti	2018	21.88-26.54	Harvesting period: 71 after planting, round bulb with length 28.15 - 32.36 mm and diameter 23.80 - 25.27 mm. Bulb color: dark purple, with average weight per bulb around 15.05 - 23.33 g. Suitable in low-land areas in West Bandung District, and during rainy season.
4.	Shallot	Ambassador 3 Agrihorti	2019	21.64-23.92	Harvesting period: 78 days after planting, round bulb with sharp edge, length 27.64 -32.99 mm and diameter 21.63-24.81 mm. Bulb color: light purple, average weight per bulb 11.08- 15.06 g. Bulb loss relatively low. Suitable in high-land areas in West Bandung District, and during rainy season.

Note: *] related to consumer's preference and agro-ecosystem suitability
Source: ICHRD, 2021

Appendix 23. List of selected chili varieties resulted by IAARD, 2016-2020

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
1.	Chili	Lingga	2016	13.40-20.50	Height: 87-97 cm, width: 4.8 – 6.1 cm, harvesting 88-95 days after planting, fruit length: 11.2-12.9 cm, sharp edge with red color during maturity. Capsaicin level is 160.3 ppm (moderate hot). Shelf-life temperature between 21-25ºC for 7-10 days after harvest. Adaptive in medium to high-land areas with the elevation of 510-550 m asl in rainy season and wet-dry season.
2.	Chili	Ciko	2016	20.50	First harvest at 81-84 days after planting, highly adaptive in medium elevation.
3.	Chili	Inata Agrihorti	2019	14-20	Height: 58-60 cm, fruit maturity: 97-120 days after planting, fruit length: 14-16 cm, fruit width 1,8 cm, shelf life period in room temperature at (24°C-27°C) with maximum duration 7 days. Adaptive in high-land and dry season.
4.	Chili	Carla Agrihorti	2020	8-20	Height: 65-68 cm, fruit maturity: 107-114 after planting, fruit length: 13-15 cm, fruit width: 1 cm, shelf life period in room temperature (24°C-27°C) with maximum duration 7 days. Adaptive in high-land areas in rainy season, tolerant to fruit flies (Bactrocera dorsalis).
5.	Chili	Rabani Agrihorti	2018	13.00	Adaptive in high-land areas with capsaicin level 980 ppm (very hot) and shelf-life in room temperature 21-23˚C with maximum duration 10-12 days after harvesting.

Note: *] related to consumer's preference and agro-ecosystem suitability
Source: ICHRD, 2021

Appendix 24. List of coffee varieties resulted by ICCRI, Indonesia, 2019

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
1.	Coffee	Hibiro 1: (BP 936 X Bp 534)	2019	2.80	Stable, highly adaptive, cupping score 83 (extremely good/premium), bean quality very good.
2.	Coffee	Hibiro 2 : (BP 534 X Bp 936)	2019	2.70	Stable and very adaptive, cupping score 83.25 (extremely good)/premium, bean quality very good.
3.	Coffee	Hibiro 3 : (BP 939 X Bp 936)	2019	2.60	Stable and very adaptive, cupping score 85 (extremely good/premium) or known as cups of excellence, has a potential as fine flavor coffee, high quality bean with medium bean size.
4.	Coffee	Hibiro 4 : (BP 935 X Bp 436)	2019	2.50	Stable and adaptive in wet-type micro climate, cupping score 82,75 (extremely good/premium), bean quality medium.
5.	Coffee	Hibiro 5 : (BP 534 X Sa 13)	2019	2.40	Stable and adaptive with cupping score 84,25 (extremely good/premium), has a potential as fine flavor coffee, bean quality medium.

Note: *] related to consumer's preference and agro-ecosystem suitability
Source: ICHRD, 2021

Appendix 25. List of cocoa varieties resulted by ICCRI, Indonesia, 2019

No.	Commodity	Variety Name	Year of release	Potential yield (ton/ha)	Main characteristics*]
1.	Cocoa	Klon ICCRI 09	2019	1.84-2.75	Resistant to VSD, has flora. Bean quality: weight 1,07-1,55 grams; kernel contains 11,0-21,7%; and fat contains 48,55%

Note: *] related to consumer's preference and agro-ecosystem suitability
Source: ICHRD, 2021

Appendix 26. List of selected poultry and cattle improved feed composition resulted by IAARD, 2015-2021

No.	Livestock	Component or Package of Technology	Year of the First Dissemination
1.	Poultry	Enzyme Manganese BS4 for feed additive	2021
2.	Poultry	Herbal drinks formula “antikoksi” for poultry	2019
3.	Poultry	Development of probiotic “Bioviab” as feed additive for poultry	2018
4.	Cattle	Feed based technology on palm kernel oil with low fiber and high protein contained.	2021
5.	Cattle	Formulation of feed concentrate (pellet) production using *Gliricidia sepium* leaf for cattle fattening	2019
6.	Cattle	Complete Rumen Modifier feed additive	2019
7.	Ruminant	Formulation of Green Leaves Concentrate for feed additive for ruminants	2019
8.	Cattle	Formulation and process feed additive as the source of antioxidant for cattle	2019
9.	Ruminant	Formulation Agent Defaunasi Protozoa Rumen using molasses as ingredients and Waru leaves.	2019
10..	Ruminant	Formulation of Green Leaves Concentrate for feed additive for ruminants	2019
11.	Cattle	Formulation and process feed additive as the source of antioxidant for cattle	2019
12.	Ruminant	Formulation Agent Defaunasi Protozoa Rumen using molasses as ingredients and Waru leaves.	2019
13.	Ruminant	High Yielding Plants for Feed “*Indigofera gozollagribun*”	2019
14.	Ruminant	Development of Probiotics Bio-plus Calf	2016
15.	Ruminant	The process of making selection probiotic microbes rumen for feed additive toxic tolerant for ruminant	2016

Source: IAARD, 2021

Appendix 27. List of selected postharvest technologies resulted by IAARD, 2016-2020

No	Component or Package of Technology	Commodity or Product Developed	Year of the First Dissemination
1	Artificial rice making process from Indonesia indigenous-flour	Flour from local food sources	2020
2	The production process of gluten free noodle from cassava-based ingredients	Noodle gluten from cassava	2020
3	The production process of cassava-paste with no additional wheat flour	Cassava paste	2020
4	The production process of vinegar from coconut water in powder base	Vinegar	2020
5	The production process of noodle from sago with natural red color extract	Noodle from sago	2020
6	The production process of antioxidant coffee powder	Coffee antioxidant	2019
7	The process of removing bitterness in aloe vera jelly drink	Aloe Vera drink	2019
8	Instant rice production process	Instant rice	2019
9	The formulation and production process of gluten free cake using cassava flour	Cake gluten free from cassava	2019
10	The production process of instant mungbean	Mung beans	2019
11	The production process of gelatin from chicken feet	Chicken gelatin	2019
12	The production process of shallot powder	Shallot powder	2019
13	The process and formulation of fortified rice milk	Milk-rice fortified	2019
14	The technology process for reducing glycemic index on sweet potato noodles	Sweet potato low glycemic index	2019
15	The production process of shallot oil	Shallot oil	2018
16	The production process of pre-gelatinized cassava flour	Cassava flour	2018
17	Formulation and process of instant tiwul (processed cassava)	Processed cassava	2018
18	The production process probiotic yoghurt	Dairy (yogurt)	2018
19	The composition of purple sweet potato ice cream	Sweet Potato ice cream	2018
20	Formulation and process of local root (kimpul) sweet bread	Bread from local root (*kimpul*)	2017
21	The production process of cassava rice	Processed cassava	2017
22	The production process of catfish feed from rice bran, soybean flour, and blood flour	Fish feed	2017
23	The method to reduce unsaturated fat in vegetable oils	Vegetable oil	2017
24	The composition of sweet potato noodle	Noodle from sweet potato	2016
25	The composition of bread fruit noodle	Noodle from breadfruit	2016

Source: IAARD, 2021

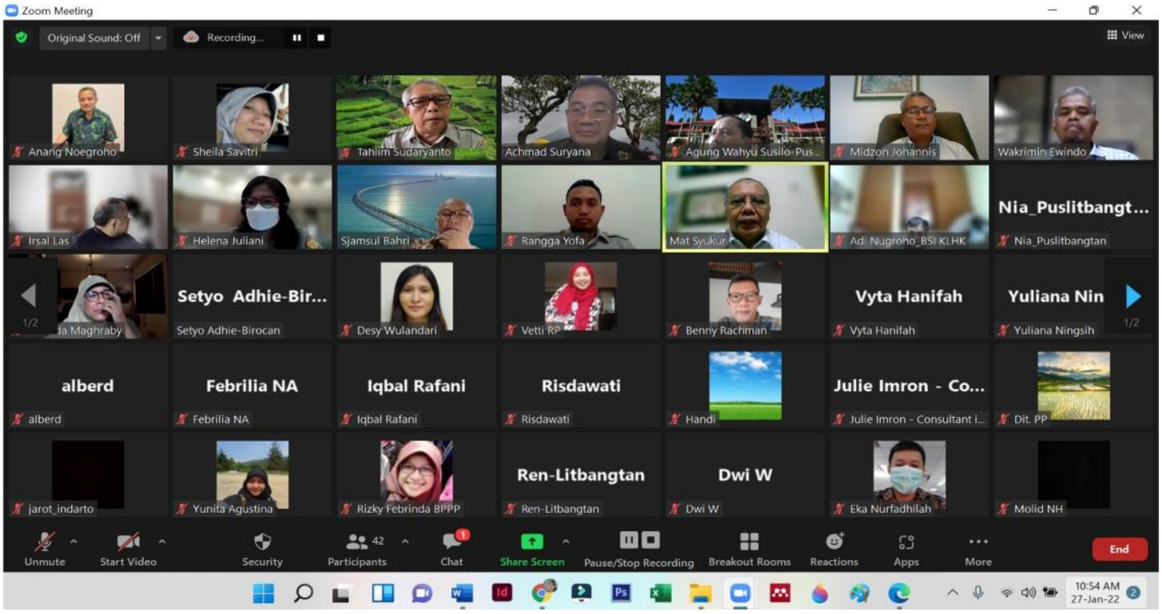
Appendix 28. Research activities documentation

1. Kick off Meeting of the Full team, 04 January 2022 (offline)

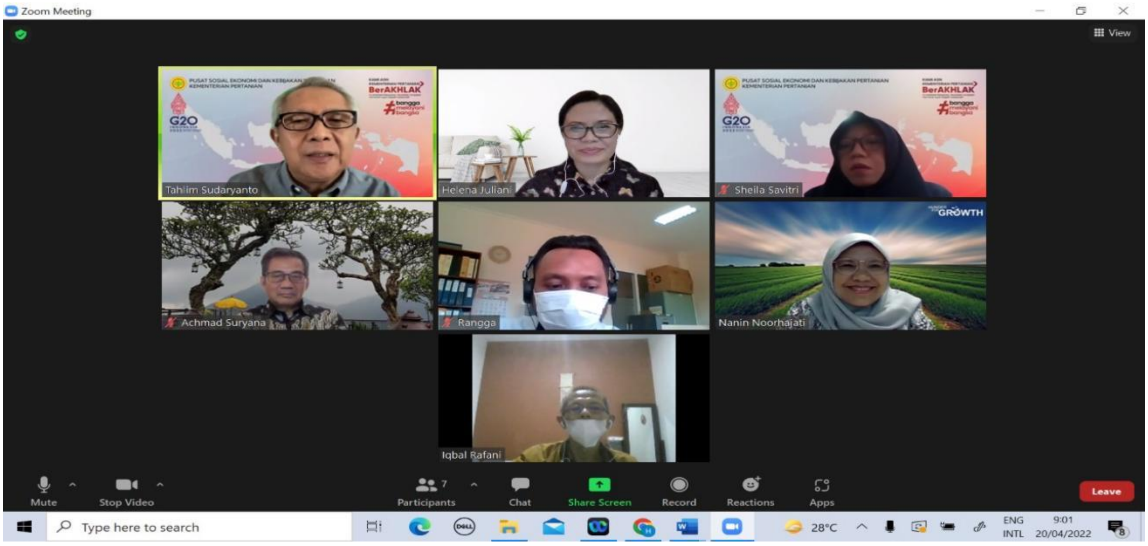
2. Meeting and Discussion with Person in Charge about R&D Budget at IAARD office, 13 January 2022

3. Discussion with staff at NPR, 20 January 2022

4. Focus Group Discussion with policy maker and several stakeholders, 27 January 2022



5. Meeting and In-depth interview with Person in Charge of R&D matters at Syngenta Indonesia, 20 April 2022 (Virtual)



6. Mid-term report preparation, 27-29 Mei 2022 (offline)

7. In-depth interview with former Director of Indonesian Coffee and Cocoa Research Institute, Dr. Agung Wahyu Susilo, 27 May 2022 (online)

8. In-depth interview with Director of Indonesian Center for Food Crops Research and Development (ICFORD), Dr. Priyatna Sasmita, 09 June 2022 (offline)

9. In-depth interview with former Director of Indonesian Center for Animal Research and Development (ICARD), Dr. Atien Priyanti, 04 July 2022 (offline)

11. In-depth interview with expert from IPB University, Prof. M. Firdaus, 03 August 2022 (offline)

12. The second stakeholders meeting was conducted on 04 October 2022 (hybrid meeting platform):
    A. Foto Group

    B. Presentation session

13. The final stakeholder validation meeting in Bogor on 24 November 2022