CGIAR
Standing Panel on Impact Assessment

SPIA Viet Nam Report: Global Ambitions, Sustainable Pathways

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SPIA Country Study: Vietnam, 2nd Report

The Standing Panel on Impact Assessment

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All analyses presented in this report are fully reproducible in R and are available in Github. Additional materials can be found in the Repository and Annexes.

Cover Photo: A farmer harvests hedgerow grass planted to prevent soil erosion.
Credit: CIAT/Georgina Smith

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Abbreviations and Acronyms

1M5R	One Must Do, Five Reductions
3R3G	Three Reductions, Three Gains
ABM	Area-Based Management
ACB	Agro-Climatic Bulletin
ACIS	Agro-Climate Information Services
AGI	Agricultural Genetics Institute
AW	Mua/Autumn-Winter
AWD	Alternate Wetting and Drying
CAPI	Computer-Assisted Personal Interviews
CBFC	Community-Based Fish Culture
CBFM	Community-Based Fisheries Management
CCAFS	CGIAR Research Program on Climate Change, Agriculture, and Food Security
CH	Central Highlands
CBH	Combine Harvester
CIAT	International Center for Tropical Agriculture
CIFOR	Center for International Forestry Research
CIP	International Potato Center
CLRRI	Cuu Long Rice Research Institute
CMD	Cassava Mosaic Disease
CPC	Commune People's Committee
CPI	Consumer Price Index
CRP	CGIAR Research Program
CS-MAP	Climate-Smart Mapping and Adaptation Planning
CSO	Civil Society Organization
DAP	Diammonium phosphate
DARD	Department of Agriculture and Rural Development
DMC	Dry Matter Content
DNA	Deoxyribonucleic Acid
EAs	Enumeration Areas
ENSO	El Niño-Southern Oscillation
FAnGR	Farm Animal Genetic Resources
FAO	United Nations Food and Agriculture Organization

FCRI	Field Crops Research Institute
FPDF	Forest Protection and Development Fund
FRC	Fisheries Resource Co-management
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GIFT	Genetically Improved Farmed Tilapia
GIS	Geographic Information System
GSO	General Statistics Office of Viet Nam
HLARC	Hung Loc Agricultural Research Center
IAA	Integrated Agriculture-Aquaculture
IBS	Identity By State
ICRAF	World Agroforestry
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
INGER	International Network for Genetic Evaluation of Rice
IPM	Integrated Pest Management
IPSARD	Institute of Policy and Strategy for Agriculture and Rural Development
IRRC	Irrigated Rice Research Consortium
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
LLL	Laser Land Leveling
M&E	Monitoring and Evaluation
MAB	Marker-Assisted Selection
MAF	Minor Allele Frequency
MARD	Ministry of Agriculture and Rural Development
MAS	Marker-Assisted Selection
MCHB	Mini-combine Harvester
MoNRE	Ministry of Natural Resources and Environment
MRD	Mekong River Delta
NARS	National Agricultural Research Systems
NC	North Central
NDC	Nationally Determined Contribution
NES	No Early Sowing

NGO	Non-Governmental Organization
NM	Northern Midlands and Mountain Area
NP	Nitrogen and Phosphate
NPK	Nitrogen, Phosphate, Kali/Potassium
OLS	Ordinary Least Squares
ONI	Oceanic Niño Index
PAEC	Provincial Agricultural Extension Centers
PFES	Payments for Forest Environmental Services
PPS	Probability Proportionate to Size
PRC	Plant Resources Center
PSO	Province Statistics Office
QTL	Quantitative Trait Locus
RCRDC	Root Crop Research and Development Center
RRD	Red River Delta
RSB	Rice Straw Baler
RSM	Rice-Straw Mushroom
SA	Summer–Autumn
SCC	South Central Coastal Region
SD	Standard Deviation
SDC	Swiss Development Cooperation
SI	Sustainable Intensification
SNP	Single Nucleotide Polymorphism
SPIA	Standing Panel on Impact Assessment
SRI	Sustainable Rice Intensification
SSC	South Central Coast
SSNM	Site-Specific Nutrient Management
STRV	Salt-Tolerant Rice Variety
TiLV	Tilapia Lake Virus
VHLSS	Viet Nam Household Living Standards Survey
VietGAP	Vietnamese Good Agricultural Practices
VND	Vietnamese Dong
VNFF	Viet Nam Forest Protection and Development Fund
VnSAT	Viet Nam Sustainable Agriculture Transformation
WS	Winter–Spring

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Executive Summary

This report presents the results of a comprehensive study on the adoption and diffusion of CGIAR-related agricultural innovations in Viet Nam. It expands on the first SPIA Viet Nam country study (Preliminary Insights into the Adoption of CGIAR-Related Agricultural Innovations in Viet Nam (Kosmowski, F. et al., 2023)), including innovations across multiple CGIAR research domains: aquaculture; breeding; climate change adaptation; digital tools; environmental conservation; livestock and human health; mechanization; and sustainable intensification practices. This study aims to examine the role of CGIAR research in farmers' adoption of innovations and agricultural practices in Viet Nam.

Viet Nam's GDP per capita has increased nine-fold over the past two decades. This economic transformation has been accompanied by a shift in the agricultural sector toward a more commercial orientation. This period of transformation is believed to have driven economic growth and contributed to poverty reduction. The strategic importance of Viet Nam for CGIAR is underscored by this context and exemplified through the establishment of CGIAR centers and the recent implementation of several CGIAR Research Initiatives within the country.

Using a stocktaking approach, we identified 78 innovations, and 30 policy contributions plausibly linked to CGIAR research over the two decades from 2003 to 2023. These findings were based on extensive interviews and evidence gathering. It also identified a subset of 19 innovations that showed promise of adoption on a larger scale.

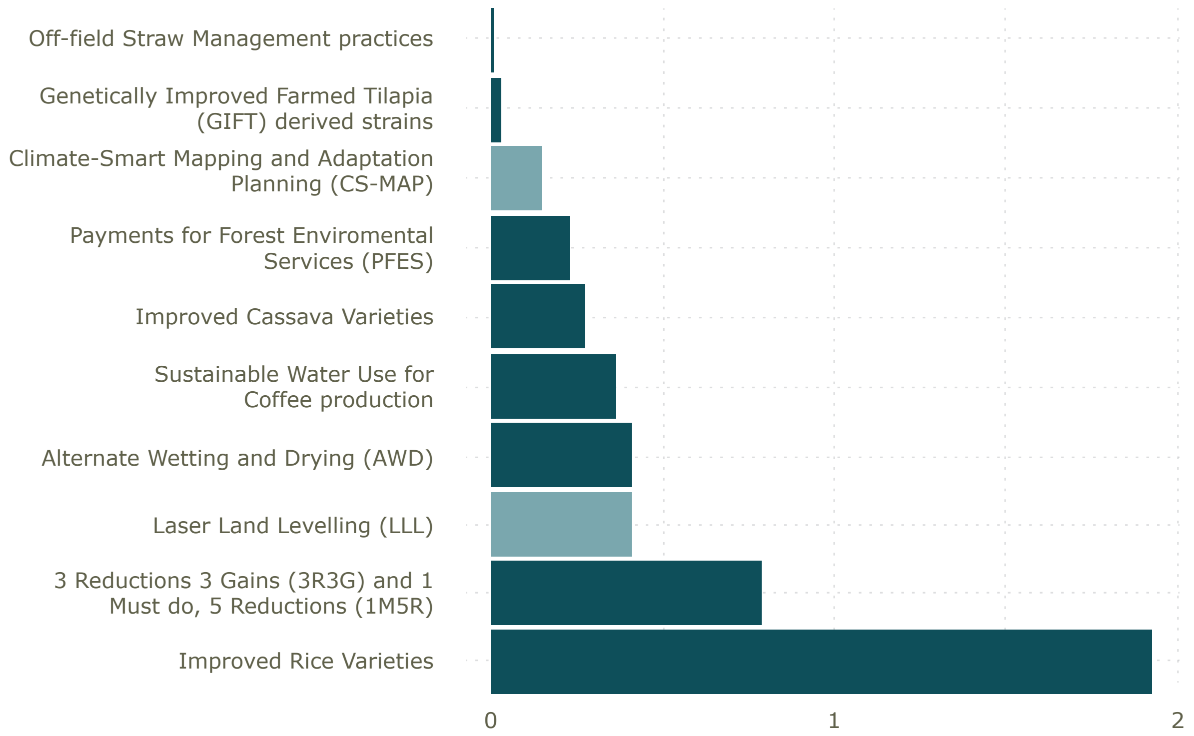
This study provides adoption estimates for each of these 19 innovations, providing insights into the geographic adoption distribution and socioeconomic characteristics of adopters. Assessing the reach of agricultural innovations, defined by adoption levels and beneficiary numbers, is key to understanding their impact.

The study partnered with Viet Nam’s General Statistics Office (GSO) and utilized data from the Viet Nam Household Living Standards Survey (VHLSS) to assess reach. By integrating new modules into the VHLSS, the adoption of 19 selected innovations was quantified using advanced methodologies, including the DNA fingerprinting of crops and aquaculture specimens. For certain innovations, further analyses were conducted using qualitative content analysis and geospatial tools to deepen understanding of adoption patterns.

The attribution of agricultural innovations to CGIAR research remains a challenge due to the involvement of multiple actors in the sector, but among the 19 innovations documented in this report, compelling links to CGIAR research were identified for 10 of them.

The study estimates that between 3.7 and 3.9 million Vietnamese households have been reached, indicating a significant potential impact on rural communities and underscoring the enduring influence of CGIAR’s work in Viet Nam. In 2023, improved rice varieties reached close to two million households (Figure 1). Sustainable intensification practices, including ‘Three Reductions, Three Gains’ and ‘One Must Do, Five Reductions’, Alternate Wetting and Drying, and Sustainable Water Use for Coffee Production, also show significant adoption. Some innovations, such as GIFT-derived tilapia strains, appear in a few farming households but are likely to be prevalent in the commercial sector, as evidenced by the high presence of GIFT-derived tilapia fingerlings in hatcheries.

Figure 1: Number of households adopting each CGIAR-related innovation in Viet Nam in 2023, in millions



Note: Innovations in dark blue are included in the lower bound of CGIAR reach. To calculate the upper bound of CGIAR's reach, we include innovations in light blue.

This success highlights the crucial roles of National Agricultural Research Systems (NARS), public sector dissemination efforts, and private sector markets in facilitating the diffusion and adoption of these innovations.

While there is considerable heterogeneity among households adopting CGIAR-related innovations in Viet Nam, we have not identified a single clear pathway that consistently links specific innovations to particular household categories. Rather, the data suggest that factors such as annual income, gender, and ethnicity are associated with adoption, but that these associations are not uniform across all innovations. The results are mixed, and only a few socioeconomic characteristics consistently show either a positive or negative correlation with the adoption of several innovations.

The adoption rates also exhibit significant regional variation, reflecting Viet Nam's diverse agroecological landscape. Interestingly, adoption extends beyond the two agriculturally intensive deltas to other areas. For instance, improved rice varieties are prevalent in the Mekong River Delta and the Southeast and Central Highlands. Sustainable intensification practices demonstrate the highest adoption rates in the Red River Delta. Concurrently, improved cassava varieties have achieved widespread adoption across all regions, except the deltas. These patterns elucidate how different innovations support farmers in diverse agricultural systems.

CGIAR emphasizes synergies between different agricultural innovations on the premise that integrated adoption enhances productivity, resilience, and overall economic outcomes (CGIAR System Organization, 2021). In Viet Nam, certain innovations are evidently synergistic – for instance, within rice-based systems, sustainable intensification, and climate services innovations likely complement one another. However, like the Ethiopian country study (Kosmowski et al., 2020), our findings in Viet Nam challenge this narrative. Our research reveals that few households in the sample adopt multiple distinct innovations. Innovations that have achieved scale often operate in silos with limited integration across systems, and no significant synergies exist between research domains or CGIAR centers.[1]

The adoption patterns outlined in this report reflect a dynamic, decade-long diffusion process, likely characterized by cycles of trial and errors. Indeed, this study offers only a snapshot of the adoption lifecycle. Nonetheless, the findings demonstrate that in a middle-income, export-oriented economy like Viet Nam, the adoption of CGIAR-related innovations is evident.

CGIAR innovations have been particularly widely adopted in three key sectors – rice exports, cassava exports, and aquaculture – in the form of improved rice varieties, improved cassava varieties, and GIFT-derived tilapia strains. Among these, only rice is indigenous to Viet Nam. The development of these varieties leveraged CGIAR germplasm as breeding material, potentially contributing to Viet Nam's integration into global rice markets since 2005. In cassava, the widespread adoption of germplasm with higher starch content has likely supported the rise of Viet Nam's cassava starch industry in the 2000s and helped establish the country as a major exporter of cassava starch and its by-products. GIFT-derived tilapia strains introduced during aquaculture expansion were dominant in hatchery supply chains in 2023, despite our findings that household ponds did not contain much GIFT-derived tilapia. This suggests a possible broader contribution to Viet Nam’s increasing aquaculture exports. Although this report cannot quantify the specific impacts of these innovations, they are likely to have contributed to Viet Nam’s agricultural transformation and integration into global markets. While designing a rigorous study to prove these hypotheses is challenging, further research is warranted.

In Viet Nam as in other country-level studies, translating farmers' adoption and practices into measurable indicators that are relevant for CGIAR is a confronting task. Further evidence was generated on the inaccuracy of farmers’ self-elicitation compared to the DNA fingerprinting benchmark. This country-level study also demonstrates that these discrepancies extend to the domain of sustainable intensification practices.

Several methodological advancements that can be replicated in future impact assessment studies were introduced. We conducted the first DNA fingerprinting strain identification survey of fish at the household level. To enhance the precision of measuring complex bundles of agronomic practices, we implemented a mixed-methods approach. However, several challenges persist. The reach of climate change adaptation recommendations presents new data collection challenges, as innovations such as climate services can only be observed in action during extreme events.

[1] We acknowledge that different innovations were measured in different survey waves and only a portion of the VHLSS sample is a panel. For example, rice DNA samples were collected in 2022, while adoption of the 3R3G/1M5R innovation was assessed in 2023. This limitation primarily affects crop-specific systems, as the crops covered in this report are typically cultivated in distinct geographical areas of Viet Nam.

This stocktaking exercise has highlighted the diverse research outputs contributing to agricultural innovations in Viet Nam. By underscoring the importance of objective and innovation-specific measurements, the data gathered from a nationally representative survey lays the groundwork for understanding the impact of these innovations in the country – SPIA will continue to measure the reach and impact of CGIAR-related innovations in Viet Nam until at least 2030.

Furthermore, the Viet Nam Household Living Standards Survey (VHLSS) will continue to refine these measurements, and its panel dimension will serve to monitor adoption trends over time. The insights provided by these data not only provide evidence of current adoption patterns but also inform future research and development efforts.

Credit: Haki Comunication

Inspecting cassava trials in Yen Bai, northern Vietnam.
Credit: CIAT/Georgina Smith

1. Introduction

CGIAR celebrated its 50th anniversary in 2021. As the largest global research partnership for a food-secure future dedicated to transforming food, land, and water systems in a climate crisis, CGIAR aims to contribute towards and beyond multiple Sustainable Development Goals. To this end, and to tackle sustainability challenges through science-based innovation, capacity development, and policy advice, the CGIAR 2030 Research and Innovation Strategy[2] sets out five thematic impact areas: Nutrition, Health and Food Security; Poverty Reduction, Livelihoods, and Jobs; Gender Equality, Youth, and Social Inclusion; Climate Adaptation and Mitigation; and Environmental Health and Biodiversity. Its work now spans 50 countries in 6 regions, drawing on expertise in multiple disciplines across CGIAR research centers[2].

It is the mandate of the Standing Panel on Impact Assessment (SPIA) to expand and deepen evidence of the impact of CGIAR's research investments. SPIA's approach to this effort recognizes that to achieve impact at scale, it is often necessary (although not sufficient) to reach a large number of beneficiaries (SPIA, 2020). Over the past decade, SPIA's national data system team has developed an approach to generate national-level evidence of reach and impact. Our objective is to generate independent estimates of the reach of CGIAR innovations while furthering an understanding of the characteristics of CGIAR's intended beneficiaries and to examine the synergies between the adoption of different innovations. In each country, the team conducts a stocktaking exercise to identify the innovations that may have diffused, then integrates new survey modules into existing national-level data collection efforts and partners with national statistics institutes to generate evidence about the actual reach and take-up of the innovations.

SPIA's most recent six-year workplan (2019 - 2024) gave it the remit to carry out this work in four countries: Bangladesh, Ethiopia, Uganda, and Viet Nam. In May 2023, the CGIAR System Council approved a new workplan for SPIA (2024-2030) to continue these four country studies and start new ones in four additional countries: Colombia, Egypt, India, and Nigeria. In addition, stocktaking exercises will be conducted in an additional twelve countries.

Viet Nam has been an important country for CGIAR research. The International Rice Research Institute (IRRI) was the first CGIAR center to establish a presence in 1992, followed in the 2000s by the International Center for Tropical Agriculture (CIAT)[3], the International Potato Center (CIP), and the International Livestock Research Institute (ILRI). Other centers, including Bioversity International[3], the International Food Policy Research Institute (IFPRI), the International Water Management Institute (IWMI), and WorldFish, have engaged in collaborative activities. During the period when CGIAR's research was organized into CGIAR Research Programs (CRPs), Viet Nam was one of six countries around the world, and the only one in

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[2] CGIAR 2030 Research and Innovation Strategy

[3] Following the One CGIAR transition, from the original 15 CGIAR Research Centers, the World Agroforestry Centre (ICRAF) and the Center for International Forestry Research (CIFOR) are no longer participating in CGIAR Initiatives (which superseded the CGIAR Research Programs) but retain local offices in Viet Nam. In 2020, the International Center for Tropical Agriculture (CIAT) and Bioversity International merged to become the Alliance of Bioversity International and CIAT. As this report includes research carried out before 2020, we refer to CIAT throughout.

Southeast Asia considered for ‘site integration++’, indicative of an extensive staff presence from multiple CGIAR centers (CGIAR Consortium Office, 2015). Since 2022, nine CGIAR Initiatives have been operating in Viet Nam.

This document provides an overview of SPIA's endeavors and highlights findings regarding 19 innovations[4], drawing on information gathered in Viet Nam between 2022 and 2024. Since 2022, SPIA has collaborated with the General Statistics Office (GSO) of Viet Nam to collect household-level information on the spread and adoption of specific key agricultural innovations. This collaboration augments GSO's current survey of Vietnamese households which is acknowledged as a legitimate data source that can help shape Viet Nam's policies.

This study aims to provide adoption estimates for CGIAR-related innovations across Vietnam, drawing on research conducted by CGIAR centers from 2003 to 2023. The findings offer insights into the geographic distribution of adoption and the socioeconomic characteristics of adopters. With this second country-level study, SPIA seeks to understand CGIAR’s role in Vietnam’s rural transformation and its contribution to resilience against environmental changes.

In Section 3 of this report, we present the methods, data, and the specific measurements implemented in the Viet Nam Household Living Standards Survey (VHLSS) modules. Section 4 provides an overview of the report’s key results. Sections 5 to 10 explore the domains of CGIAR activities in Viet Nam: Aquaculture and Capture Fisheries, Breeding Innovations, Climate Change Adaptation Options, Environmental Conservation, Mechanization, and Sustainable Intensification Practices[5]. In each section, we document the reach and scale of innovations and provide insights into the socioeconomic characteristics of adopters. An online Repository includes survey material, datasets, and information that will allow the reported results to be reproduced.

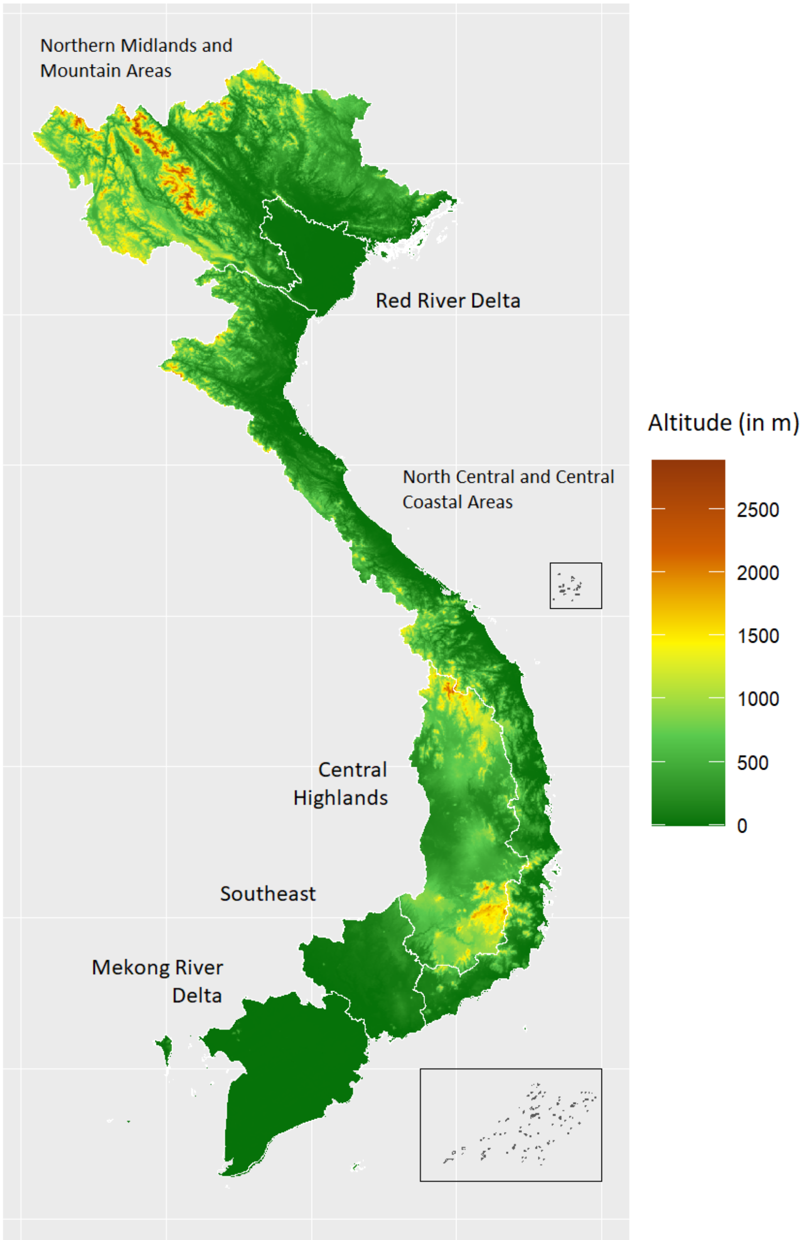
[4] This report reflects two key updates relative to the Kosmowski et al. (2023) preliminary report: (1) The total number of innovations increased from 18 in the preliminary report to 19 in this report – CGIAR-related potatoes were excluded due to limited sample size (n=32); and (2) a new innovation, Agro-Climatic Bulletins (ACB), has been added to the stocktake since the preliminary report.

[5] Two additional domains, Digital Tools and Livestock and Human Health, are presented in Appendix F and Appendix G, as no data integration occurred.

2. Context

Viet Nam boasts an extensive coastline as well as a mountainous terrain, predominantly in the north and central areas of the country (Figure 2). The nation is divided into six primary regions: Northern Midlands and Mountain Areas (NM), Red River Delta (RRD), North Central and Central Coastal Areas (NC), Central Highlands (CH), Southeast, and the Mekong River Delta (MRD). These regions collectively comprise 63 provinces and cities across the country.

Figure 2: Map of Viet Nam's six regions and their agroecology



Source: SPIA

Viet Nam's administrative structure below the province level is partially decentralized in the districts and communes. While the Communist Party of Viet Nam establishes the national policy direction, lower-level governments at the province, district, and commune levels are tasked with policy implementation and enjoy some decision-making and budgetary autonomy. The Ministry of Agriculture and Rural Development (MARD) oversees general agricultural planning, including growth targets, productivity, product output, investments, and infrastructure management. Each province's Department of Agricultural and Rural Development (DARD) develops its own plans, targets, and strategies based on MARD's guidance, whilst also addressing the Provincial People's Committee's objectives[6]. DARD's plans are further refined and executed by district-level Sub-Departments of Agricultural and Rural Development, and ultimately implemented by communal agricultural staff in collaboration with various agencies, organizations, and associations. These include agricultural extension services, cooperatives, the Farmers' Union, the Women's Union, and local Communist Party cells. This comprehensive administrative framework, combined over the past two decades with the rise of private sector actors, indicates multiple avenues through which agricultural technologies can be disseminated.

Viet Nam represents a promising case to study how agricultural innovations spread and contribute to development. First, its development pathway has been impressive. It has been classified as a middle-income country since 2010 (World Bank, 2013). Its GDP per capita has increased ninefold over the past two decades and was USD 4,109[7] in 2021 (GSO, 2023) and its annual GDP growth rate has remained above 5.5%. Evidence suggests there have been significant increases in household welfare (Tarp, 2017). Concurrently, Viet Nam's agricultural sector has transformed to have a strong commercial orientation. The value-added from the agricultural sector has grown sixfold from USD 7.5 billion to USD 46 billion at the same time as its share in GDP has fallen from 24.5% to 12.6% (World Bank, 2022). According to the Statistical Yearbook of Viet Nam, the value-added from the agricultural sector contributed to 5.1% of GDP growth (GSO, 2023). There is evidence that Viet Nam's rapid rate of poverty reduction was partly driven by higher incomes in rice-producing households (Pandey et al., 2010). These indications of successful structural transformation in Viet Nam suggest that agricultural research may have played a major role in supporting development.

Second, compared to previous SPIA country studies such as in SPIA's 1st Country Report - Ethiopia (Alemu et al., 2024) and Uganda (upcoming), the Vietnamese context helps to shed light on a very different set of innovations, and entirely different scaling pathways. Rice, rice-focused management practices, and aquaculture innovations are new areas of focus for Viet Nam that SPIA has not tackled in the work in Africa.

Third, there are challenges on Viet Nam's path to future prosperity that require an explicit orientation toward environmental challenges.

Historically, the country's agricultural growth has been driven by the intensive use of chemical inputs, land, and other natural resources (World Bank, 2016b). At the same time, projected increases in the frequency and severity of climate hazards pose significant threats to agricultural production (IPCC, 2014; Shukla et al., 2022; UNU-WIDER, 2012). It has been

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6 People's Party Committee are essential government bodies that play a role in governance and administration. Different committees operate at the level of provinces, districts, and communes.

7 In current U.S. dollars.

estimated that an 80cm increase in sea levels could leave close to one-third of the Mekong Delta Region permanently flooded (MoNRE, 2022). Viet Nam has also made commitments to reduce greenhouse gas (GHG) emissions from rice production[8]. CGIAR research has focused on developing agricultural research innovations that both adapt food production systems to environmental challenges and mitigate the negative impacts of climate change. It is of strategic importance for CGIAR's global work that we document whether these innovations have scaled, and if so, how this scaling was achieved.

[8] Globally, rice production represents 10% of global agricultural methane emissions, making rice the second contributor after livestock production (IPCC, 2014).

3. Methods and Data

3.1 Stocktaking Process

Our first step was to identify CGIAR innovations that are likely to be at scale in Viet Nam. We started by using SPIA's stocktaking approach to comprehensively document all innovations disseminated over the past two decades (Kosmowski et al., 2020; SPIA, 2023).

We examined various aspects of CGIAR's Research Initiatives in Viet Nam, how these led to specific innovations, and any evidence of the reach of these innovations among households. In acknowledgment of the broad spectrum of CGIAR's research endeavors, we define the term 'innovation' to include any novel technology, practice, decision-support tool, or policy/institutional design that necessitated research input for its development and/or promotion. CGIAR-related efforts in development and/or dissemination pertain to CGIAR Research Programs (CRPs) and/or projects with bilateral funding that produced research outputs contributing to the innovation's development or spread.

To identify innovations likely to have achieved scale, we primarily relied on discussions with CGIAR researchers and national collaborators. We examined and documented progress along the adoption pathway, as illustrated in Table 1 For each identified innovation (Column i), we began by outlining CGIAR-related efforts for development and/or dissemination (Columns ii and iii), describing an observable feature that would help to identify it in data, and its identification/measurement method (Column iv), detailing the scale and location of activities (Column v), and noting known dissemination strategies/pathways (Column vi). Collectively, we could use this information to assess the likelihood that the innovation had diffused widely. Table 1 provides examples for two innovations: Genetically Improved Farmed Tilapia (GIFT)-derived Strains and Climate-Smart Mapping and Adaptation Planning (CS-MAP).

Table 1: Examples of stocktaking entries for two CGIAR-related innovations for inclusion in Viet Nam's national data systems

Innovation	CGIAR-related efforts for development and/ or dissemination	Description	Observable feature	Scale and location of AR4D activities	Notes on known dissemination strategies/pathways
(i)	(ii)	(iii)	(iv)	(v)	(vi)
Genetically Improved Farmed Tilapia (GIFT)-derived strains	1. GIFT dissemination in 1994, 1996, and 1997 to RIA1 (Hanoi) 2. GIFT dissemination in 1996 and 2006 (G10) to RIA2 (HCM) 3. Enhancing community resilience to climate change by promoting smart aquaculture management practices along the coastal areas of North Central Viet Nam (ECO-SAMP, CCAFS, 2015-16)	GIFT are originally pure-bred lines of male tilapia that have two Y chromosomes, thus producing only male progeny. GIFT is a faster-growing strain of Nile tilapia (*Oreochromis niloticus*) improved through selective breeding, made available by WorldFish since 1988. 1. GIFT-derived strains in Viet Nam include: • Cold tolerant tilapia (RIA1, 1999) • NOVIT-4 Nile tilapia (2004)-derived from GIFT O. niloticus and Red tilapia *Oreochromis spp*. The strain was selected over seven generations for high growth in a freshwater environment at RIA1 from 1998 to 2006 (Dinh Luan et al., 2008). • Saline-tolerant Nile tilapia (2014): Base population of the selective breeding programme formed of three strains of Nile tilapia, namely GIFT, a Taiwanese strain, and NOVIT-4 strain. Four generations were selected for high growth in 15–20ppt brackish water (2007 to 2011) at RIA1 (Ninh et al., 2014a). 2. Seven generations (G10 to G17) of male/female tilapia were released. Clean seeds free from Tilapia Lake Virus (TiLV) disease 3. Monosex tilapia integrated into shrimp-seaweed systems	Household has farmed hatchery-produced GIFT-derived tilapias. Identification using fish seed source (potential reach) or DNA fingerprinting (reach)	1. Still under investigation 2. ~4000 breed broodstock released per year to hatcheries for commercial purposes 3. Commune of Hoang Phong in Thanh Hoa province	• RIA1 and RIA2 provide broodstocks to provinces and local hatcheries that produce fingerlings sold to farmers (~80%) and private companies (20%). • Viet Nam Master Plan for Aquaculture Development (2003-10) mentions the distribution of high-quality broodstock. For tilapia, the plan calls for the use of "newly developed strains of tilapia". • Viet Nam's Fisheries Development Strategy 2010-20 (Decision No. 1690/ QD-TTg)[9]: Tilapia is the 3rd commodity after catfish and shrimp. • The tilapia market is dominated by imported strain from China (Đường Nghiệp strain, possibly GIFT-related). In 2020, GIFT tilapia came back to the South, due to the development of rotational shrimp–tilapia culture in coastal areas of MRD (RIA2 interview). • Increase in tilapia exports since 2010, mostly processed and sold in fillets. • Viet Nam aims to reach 400,000 tonnes of tilapia in 2030 (MARD, 2017). Cages farming in rivers and lakes and intensive farms in delta areas

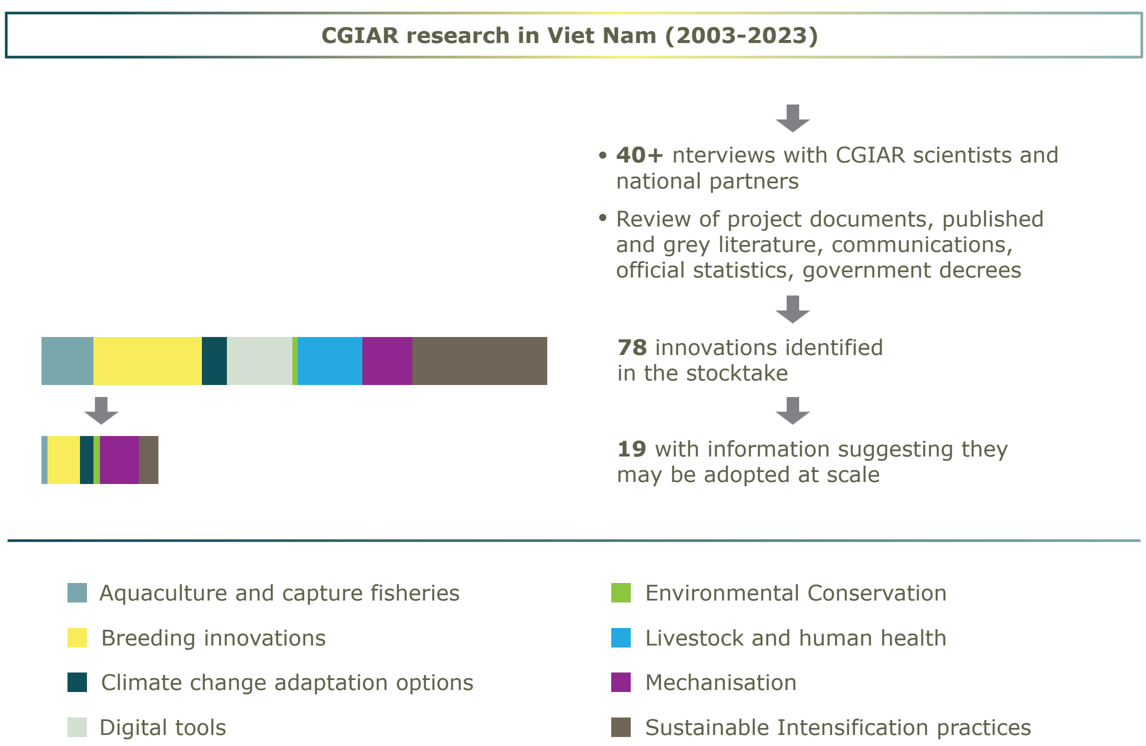
[9] Decision No. 1690/QD-TTg approving Vietnam's Fisheries Development Strategy in Vietnam. https://thuvienphapluat.vn/van-ban/EN/Tai-nguyen-Moi-truong/Decision-No-1690-QD-TTg-approving-Vietnam-s-fisheries-development-strategy/114738/tieng-anh.aspx

Innovation	CGIAR-related efforts for development and/ or dissemination	Description	Observable feature	Scale and location of AR4D activities	Notes on known dissemination strategies/pathways
(i)	**(ii)**	**(iii)**	**(iv)**	**(v)**	**(vi)**
Climate-Smart Mapping and Adaptation Planning (CS-MAPs)	1. Climate Change, Agriculture, and Food Security CRP (CCAFS, 2016-2021) 2. Applying seasonal climate forecasting and innovative insurance solutions to climate risk management in the agriculture sector in SE Asia (DeRisk, 2018-2022) 3. Transforming Farming Systems under Climate Change (TFCC)	1. Develop and test a participatory approach for mapping climate risks and adaptive interventions (Tan et al., 2019). These maps integrate scientific evidence with local knowledge of stakeholders on topography, infrastructure, hydrological management schemes, and land use plans. 2. Supported the scaling of CS-MAP in four SSC provinces and 12 NM and RRD provinces. 3. Downscaling at the commune level. CS-MAP is currently being used to identify areas of rice production that are not adaptable to the current farming system and propose suitable farming systems.	Households applied an adaptation derived from CS-Map adaptation plans. The most common adaptation practices are changes in rice varieties and changes in rice sewing/planting dates	1. Thirteen provinces in MRD 2. Four SSC and 12 NM and RRD provinces. 3. Three selected communes in MRD: Hoa Chanh (U Minh Thuong district, Kien Giang province), An My (Ke Sach district, Soc Trang province), and Tan Phuoc (Go Cong Dong district, Tien Giang province)	• Recognized in MARD’s Decision No. 2559 recognizing initiatives and scientific research projects (2020). • To implement the adaptation plans based on the CS-MAP, the government issued the MARD Official Document No. 8278 to instruct the 12 provinces in applying the water discharge schedule and cropping calendar for the Winter-Spring season 2020-2021 • In 2023, 41 provinces had received CS-Maps. • The adoption pathway can be described as follows: 1) Participatory mapping exercise with stakeholders leading generated: 2) Adaptation plans that are risk, season, and location-specific and 3) CS-Maps. Each cropping season, ENSO predictions on whether a normal or extreme year are used to advocate the risk-specific adaptation plan. 4) Annual crop planning at the province and district level may include these adaptation plans and diffuse information to the household through extension services and agricultural agents.

Notes: AR4D = Agricultural Research for Development, CRP = CGIAR Research Program, ENSO = El Niño–Southern Oscillation, IWMI – International Water Management Institute, MARD = Ministry of Agriculture and Rural Development, MRD = Mekong River Delta, NMA = Northern Midlands and Mountain Areas, RRD – Red River Delta, SSC = South Central Coastal Region

The stocktaking process began with an assessment of CGIAR's research activities in Viet Nam, from 2003 to 2023 (Figure 3). We found that these activities cover six primary areas: Aquaculture and Capture Fisheries, Breeding Innovations, Digital tools, Environmental Conservation, Livestock and Human Health, Mechanization, and Sustainable Intensification practices. The stocktake that documents the full extent of our findings is available in the Repository. This stocktaking approach served as the basis for including new data protocols in a nationally representative household survey, the Viet Nam Household Living Standards Survey. Overall, we identified 78 distinct innovations and attributed 30 policy contributions to CGIAR's research efforts. Appendix A lists the policy outcomes likely attributable to CGIAR research. We broadly define policy outcomes by examining councils, forums, platforms, and working groups that may have influenced policy. These findings were compiled through desk review and stakeholder interviews. The desk review involved gathering information from published literature, project reports, online communications from CGIAR centers and partners, and government documents. Relevant data from these sources were organized to document the topic and influence. Concurrently, key stakeholders were identified and contacted to clarify CGIAR's role when unclear. Email exchanges and interviews aimed to fill gaps and provide additional insights into policy influence. No standard interview guides were used; instead, questions were tailored to seek specific information about policy influence, with varying durations. Special care was taken to separate facts from opinions in stakeholder interviews. Detailed reports for each policy outcome are available in Annex G.

Figure 3: Schematic diagram of the process of identifying priority innovations for improved data collection



Source: SPIA

3.2 The Viet Nam Household Living Standards Survey

The Viet Nam Household Living Standards Survey (VHLSS) is a comprehensive, nationally and regionally representative household survey designed to collect detailed data on living standards, socio-economic conditions, and poverty levels across various regions of the country. It employs a two-stage stratified sampling design based on the 2019 population Census Master Sample, with strata (subgroups) defined by geographical regions and urban/rural areas.

From the list of all enumeration areas (EAs) in the country, the Census Master Sample is selected by using the Square Root Allocation method[10].

In the first stage of the multi-stage sampling process, 40% of the EAs are selected using probability proportional to size sampling method, based on population. This means that EAs with larger populations have a higher likelihood of being selected. From this master sample, 3,133 EAs are randomly selected for the VHLSS.

In the second stage, 15 households within the selected EA are selected into the sample for that year, ensuring each household within the EA has an equal probability of being chosen[11].

The VHLSS is an EA-level rotating panel survey. Among the 3,133 EAs randomly selected each year from the Census Master Sample, 25% are newly surveyed EAs while 75% are re-sampled from the two recent waves. In each EA, 15 households are selected. If it is a re-sampled EAs, then these 15 households are the same households that participated in the previous wave(s). If it is a newly included EA, the 15 households are drawn through systematic random sampling.

The survey is weighted to account for its multi-stage sampling design and to provide results that reflect the population distribution[12].

In 2021, the GSO started to use Computer-Assisted Personal Interviews (CAPI) to conduct the VHLSS, which significantly decreased data processing time. The VHLSS CAPI tools were developed by in-house programmers and made available to GSO enumerators through the Google App Store.

In this report, we mainly rely on VHLSS data to measure households' adoption and practices, describe farmers' socio-economic characteristics, and map the adoption rates across the country.

3.3 Province-level Agricultural Plans (2021-2024)

We also use ancillary data sources. Since the 1960s, Viet Nam has implemented annual crop plans, and it is customary for local governments and agricultural extension services to provide

[10] The Square Root Allocation method is a sampling technique where the sample size for each stratum is proportional to the square root of the population size of that stratum.

[11] For example, of the 3,133 EAs in the VHLSS 2022 round, 25% were surveyed only in 2020, 25% were surveyed in both 2020 and 2021, 25% were surveyed in 2021 only, and the remaining 25% are new EAs.

[12] In Appendix B we describe how we utilized these weights in conjunction with the sampling procedures used for the additional survey modules integrated into the VHLSS to arrive at adoption estimates for different agricultural innovations.

agricultural recommendations. For each year and cropping season, Viet Nam's authorities formulate agricultural production plans, at the province, district, and commune levels.

By contacting the focal points of the Sub-Departments of Crop Production and Plant Protection, we collected 217 province-level agricultural production plans for 2021-2024 from the Mekong River Delta (MRD) (11 provinces), Northern Midlands and Mountain Areas (NM), and Red River Delta (RRD)(10 provinces), and the South Central Coast (SCC) and Central Highlands (CH) (14 provinces). This provides us an opportunity to detect signals of the institutionalization of certain innovations. Specifically, we qualitatively analyzed these plans to identify references indicating that the authorities were promoting the CS-MAPs and the 'Three Reductions, Three Gains' (3R3G)/'One Must Do, Five Reductions' (1M5R) practices. The agricultural plans, coding, and content analysis are available in the Repository.

3.4 Measurement and Categorization of Agricultural Innovations

We now present the measurements and computational steps followed to document the reach of the 19 CGIAR-related innovations presented in this report. The modules integrated into the VHLSS to measure these innovations are available in English (Annex A) and Vietnamese (Annex B) versions.

3.4.1 Genetically Improved Farmed Tilapia (GIFT)-Derived Strains

Data on the adoption of tilapia strains come both from households that grew tilapia, and from hatcheries that were sources of tilapia fingerlings for the households. Data from households were collected using the following two-step procedure.

First, the sub-sample of all households who answered in the VHLSS 2023 that they produced tilapia in the previous 12 months, was used as a nationally representative sampling frame for tilapia-producing households in Viet Nam. A new questionnaire module was developed and integrated into the VHLSS 2023 survey (modules 4b5.1a and 4B5.1.A, Annex A). A visual aid was also introduced to communicate clearly to respondents and to prevent them from responding they farmed tilapia when in fact it was koi (Anabas testudineus, Annex C).

Given the ancestry of the GIFT strain, we focused on *Oreochromis niloticus*, so farmers who only grow red tilapia (*Oreochromis spp.*) would not be coded as tilapia growers in our study. Following each quarter of data collection, the GSO provided information about tilapia-growing households as identified in February, May, August, and November 2023. Data were shared in a manner that respected the principles of household anonymity and consent.

Second, a team of enumerators supervised by the SPIA team organized a follow-up survey. Province Statistics Offices (PSOs) visited the tilapia growing households identified above, to collect fin-clippings from a sample of their individual tilapia fish[13]. In each household, five fish

[13] Fin-clipping is an invasive but non-lethal method of obtaining a biological sample for fish genotyping. Once the fin-clips had been collected, the fish were returned to their habitat. This study received animal ethics approval from the International Livestock Research Institute Institutional Animal Care and Use Committee (IACUC, protocol reference ILRI-IACUC2023-02).

were randomly sampled from the pond where the household grew tilapia. Despite household support for enumerators to access ponds and fish, the team faced several challenges, including slippery access to natural ponds, struggle with catching tilapia when the farmer used polyculture systems, and the difficulty of clipping the fins. On occasion, by the time enumerators arrived, the fish had already been harvested, which meant that no fin clips could be collected. The questionnaire module also asked farmers to report the history of their households' broodstock and their current facilities[14].

The enumerator team also visited tilapia hatcheries. A list of those operating as of 2021 was obtained from public sources, and an attempt made to contact each hatchery. Of the 85 hatcheries listed, 30 were still in operation at the time of data collection. We identified 50 additional hatcheries using information obtained at the Department of Agriculture and Rural Development (DARD) in each of the provinces that the mobile enumerator team visited. We identified a further thirteen through households' reports on the hatcheries where they had purchased tilapia fingerlings, both in the VHLSS 2023 and the follow-up household survey. At each hatchery, the team enquired about business operations, volumes, and available strains for sale. The enumerators then randomly selected three fish per strain and collected fin-clips from each[15].

Data collection and fish sampling were completed in December 2023. Of the 254 tilapia-farming households identified in VHLSS 2023, 204 were still farming tilapia at the time of the mobile team visit. At the hatchery level, 87 of the 93 hatcheries were able to provide sufficient fin samples[16].

We expected the sampling distribution of GIFT-derived tilapia adoption to follow a binomial distribution. Based on the information gathered from hatcheries in Viet Nam, we expected approximately 5% of households in the known population to have adopted GIFT-derived tilapia. However, we expected the national adoption rate to be lower than 1% in the VHLSS sample, since GIFT-producing hatcheries are concentrated in particular regions such as RRD, NM, and MRD regions. At the 95% confidence level, the collected samples from 204 tilapia-growing households allowed for detection with a statistical power of approximately 80%.

3.4.1.1 Reference Library: 17 Key Tilapia Strains Clustered into GIFT, GIFT-derived and Non-GIFT-derived Populations

In order to build the reference library for this study, Vietnamese tilapia strains were sampled at the Research Institute for Aquaculture 1 (RIA1) facilities in Quang Nam in July 2023. The strains, residing in different ponds, were segregated by sex. The sample included two strains currently disseminated in Viet Nam: NOVIT-4 12th generation (Tran, 2010; Tran et al., 2008) and Phu Ninh (Tran et al., 2019), and four parent strains: GIFT 13th generation, a strain from Taiwan, ProGIFT China (Thodesen et al., 2011), and a strain from the Philippines. We also contacted GenoMar, a private Norwegian company, to request broodstock samples from its main tilapia product GenoMar GAIN. Although they refused us access to their core population, they

[14] A description of the fin-clipping procedure performed by enumerators is available in Annex C. The questionnaires and datasets used in the follow-up survey are available in the Repository.

[15] Whereas we collected fin-clips from five fish from household-level ponds, we only collected them from three fish at the hatcheries. This is because we expected greater genetic heterogeneity at the household-level.

[16] Six hatcheries were visited but not sampled as the fish were too small (1-2 cm) for fin-clipping.

informed us of an upcoming shipment to a hatchery in Hai Duong province. We visited the day after they arrived and fin-clipped 30 individual fish per strain. The seven populations sampled at RIA1 and GenoMar are representative of the core breeding populations in Viet Nam.

These Vietnamese strains were supplemented with ten core tilapia strains sampled by Hamilton et al. (2020). The number of fish sampled for each strain ranged from 21 to 172, with an average of 85 fish per strain. These included two pure GIFT strains from Malaysia and the Philippines, four GIFT-derived strains (BEST, Get-ExCEL, Molobicus, Nile × Moss), and four non-GIFT populations (Abbassa, Chitralada, FaST, and O. mossambicus) originating in Egypt, Thailand, and the Philippines. See Annex E for the list of strains used to constitute the reference library.

3.4.1.2 DNA sequencing

The collected samples were sent to RIA1 for DNA extraction. Quality and quantity were monitored before being shipped to Diversity Arrays Technology (DaRT), Australia. The samples were genotyped in two batches (DTi23.8867 and DTi24.9029)[17].

3.4.1.3 Analysis

After merging the SNP data for all samples[18], including reference library, hatchery, and household-level samples, SNPs that were not present in the "full DArTseq panel" as defined by Hamilton et al. (2020) were excluded. SNPs with a minor allele frequency (MAF) of less than 0.01, and those with a call rate of less than 0.25, were also removed. After these quality control steps, 6,647 SNPs remained in the dataset used for the analysis.

To assess the adoption of GIFT-derived and non-GIFT-derived strains by Vietnamese households, we attempted to match the samples obtained from Vietnamese core populations, hatcheries, and households to strains[19].

Each of the 87 hatcheries and 204 households was then assigned to the strain whose core population was represented by the most individuals (i.e. the 'modal population'). In cases where more than one strain was available for sale (a situation that occurred in only ten hatcheries), the assignment was made on the strain that had the highest number of broodstocks or reported as being economically most important[20].

[17] The DArTseq genotyping-by-sequencing platform and DArT proprietary analytical pipeline were used to identify markers and sample genotypes, respectively (Kilian et al., 2012). Genotypes were called for both single-nucleotide polymorphisms (SNPs) (genetically codominant) and silicoDArT markers (genetically dominant).

[18] The SNP data for all samples were merged according to the DArT cloneID (i.e. unique identifier for the sequence in which the SNP marker occurs) and SnpPosition (that is, base position and base variant; for example, 9:A>T). Only SNP markers present in both the Vietnamese dataset and the full Hamilton et al. (2020) dataset were retained in the merged dataset (7,456 SNPs).

[19] Strain predictions were made using the predict.dapc function after completing Discriminant Analysis of Principal Components (Jombart et al., 2010) using Hamilton et al. (2020) core population data only (i.e. ten strains) and Hamilton et al. (2020) and Vietnamese (GenoMar Gain and RIA1 combined) core populations (in total, 12 strains). Individuals were then assigned to the strain with the greatest posterior membership probability (referred to as 'individual-fish level' assignment).

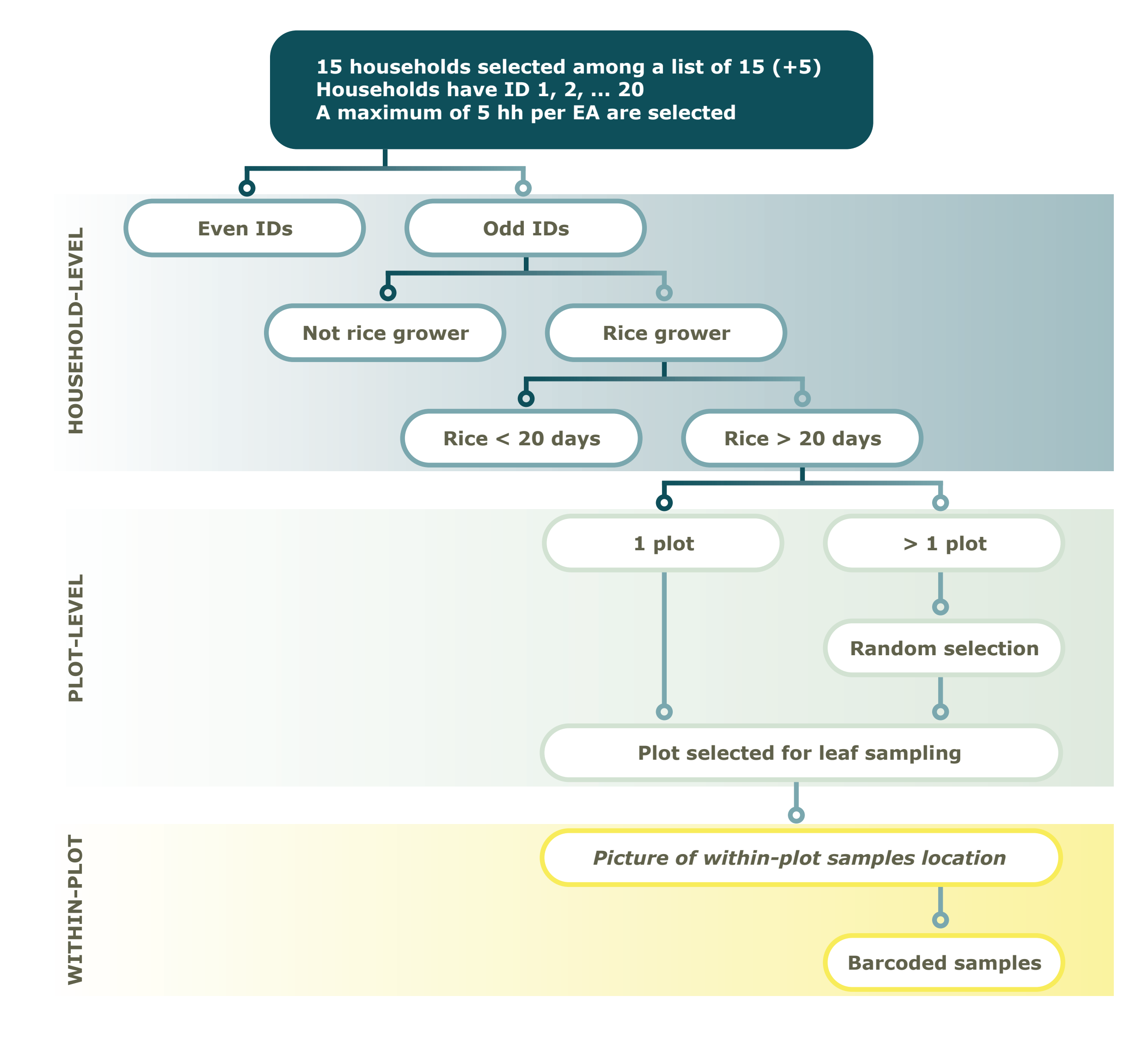
[20] For a more extensive description of this analytical approach, please refer to Hamilton (2024).

3.4.2 Improved Rice Varieties

Since the VHLSS does not usually ask farmers to report data at the plot-level or include enumerator visits to plots, we collaborated with the GSO to design a new questionnaire module. This included plot visits for crop sampling for a random subset of rice-growing households in the VHLSS 2022 sample (Figure 4).

This module was only administered to households that had odd-numbered GSO IDs, thereby generating a random subsample. A crop sample was collected if the odd-ID household had planted rice in the past 12 months, and at the time of the survey, had at least one plot where a rice crop was currently being cultivated and had been planted at least 20 days prior. Crop samples were collected from up to five households per EA.

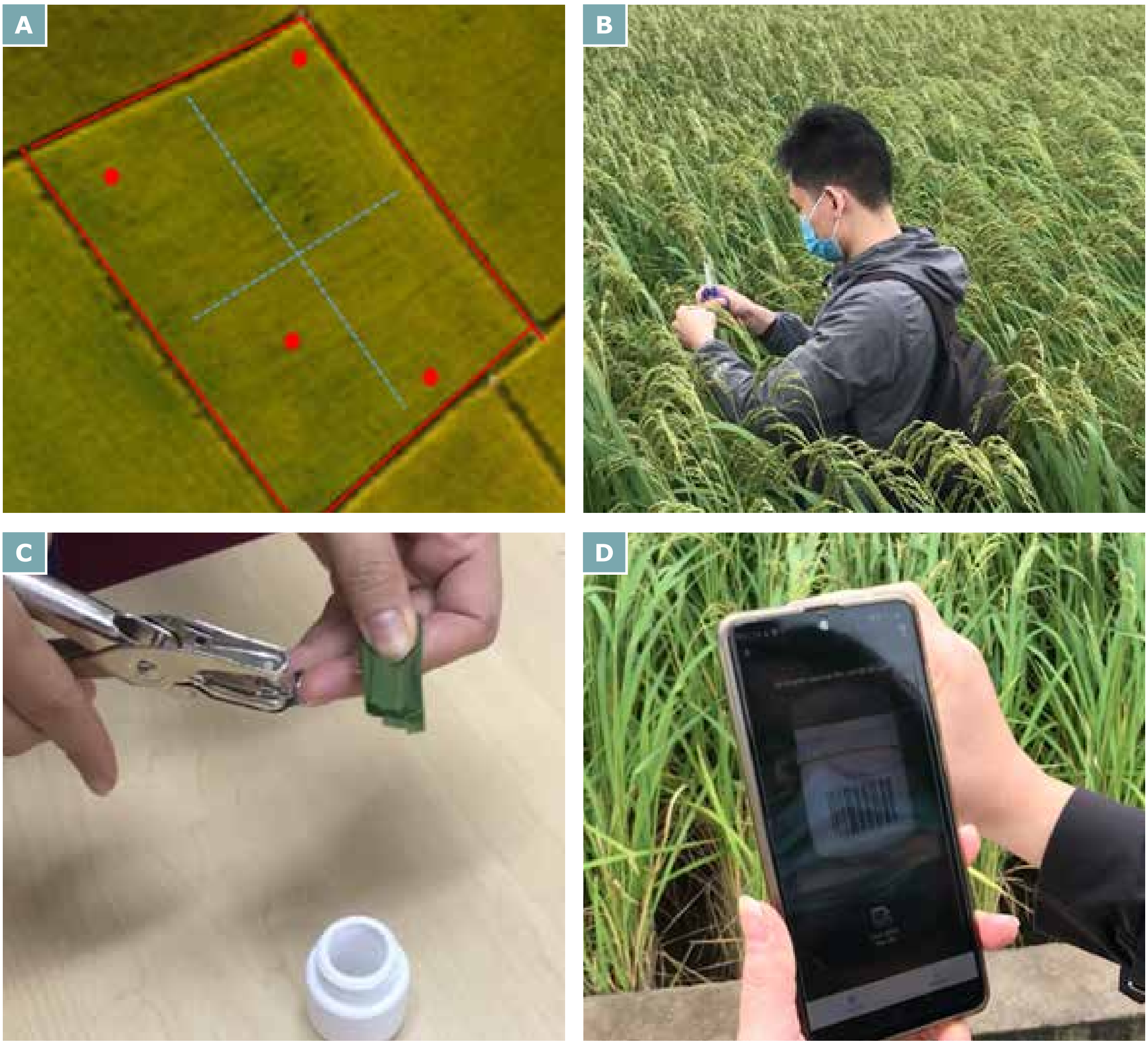
Figure 4: Sampling procedure for rice DNA fingerprinting in the VHLSS 2022



Source: SPIA

For each farmer who was screened into the sample, all eligible rice plots were listed on a plot roster, and one plot was randomly selected by the CAPI program. The selected plot was divided into four quadrants, and one rice plant was randomly sampled within each quadrant. To obtain a sample, the enumerator plucked leaves from the plant, stacked them, and then used a hole puncher to cut out small circles of leaf material. The enumerators had received specific training in advance (Figure 5).

Figure 5: Overview of the leaf sampling procedure performed by enumerators in VHLSS 2022



Note: After dividing the plot into four subplots (A), enumerators randomly selected one plant from each subplot (B). The collected leaves were stacked before taking the sample with a 6 mm hole puncher (C). The bottle containing the four samples and 4 g of silica gel was closed, and the barcode on the bottle was scanned using the VHLSS CAPI program (D). Photo credits: Oanh Nguyen.

This crop sampling exercise suffered from delays at the start of the VHLSS survey owing to COVID-19 pandemic-related restrictions. Sixty-two percent of the samples were collected between March and April 2022. Because of the fixed timing of data collection and the heterogeneity of cropping patterns in the country, samples were collected during different cropping seasons: 73% during the Winter-Spring (WS) season, 11% during the Summer-Autumn (SA) season, and 16% during the Mua/Autumn-Winter (AW) season. The samples obtained represent 5.6% of the rice-growing households surveyed in VHLSS 2022 and are representative at the national and regional levels.

The samples collected by the enumerators were checked by the PSOs and shipped to the Agricultural Genetics Institute (AGI) in Hanoi, where they were arranged into plates. Of the 832 samples collected by the PSOs, 770 were matched to a sample household[21] and sent for genotyping. Twelve samples failed to achieve a call rate[22] (>66%) and were discarded because of insufficient amounts of DNA. Table 2 presents the final sample size of households and EAs from which we obtained DNA fingerprinting data by region.

Table 2: Distribution of DNA fingerprinting samples of rice EAs and households in VHLSS 2022

Region	Total		
	EAs	Households	Rice plots/ Household
Red River Delta	57	155	1.52
Northern Midlands and Mountain Areas	46	178	1.72
North Central and Central Coastal Areas	45	171	1.46
Central Highlands	11	44	1.05
Southeast	8	24	1.08
Mekong River Delta	81	194	1.07
Viet Nam	**248**	**766**	**1.4**

[21] 62 samples could not be tracked to a VHLSS rural household because these were collected in urban EAs, or because the enumerator did not record the barcode on CAPI.

[22] The call rate indicates the proportion of successfully determined genotypes among the 1,040 markers characterized by the RiCA v4 panel.

3.4.2.1 Improved Rice Varieties Released in Viet Nam (2003-2023)

Researchers have made efforts to establish the pedigree of improved rice varieties released in Viet Nam over the last two decades. Official recognition for new varieties is given by the Ministry of Agriculture and Rural Development (MARD) after the variety has been tested for cultivar quality, productivity, and suitability for production in Viet Nam. We started by listing all 632 improved rice varieties mentioned in sources from MARD, the Plan Resources Center (PRC), the International Network for Genetic Evaluation of Rice (INGER), and Cuu Long Rice Research Institute (CLRRI) (MARD, 2009). We found 632 improved rice varieties released between 1960 and 2019, of which 347 had been released in the past two decades (Annex F). Since the information about the pedigree of each variety was not systematically available, we collaborated with MARD to retrieve data from their archival documents. In this way we obtained information about a total of 301 official decisions on seed circulation, extension of circulation, or both, (see Repository).

When we put together the first database (Source One) with MARD's official decisions on seed circulation (Source Two), we could match 413 varieties by name. However, information about pedigree was absent from both sources for 21% of these 413 varieties. For 12% of the 413 varieties, pedigree information from Source One was confirmed by Source Two. For another 3%, the two sources provided different information about pedigree. Due to missing data from one of the two sources, we used pedigree information from Source One in 35% of the cases and from Source Two in 28% of the cases.

The 326 varieties for which information on pedigree existed were classified by parentage into one of the following six categories:

- IRRI-related Line: Officially released seeds directly derived from IRRI breeding lines (for example, IR17494).
- IRRI-related (P): Officially released seeds with a parent that is an IRRI-related line. The IRRI parentage is at the primary level (P). For instance, this category includes PY2, whose parent IR50404 is an IRRI line.
- IRRI-related (P2): Officially released seeds with a grandparent that is an IRRI-related line. The IRRI parentage is at the second-generation level (P2).
- Not IRRI-related: The pedigree data indicate no relation to IRRI breeding lines or genetic resources.
- Parents Pedigree Unknown: Cases in which only the parent plant's pedigree information is missing.
- No Pedigree Data Available: No information on the genetic background of the officially released seed could be found in any database or records.

To identify the year of release, we prioritized dates from Source One when available, and Source Two when not[23].

[23] This is because for a particular seed Decision, the date at which the Decision was issued may not always be the official date of release (ex: Decisions on extension of seed circulation are typically issued years later after the seed is commercialized).

3.4.2.2 Reference Library: 122 Rice Varieties (Viet Nam) and 177 IRRI Elite Lines (Philippines)

To identify the varieties of farmers' seeds, we first needed to create a reference library consisting of varieties known to have been released in Viet Nam. The genetic information of each farmer sample would then be used to match it to a reference.

We first reached out to the main seed actors in Viet Nam, consisting of 17 public and private organizations that have bred and/or released improved rice seeds. Official letters were sent requesting samples of the breeder seeds. Of the 147 seeds requested, we obtained samples of 99 from 6 organizations: PRC, CLRRI, AGI, the Field Crops Research Institute (FCRI), Binh Thuan Seed Co., and Nghe Agricultural Materials Company. The most frequent reason for refusal was that the variety was no longer produced. In some cases, we were told that the varieties were unavailable at the time of request because the growing season had ended. The two largest private seed companies (Thai Binh Seed Co. and Vinaseed Co.) refused to grant access to their seed material.

In cases where we were unable to obtain breeder seeds, we used a second-best approach and searched for and purchased commercial seeds and grains from seed shops. We hoped that in this way we would be able to identify varieties that were released several decades ago and are still widely grown in Viet Nam (Bui & Nguyen, 2017). Through this method, we retrieved a total of 21 unique varieties which were either commercial seeds or grains. Finally, 177 IRRI lines that had been genotyped using the IRRI Rice Custom Amplicon SNP panel were integrated into the reference library. Details of the reference library used for rice varietal identification can be found in Annex E.

3.4.2.3 DNA Sequencing

Genotyping was performed by Agriplex, using the Genomics' PlexSeq platform[24]. To analyze the rice DNA, we used Version 4 of the IRRI Rice Custom Amplicon SNP panel[25] (Arbelaez et al., 2019) which looks at 1,040 markers[26]. Through pairwise matching, we identified the variety that the farmer was growing. In addition, we identified the presence or absence of markers that have been linked to specific rice traits.

3.4.2.4 Analysis

The objective of this analysis was to estimate the genomic relationships between field-collected samples and reference material to ascertain the extent to which IRRI-related rice varieties have been adopted in Viet Nam. A total of 1,017 SNPs were used to genotype the rice reference and field samples. For quality control, genotypes were filtered by call rate (0.5), SNPs were filtered by minor allele frequency (0.01), call rate (0.8), and elimination of monomorphic markers. Other metrics evaluated included polymorphism information content (PIC), heterozygosity, and the inbreeding coefficient.

[24] A mid-density SNP panel by high-level multiplexing.

[25] Single Nucleotide Polymorphisms (SNPs). In this context, SNPs are specific sites in a rice plant's genome where an individual base – of the four that make up DNA (adenine - A, cytosine - C, guanine – G, or thymine - T) is found. The location of the bases can vary across individual plants in such a way that, when information about many of them is used together, it can help us build a profile of the plant's genetic identity.

[26] These included 797 SNPs originating from the Cornell 6 K Array Infinium Rice Chip (Thomson et al., 2017), 205 trait-related SNP markers, and 22 pure SNP markers.

SNP filtering resulted in 903 good-quality markers, 772 of which were general and 131 were trait-specific. For varietal assignment, the two marker types were not distinguished. The field samples that passed the quality control had 789 references. Analysis of heterozygosity showed that 63 references had high levels of heterozygosity (>0.12 and up to 0.5), beyond the threshold for varieties[27]. In addition, 14 had low inbreeding coefficients, suggesting that they were recent crosses. For the field samples, 232 had high levels of heterozygosity at a rate of ~30% for both genotype classes.

The process of assigning field samples to references involved calculating pairwise comparisons between all samples and references to determine the purity of the match, using a measure called "percentage similarity". The genetic distance between all samples and references was estimated and an identity by state (IBS) distance matrix was generated. Genotypes were classified as related if the IBS was below 0.05%. The determination of an ideal match between a sample and a reference was based on the lowest IBS and highest purity scores.

Because of the considerable similarity between some references, many genotypes were initially assigned to more than one reference. In such a scenario, the top reference was determined to be the one with the lowest IBS score and highest purity score, and this was indicated as the 'Top Reference', which is the assigned ID of the sample. In all, 390 (51%) samples were matched to a reference.

3.4.3 Salt-Tolerant Rice Varieties and Submergence-Tolerance Rice Varieties

The genotyping data generated for varietal identification also assesses the presence of 205 trait-related SNP markers. For this innovation, we present statistics showing the likelihood of the presence of saltol and Sub1 Quantitative Trait Loci (QTLs)[28] in the subsample of rice-growing households collected in the VHLSS 2022. These genetic traits help rice survive in salty soil (Saltol) or recover from flooding (Sub1).

Salinity-tolerant rice poses an interesting allocation question in terms of understanding if salt-tolerant rice is grown by households living in the most vulnerable areas. We explore this by merging the VHLSS dataset with a geo-referenced map of salinity risk in MRD. This map is the output of another CGIAR-related innovation, CS-MAP (Section 7.2). Household GPS locations were used to link each household to the nearest salinity risk polygon.

[27] Heterozygosity is the state of having two different versions (alleles) of a SNP inherited from each parent. In the process of variety development for inbred crops like rice, heterozygosity is reduced with subsequent generations of development (the technical term is backcrossing). By the fourth generation at which point a variety can be defined, the level of heterozygosity is 12% and lower in subsequent generations. Hence, it is a proxy measure of the uniformity of a plant's genome.

[28] For Saltol, the presence of the QTL was inferred using two markers: IRRI_SNP0994_SALTOL-AUS [G/T] and IRRI_SNP0995_SALTOL-ARO [C/T]. Alleles G and T were favorable to the trait for each SNP respectively. In the case of Sub1, markers IRRI_SNP3090_MSU7_9_6374718_A-G [A/G] and IRRI_SNP3091_MSU7_9_6605118_T-G [T/G] were associated with the trait with alleles A and T being favorable to the trait for each SNP respectively.

To test the hypothesis that alleles associated with the Saltol gene are more prevalent in vulnerable provinces, we employed an ordinary least squares (OLS) regression[29]. The dependent variable of the model was the presence of the alleles associated with the Saltol gene in a household's rice field in 2022. For independent variables, we used binary indicators representing the household's salinity risk categories (medium and high risk), determined by its geographical position. Results are discussed in Section 6.4.

3.4.4 Improved Cassava Varieties

3.4.4.1 Data Collection

Similarly to rice, a protocol for cassava leaf collection was included in VHLSS 2023. In each EA all cassava-growing households in the VHLSS sample were listed, and a maximum of five households/plots were selected for sampling. Enumerators visited the plot, randomly selected one plant from the main variety growing there, and plucked three young green leaves from it. The leaves were stacked and punched to create three circular plant tissue samples, which were then placed in labeled bottles containing 4g of silica gel. The sample barcode was scanned using the CAPI application, and the samples returned to PSOs before being sent to the AGI in Hanoi. A total of 805 household samples were collected.

3.4.4.2 Improved Cassava Varieties Released in Viet Nam

The list of officially released cassava varieties was obtained from MARD, which was cross-checked and completed with data available in Hoang et al. (2024) and Ocampo et al. (2022). This list is available in Annex F.

3.4.4.3 Reference Library: 16,897 Accessions from the CIAT Collection

To classify the collected cassava samples, we used CIAT's cassava genetics reference set (16,897 samples) of local varieties and improved materials from Asia, Africa, and Latin America. This database contains 1,600 cassava samples collected in the agroecological zones of Viet Nam in 2015 and 400 samples provided by Hung Loc Agricultural Research Center (HLARC), the Root Crop Research and Development Center (RCRDC), and the Agricultural Research Institute (AGI) (Ocampo et al., 2022). Details of the reference library used for cassava varietal identification can be found in Annex E.

3.4.4.4 DNA Sequencing

The samples were processed by Intertek Australia using low-density genotyping of 96 SNPs corresponding to SNPs developed at CIAT for DNA fingerprinting, and four trait SNPs/markers. The trait markers included two SNPs for cassava mosaic disease (CMD), one of which was more informative (Rabbi et al., 2022), and one SNP for dry matter (DM) content.

3.4.4.5 Analysis

The similarity between a reference and a field sample was determined using a distance matrix based on the Hamming distance[30]. Samples were clustered using the DBSCAN algorithm from sci-kit-learn (Hahsler et al., 2019), and classified into clusters if there were at least two

[29] Ordinary Least Squares (OLS) regression is a statistical method that estimates the relationship between dependent and independent variables, under a set of assumptions.

[30] The Hamming distance measures the number of differing elements between two sequences of equal length.

samples with the same fingerprint. Samples whose fingerprint did not match any other sample's fingerprint were classed as unique. Samples were excluded if they had more than 20% missing SNP data (n=58). The total number of samples merged with the household data was 758.

3.4.5 Cassava Mosaic Disease (CMD)-Resistant Cassava Varieties

The genotyping data generated for cassava varietal identification also included four trait-related SNP markers. Here, we present statistics using the subsample of cassava-growing households collected in the VHLSS 2023, where the presence or absence of a validated SNP marker for cassava mosaic disease named snpME0021 (Rabbi et al., 2022) was assessed. CMD resistance is a dominant trait, and genotypes with only one allele (heterozygous) may also exhibit some level of resistance. Thus, we used either the homozygous favorable allele (TT) or the heterozygous allele (TG).

3.4.6 Agro-Climatic Bulletins

Agro-Climatic Bulletins (ACBs) are context-specific agricultural recommendations that have been delivered to farmers in some communes of MRD since 2022. The bulletins are based on weather forecasts and modeling and are intended to facilitate farmers' decision-making.

In the VHLSS 2024, a new module was integrated at the commune-level to measure the reach of this innovation. These questions were only asked in communes located in MRD. Respondents were shown an image of a sample ACB and asked: "Do farmers in this commune receive Agro-Climatic Bulletins that deliver recommendations based on weather forecasts?". We also enquired about the frequency of ACB bulletins (seasonal, monthly, or every 10 days).

To validate this measurement, we compared the results with the project monitoring data pertaining to the districts where the ACBs are known to have been disseminated.

3.4.7 Climate-Smart Mapping and Adaptation Planning

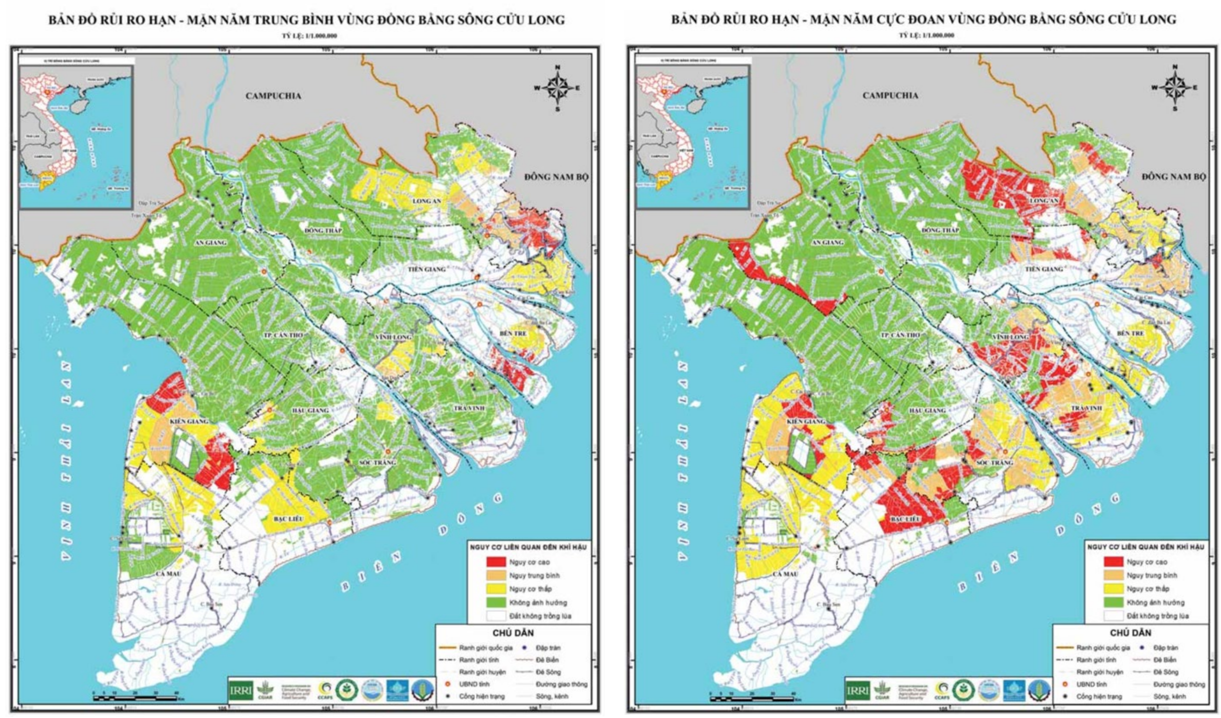
Starting in 2017, 41 provinces across four regions in Viet Nam have created climate change adaptation plans that are location-, risk-, and season-specific. These efforts were part of the Climate-Smart Mapping and Adaptation Planning (CS-MAP) Initiative, where CGIAR centers designed and implemented a participatory process to help policymakers design maps that would depict the climate risks faced in different parts of their province. These maps could be used to communicate the appropriate interventions if extreme climate conditions were realized (Tan et al., 2019). For example, drought risks in different locations could be identified, and location-specific recommendations documented on the maps. Agricultural recommendations, likely derived from collaborative research between Viet Nam's MARD and CGIAR centers, include shifting from rice to another crop or no crop, changing planting dates, or changing the irrigation schedule. It was envisioned that these recommendations would then be disseminated to households through province-level agricultural planning and agricultural extension services.

CS-MAPs in different regions focused on different types of risk, different cropping seasons, and different adaptation options. In provinces in MRD, these included the risks of drought, increased soil salinity, and flooding. In the NM, RRD, SCC, CH, and NC regions, the focus was the risk of drought.

In Figure 6 we see an example of the CS-MAPs in MRD illustrating the vulnerability of different areas in the region to drought-salinity risks under two distinct scenarios: a 'normal' year (Map A) and a 'severe' year (Map B). A color-coded system is used to represent the different levels of drought and salinity risk. Red indicates areas of high risk, orange represents medium risk, yellow signifies low risk, and green indicates no or minimal risk. White denotes areas with no rice cultivation.

Figure 6: CS-MAPs of drought-salinity risk in the Mekong River Delta region

(A) Normal year | **(B) Severe year**



Source: Risk Maps and Climate Change Adaptation Plan for Rice Production in the Mekong River Delta (MARD DCP, 2021)

In the scenario of a 'normal' year (Map A), the map is mostly green and yellow, indicating that most areas experienced low or no risk under typical conditions. However, coastal areas, such as Kien Giang, Long An, and Ben Tre, exhibit more orange and red zones, signaling higher vulnerability to drought and salinity. In contrast, in the scenario of a 'severe' year (Map B), more land is categorized with a high risk of drought salinity. Many areas that were green and yellow in the normal-year scenario became orange and red, reflecting an escalation in risk levels.

We obtained CS-MAP books that contain the maps for all 41 provinces across 4 regions. Table 3 provides an overview of the different climate risk levels and adaptation options recommended by CS-MAPs across the four regions.

Table 3: Overview of climate risk categories and recommended adaptation options by region

Region	Provinces	Risk level definition	Recommended adaptations
Mekong River Delta (MRD)	Can Tho, An Giang, Tien Giang, Dong Thap, Long An, Vinh Long, Ben Tre, Tra Vinh, Soc Trang, Hau Giang, Bac Lieu, Ca Mau, Kien Giang	**Climate risk levels are based on the forecasted impact of climate conditions on productivity.** High risk = Flood/drought/saltwater intrusion likely to cause losses of more than 70% of rice productivity. Medium risk = Flood/drought/saltwater intrusion likely to cause 70% to 30% loss of rice productivity. Low risk = Flood/drought/saltwater intrusion likely to cause 30% or less loss of rice productivity. No risk = No forecasted effect of flood/drought/saltwater intrusion on rice productivity.	Two recommendations for the Winter-Spring and Autumn-Winter seasons: • Cropping pattern changes: shift to one crop; two crops; three crops; crop + aquaculture; no rice planting • Planting date changes: by fortnight
Northern Midlands and Red River Delta (NM-RRD)	Ninh Binh, Nam Dinh, Thai Binh, Vinh Phuc, Hai Duong, Hung Yen, Bac Ninh, Ha Nam, Ha Noi, Hai Phong, Bac Giang, Phu Tho	**Climate risk levels are based on the forecasted water reservoir levels.** High risk = The water level in reservoirs (Whi) falls below 50% of capacity. Medium risk = The water level in reservoirs (Whi) lies between 50% to 85% of capacity. No risk = Water level (Whi) exceeds 85% of reservoir capacity, ensuring sufficient water supply for timely rice production.	One recommendation[31] for the Winter-Spring season: • Area (in ha) that needs to shift from rice to other crop
South Central Coastal and Central Highlands (SCC-CH)	Da Nang, Quang Ngai, Quang Nam, Binh Dinh, Khanh Hoa, Phu Yen, Binh Thuan, Ninh Thuan, Dak Lak, Gia Lai	**Climate risk levels are based on the forecasted water reservoir levels.** High risk = Water shortage results in more than a 30% decrease in crop production. Medium risk = Insufficient water results in less than a 30% decrease in crop production. No risk = Water is sufficient to ensure production.	One option recommended for the Winter-Spring, Summer-Autumn and Mua seasons: • Planting date changes: early planting; on time; late planting; shift crop; no rice planting
North Central (NC)	Thanh Hoa, Nghe An, Ha Tinh, Quang Binh, Quang Tri, Thua Thien Hue	**Climate risk levels are based on the forecasted rainfall and water reservoir levels.** High risk = Forecasted rainfall during the production season is >75% of average rainfall; The water level in reservoirs at the beginning of the season falls below 50% of capacity. Medium risk= Forecasted rainfall during the production season is 75% - 50% of average rainfall; The water level in reservoirs at the beginning of the season is between 50 to 70% of capacity. No risk = Forecasted rainfall during the production season is < 50% of average rainfall; The water level in reservoirs at the beginning of the season is above 75% of capacity.	One recommendation for the Winter-Spring and Summer-Autumn seasons: • Planting date changes: on time; seasonal schedule adjustment; shift crop or no rice planting

Source: Compilation by the authors using Risk Maps and Climate Change Adaptation Plan for Rice Production in the Mekong River Delta (MARD DCP, 2021a); Risk Maps and Climate Change Adaptation Plan for Rice and Short-term Crop Production in the Northern Midlands and Red River Delta (MARD DCP, 2021b); Risk Maps and Climate Change Adaptation Plan for Rice and Short-term Crop Production in the South Central Coast and Central Highlands (MARD DCP, 2021c); and Risk Maps and Climate Change Adaptation Plan for Rice and Short-term Crop Production in the North Central (MARD DCP, 2021d).

[31] Note: In the NM-RRD region, the recommended planting dates are the same in both normal and extreme year maps. Therefore, the planting date recommendations are not considered for analysis.

It is complex to link the province-level risk maps, a top-down policy innovation, to changes in the farming practices of Vietnamese farmers. First, for CS-MAPs to influence practices in farms, the information would have to be transmitted through several administrative layers (province, district, and commune) before it reached the farmers. Second, province-level recommendations depend on a multiplicity of policies and circumstances.

While each region decided upon its own context-relevant mapping approach and adaptation options, the theory of change is similar across regions.

The hypothetical pathway from CS-MAPs recommendations to farmers' adoption can be described as follows:

1. Participatory mapping exercises were conducted with MARD stakeholders to create risk maps and identify adaptation options. CS-MAPs were then provided to DARD, where they could be used for policymaking, and modified as needed.
2. Provincial DARDs identify an upcoming risk. They consult the CS-MAP for information to guide new rice planting regulations to respond to the risk, then communicate the risk and the new regulations in their annual and seasonal production plans.
3. The provincial production plans are an input into the annual and seasonal production plans designed at the district level, and further at the community level. In some provinces, CS-MAPs have been handed over to district authorities to improve climate resilience planning.
4. In each commune, information on the new recommendation is disseminated to farmers through extension services and agricultural agents.
5. Farmers follow the recommendation in a given cropping season.

Based on this theory of change, Section 7.2 documents the potential reach of CS-MAPs. Out of the five adaptation options recommended in the four regions, two changes in planting dates in the SCC-CH and SCC provinces could not be investigated due to the absence of available georeferenced maps in these provinces. Thus, Section 7 is based on the following three adaptation options:

- Shift land from rice to other crops in NM-RRD provinces.
- Change in cropping patterns in MRD provinces.
- Change in planting dates in MRD provinces.

We used a mixed set of methods:

Coding of adaptation measures recommended by CS-MAPs by season and risk-level

In each province, we started by using the online version of CS-MAPs to code the recommended adaptation options for the different agricultural seasons and for different risk-levels (no risk, low, medium, and high risk) in each area, and the percentage of land in the province to which the adaptation options relate. This file is available in the Repository.

Phone survey on the use of CS-MAPs by provincial DARDs

We then conducted a phone survey of officials from DARD in each of the 41 provinces. The objectives were first, to understand the decision process for recommending adaptation options and second, to enquire about the extent to which CS-MAPs were an input in agricultural planning in the previous three years. The target respondents were senior staff at DARD in charge of designing agricultural plans, sowing schedules, and water discharge schedules.

A list of 82 respondents was established in collaboration with MARD. In February 2023, two enumerators administered a short questionnaire (8-10 mins) through phone interviews. The final data consist of 74 interviews conducted in 41 provinces.

Qualitative content analysis of provincial agricultural plans (2021-2024)

Viet Nam has had annual crop plans in place since the 1960s, and it is common for local governments and agricultural extension services to make agricultural recommendations. For each year and cropping season, Viet Nam's provincial authorities design agricultural production plans, from province to commune levels.

This valuable data source provides an opportunity to detect signals regarding the expected climate risk levels that provincial authorities expect in any given year and the adaptation recommendations they take on board. We used 217 agriculture production plans across a 4-year period (2021-2024) from 35 provinces in Viet Nam[32], specifically from MRD (11 provinces), NM-RRD (10 provinces), and SCC-CH and NCC (14 provinces). These annual or seasonal plans were provided by the focal points of the Sub-Departments of Crop Production and Plant Protection.

We used qualitative content analysis of the agricultural plans to collect indirect evidence of CS-MAP use by provincial authorities. The primary root codes consisted of hydrometeorological forecasts and risk assessment and rice production and adaptation practices. Each of the 217 provincial agricultural production plans was coded meticulously using the Dedoose software. This involved systematically applying a coding tree to categorize and label the relevant information. Under each of these primary root codes, a hierarchical structure of parent and child codes was generated, resulting in 267 codes. The crop production plans, coding tree, and final output containing all codes are available in the Repository.

The analysis of the coded content consisted of descriptive statistics on the frequency of themes by province.

Quantitative analysis of households' planting dates in MRD (2022-2023)

In three of the four regions, a key recommendation in CS-MAPs is that farmers change their planting dates. Therefore, to measure the extent to which farmers followed this recommendation, new questions about rice planting dates were included in the VHLSS 2022 and 2023 questionnaires.

The VHLSS dataset was subsequently merged at the district level with the georeferenced CS-MAPs from MRD, utilizing the modal planting date of the district.

To assess the association between CS-MAPs' recommended planting dates and households' planting dates in MRD, we use an OLS regression approach. Our estimation sample consists of 3,264 household-level observations from two years (2022 and 2023), in 13 MRD provinces. The specifications are detailed in Appendix C.

[32] Crop production plans could not be accessed for the provinces of Tien Giang, Vinh Long (MRD), Khanh Hoa, Gia Lai (Central Highlands) or Ha Nam, Vinh Phuc (RRD).

To assess the reach, we calculated the number of households whose planting dates in 2023 corresponded to the modal district-level recommended planting dates in the CS-MAP extreme scenario, for both the Summer-Autumn and Winter-Spring seasons.

3.4.8 Laser Land Leveling

Laser land leveling (LLL) is a technology directed by lasers that levels terrain by transferring soil from elevated areas to lower areas of the field. This method enhances crop initiation and promotes even maturation of crops. LLL also cuts down on greenhouse gas output by conserving energy, shortening farming duration, and boosting the effectiveness of resource utilization. The technology has been showcased in Viet Nam, with services offered by governmental organizations (CGIAR Research Program on Rice, 2019).

SPIA introduced a question into the VHLSS 2023 questionnaire to ask rice farmers if they had applied laser leveling in their largest rice plot.

3.4.9 Drum Seeder

Viet Nam first introduced a plastic drum seeder in 2000. This was an improved version of the original 1990 IRRI steel design. This seeder allows for precise seeding in rows, using fewer seeds and reducing the risk of pests, thus leading to a decrease in pesticide use, improved plant health, and lower losses during harvest.

In the VHLSS 2022 and VHLSS 2023 surveys, questions were integrated about the seeding method used by rice farmers. In 2022, the question was framed as "During the last Winter-Spring season, which method did you use for seeding?". In 2023, it was rephrased as "During the last Winter-Spring season, which method did you use for seeding in your largest plot?". In both years, the drum seeder was provided as an answer option, although in 2022, the option was 'Row seeder,' while in 2023 the option was 'Row seeder/Drum seeder.'

3.4.10 Combine Harvester, Mini-Combine Harvester, and Rice Straw Baler

A combine harvester (CBH) is a large agricultural machine that efficiently reaps, threshes, and cleans grain crops in a single operation, significantly reducing the labor and time needed at harvest time. Although it is designed to harvest several crops, we focus on its use for harvesting rice in Viet Nam.

The mini-combine harvester (MCBH) is a compact version of a combine harvester and is better suited for smaller farms or less accessible plots. The device performs the same tasks but is more affordable and easier to maneuver for smallholder farmers.

A rice straw baler (RSB) is a collecting machine that performs a compacting action (baling), suitable for collecting rice straw left in the field by combine harvesters. This helps manage straw waste efficiently and makes it easier to transport and store.

A similar question with multiple possible options was used to measure the adoption of these three machines. Farmers were asked about their harvesting method for rice in both VHLSS 2022 and VHLSS 2023. Among the multiple answer options provided, were CBH, MCBH (although this was only included only in VHLSS 2022), and RSB.

3.4.11 Off-field Straw Management Practices

Off-field straw management practices involve the use of rice straw outside of the plot to reduce its environmental impact. CGIAR research in Viet Nam has explored the potential for straw to be transformed into by-products through rice straw-based composting, rice straw silage for cattle feed, and the use of rice straw for mushroom production (Rice-Straw Mushroom (RSM)). The adoption of these straw management practices was measured in the VHLSS 2022 through the question: "What did you mostly do with the straw removed from the plot?" with possible response options: feed for livestock, used for cooking, used for mushroom cultivation, and used for compost.

3.4.12 'Three Reductions, Three Gains' and 'One Must Do, Five Reductions'

'Three Reductions, Three Gains' (3R3G) and 'One Must Do, Five Reductions' (1M5R) are packages of sustainable practices introduced in 2003 and 2013 respectively. They include sets of criteria with very specific recommendations in different domains – seeds (both the quality of seed and the seed rate), fertilizer, pesticides, water, and harvesting. For instance, rather than loosely recommending that farmers reduce seed rates, the recommendation is that the seed rate should not exceed 120kg/ha. These recommendations are described in IRRI's handbook (Nguyen-Thi-My-Phung et al., 2020) under either "lenient" or "strict" criteria (Table 4).

Table 4: Overview of 'One Must Do, Five Reductions' (1M5R) lenient and strict criteria

	Lenient	Strict
1M (Certified Seeds)	Plant a combination of certified and own seeds	Only plant certified seeds
1R (Seed Rate)	Max 120 kg/ ha	Max 100 kg/ ha
2R (Fertilizer)	Max 110 kg of Nitrogen/ ha, across at least 2 applications	Max 100 kg of Nitrogen/ ha, across at least 3 applications
3R (Pesticide)	Maximum 3 insecticide and 3 fungicide applications No insecticides and fungicides in the 40 days after sowing No insecticides and fungicides in the 20 days before harvesting	Maximum 1 insecticide and maximum 2 fungicide applications No insecticides in the 40 days after sowing No fungicides after flowering
4R (Water)	Minimum 2 drydowns during reproductive stages of the plant Each drydown lasts at least 5 days (for dry season)	Safe Alternate Wetting and Drying measured using water ('pani') pipes
5R (Post-harvest loss)	Harvest only when 80-90% of the grains per panicle are straw-colored or yellow, and use combine harvester or certified thresher	Harvest only when 85% or more of the grains per panicle are straw-colored or yellow, and use certified combine harvesters
	Dry at temperature ≤ 43°C in flatbed and recirculating columnar dryers, within 24 hours after harvest until evenly dry, with <=3% moisture gradient in a batch	Dry: Dry at temperature ≤ 43°C in certified dryers and within 24 hours until evenly dry with <=2% moisture gradient in a batch
	Store grains at ≤ 14% moisture, store seeds at ≤ 12% moisture Store in bag or bulk in warehouse for ≤3 months	Store grains at ≤ 14% moisture, store seeds at ≤ 12% moisture Use hermetic/aeration storage Do not use fumigation in storage

Source: Nguyen-Thi-My-Phung et al., 2020

A mixed-method approach using both quantitative and qualitative analyses documented the reach of these innovations. The SPIA team conducted exploratory interviews to understand the context in Dong Thap province in March-April 2022. Insights from the interviews helped to develop, test, and refine a questionnaire module that was embedded in the VHLSS. We also use ancillary data from analyzing the texts of the provincial annual agriculture plans from 2021-2024. Specifically, we measure whether the plans mention (or repeatedly mention) the 3R3G or 1M5R packages or their components. These data reveal interesting insights about the relationship between the top-down efforts at dissemination of these innovations, and the actual adoption by farmers in the fields.

Our qualitative research in Dong Thap in 2022 revealed that the terms 1M5R and 3R3G are used interchangeably by farmers and extension officers. Farmers mention 1M5R when referring to the practice of reducing seed rates, fertilizer, and pesticides. Given this, in Section 10.1 we only discuss the adoption of certified seeds and 3R3G. In addition, since the strict water use recommendation in the 1M5R package is to adopt Alternate Wetting and Drying (AWD), in Section 10.2 we analyze the adoption of AWD. In Section 9 we measure the reduction of post-harvest losses (the sixth component of 1M5R) indirectly (and arguably insufficiently) through the adoption of mechanization, since one of the recommendations there is to harvest using a combine harvester.

Appendix D provides more details on the measurement of 3R3G components.

3.4.13 Alternate Wetting and Drying

Alternate Wetting and Drying (AWD) is an irrigation strategy where farmers periodically cut off irrigated water to allow the field to dry before reapplying water. This cyclical pattern of watering and drying reoxygenates the soil, reducing the growth of anaerobic microorganisms. Killing these bacteria is beneficial as it minimizes the production of harmful gases like methane By implementing AWD, farmers can conserve water resources and decrease methane emissions while sustaining rice production levels. AWD is also the fourth domain in the 1M5R practice.

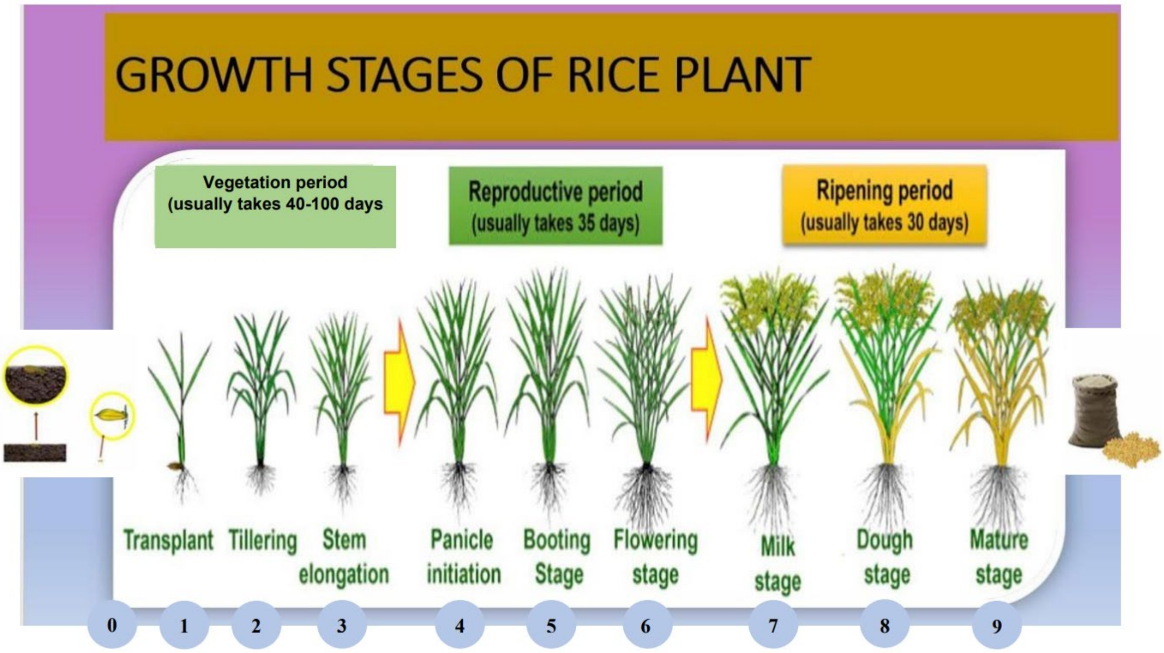
In VHLSS 2022, we measured AWD using two approaches. First, the survey asked farmers about their awareness of the term and whether they had applied it. Second, it asked about the specifics of their irrigation practices such as whether the farmer had dried their field, when they had dried it, and for how long. Their answers were compared to the AWD recommendations to more objectively calculate the adoption rate. The results showed that, depending on the method of measurement, estimates of AWD adoption ranged from 400,000 to several million households. The conclusion after this first year of data inclusion was that more accurate and nuanced methods were required to measure AWD adoption.

In November 2022, SPIA conducted a qualitative study to develop a new, comprehensive survey module designed to more accurately capture irrigation practices adopted by farmers. As part of this study, 45 open-ended semi-structured interviews were conducted with rice farmers in the upstream area of MRD. These qualitative data were analyzed, and the findings informed the development of new close-ended survey questions designed to capture farmers' actual agricultural choices. The questions were designed to be comprehensive enough to account for seasonal variations in agricultural conditions and the influence of different institutional structures, particularly those related to irrigation systems.

The newly developed questions were then field-tested across four regions: MRD, RRD, NC, and SCC. This process included open-ended discussions with farmers who were interviewed to assess how well the questions captured the desired information, identify any issues and refine the questions accordingly. Finally, a team of enumerators tested the improved module with 150 rice farmers across six provinces in three regions (MRD, RRD, and NCC).

In VHLSS 2023, SPIA and GSO further improved 3R3G/1M5R and AWD measurements by adopting a more detailed approach. This involved the use of a visual aid that depicted the rice growth cycle (See Figure 7). Households were asked about each specific drydown event and to indicate when it had occurred with the help of the rice growth stages visual aid. Additionally, the duration of each AWD drydown was recorded in days. Although we did not ask about the exact depth to which the water level had dropped (the AWD recommendation is that water levels drop 15 cm below the soil surface to provide GHG mitigation benefits), there is evidence that a five-day drydown period likely correlates with this depth (Reavis et al., 2021).

Figure 7: Visual Aid used to measure the timing of 3R3G/1M5R agricultural practices



Source: SPIA

Based on updated information from MARD (Nguyen-Thi-My-Phung et al., 2020) and scientific studies (Lampayan et al., 2015; Reavis et al., 2021), the analysis was also adjusted to define AWD as any drydown lasting at least five days (compared to seven days and ten days in the Viet Nam preliminary report). In VHLSS 2023, AWD adoption was computed using the improved survey module. Farming households were defined as adopting AWD if they allowed their plots to dry for at least five days between the rice transplanting and flowering stages. We report data on the occurrence of one drydown as well as two or more.

Importantly, the practice of AWD could result from independent decision-making by individual farmers, or, more commonly, from community-level decisions about irrigation discharge schedules. Note also that our measurement approach would count a farmer as adopting AWD whether they intentionally dried their field, or whether the field dried accidentally or due to natural circumstances outside their control, such as low rainfall or high temperatures.

3.4.14 Sustainable Water Use for Coffee Production

Sustainable Water Use for Coffee Production is an innovation following a recommendation developed by the International Water Management Institute (IWMI), the Hanns Neumann Stiftung, and Nestle, based on coffee water footprint calculations. It has been found that under normal climatic conditions, 400 L of water/plant/irrigation application is sufficient to sustain coffee yields.

SPIA integrated a survey module into the VHLSS 2023 to ask coffee farmers about the number of times they had irrigated their coffee plants and the quantity of water they used for each irrigation. Households are categorized as adopters if they reported a maximum of 400 liters per coffee plant/irrigation round during the previous growing season. The computed variables relied on two questions: "In the last dry season, how many rounds of irrigation did you use?" and "In each irrigation round, how many liters did you use per plant?"

3.4.15 Payments for Forest Environmental Services

Payments for Forest Environmental Services (PFES) is a payment mechanism that provides incentives for the sustainable management of natural resources. Provincial agencies sign entrusted contracts with forest users and collect and distribute payments to forest environmental service providers, based on the area that is currently forested. These payments incentivize forest providers to adopt environmentally beneficial land-use practices.

The reach of PFES can be measured at the commune level since forest providers may be local organizations or entities. A new module was designed and integrated into the VHLSS 2024 community questionnaire. The target respondents were commune-level staff in charge of agriculture/forestry or officers of agriculture/forestry departments.

The main variable used to determine if a commune had an existing PFES mechanism is the answer to the question, "In the year 2023, did your commune have any Payments for Forest Environmental Services area?" Subsequent questions also enquired about the amount of forest area covered and the payment received from the Forest Protection and Development Fund (FPDF).

The data presented in this report are preliminary and only cover data collection that occurred during the first three quarters of 2024. Final estimates of the reach of the PFES will be available in Q1 2025.

In VHLSS 2024, we focus solely on the PFES money distributed to the Commune People's Committee (CPC). This excludes other forest owners, such as individuals, households, communities, forest management boards, and forestry companies[33]. CPCs primarily use the PFES revenues to pay for wages and allowances for members of the commune's forest patrol teams.

[33] PFES payments are made directly from provincial funds or national parks (for contractor households) to households or villages. However, the VHLSS survey only collects data at the commune level. Since Commune People's Committees do not manage household funds, they are unable to provide answers to questions related to household or village-level financial matters.

When calculating the number of households benefiting from PFES, it is crucial to recognize that forests are both monetary and common-pool resources. Consequently, the protection and development of forests through PFES payments likely benefit all households in the commune (and possibly even beyond), regardless of their direct association with the forest.

To compute the number of households reached, we limited the scope to the number of households in the commune where the PFES scheme was reported as operational. We used the actual number of households in a commune reported in the Population Census 2019. If a commune reported receiving PFES money in 2023, all its households are counted as PFES beneficiaries.

3.5 Data Analysis

The tables and figures presented in this report aim to summarize the main empirical results obtained through a detailed descriptive analysis of the collected information. The sample consists of approximately 47,000 households per survey year, for the VHLSS 2022 and 2023. Statistics are calculated over the population of crop growers surveyed in different years.

One innovation - Payment for Forest Ecosystem Services – was measured in the VHLSS 2024 community survey. Preliminary results presented in this report are based on 198 enumeration areas (EAs) surveyed during the first three quarters of data collection.

Analysis was conducted using the raw VHLSS datasets available here. Statistics on adoption are calculated at two levels: 1) the EA-level[34]: an EA is coded as having adopted an innovation when at least one household in the EA was deemed to use/follow an innovation; and 2) the household-level: a household is coded as having adopted an innovation if it is found to be using the innovation. The EA level measure can be considered as indicating the spread of the innovation, while the household-level measure indicates the intensity of adoption.

The detailed results on which the tables are drawn, complementary empirical analyses, as well as all the program files that allow replication of the analysis, are available in the Repository.

3.5.1 Share and Number of Households Reached

Section Four presents an overview of our estimated adoption rates for each innovation, based on data from the VHLSS household sample for 2022 and 2023, and VHLSS commune sample for 2024. As discussed above, adoption rates are estimated at both the EA and household levels, applying sampling weights to ensure national and regional representativeness. Each adoption rate is calculated based on the specific population most relevant to the respective innovation (Table 7 in Section Four).

Since households may adopt multiple innovations, a simple sum of the number of households adopting each CGIAR-related innovation (Table 7, in Section Four) cannot tell us how many households have been reached by CGIAR-related agricultural innovations. To calculate the total reach, we started by adding all weighted estimates for households that adopted only one innovation (single-adopters) in a given year, using the general population weight (wt45), and then attempted to add in the households who adopted multiple innovations (multi-adopters).

This process is somewhat complicated by the fact that adopters of improved rice and improved cassava are identified using the DNA fingerprinting data, which was collected only from a subsample of the VHLSS rice and cassava growers. For these adopters, we used crop-specific weights (Appendix B) instead of the general population weight.

[34] An EA is defined to be either urban or rural based on the classification of the specific third administrative unit above it. Hence, an EA is rural if it is in a commune and is urban if it belongs to either a ward or a township. In our analysis, we used the list of administrative units issued by GSO to classify urban/rural EAs (GSO, 2022).

In cases where multi-adopters included one innovation measured with a DNA subsample (e.g., adopters of improved cassava and sustainable coffee for water production), we applied the crop-adjusted weight and then subtracted the general population weight (wt45) to obtain the final estimate.

Finally, we are not well situated to measure multi-adoption since we measured different innovations in different survey waves and only a part of the VHLSS sample is a panel. For instance, rice DNA samples were collected in 2022, but we attempted to identify adoption of the 3R3G/1M5R innovation in 2023, resulting in only partial sample overlap. This limitation primarily affects crop-specific systems, as the crops covered in this report are typically cultivated in distinct geographical areas of Viet Nam. This limitation is acknowledged in the analysis.

3.5.2 Socio-Economic Characteristics of Adopters

Adopters of CGIAR-related innovations are characterized using a set of household-level variables collected in the VHLSS 2022 and 2023. These variables were selected based on their reflection of the smallholder farmer context, income, and gender, which are focus impact areas for CGIAR. Descriptive statistics of these variables are presented in Table 5.

Table 5: Overview of socio-economic variables used to characterize the adopters of CGIAR-related innovations in Viet Nam

	2022		2023	
Variable	**Mean**	**SD**	**Mean**	**SD**
% of households with female head	16.2	36.9	16.5	37.1
% of households whose head is an ethnic minority[35]	35.8	48.0	35.2	47.8
% of households with internet access	62.1	48.5	68.9	46.3
Total agricultural land managed or used by the household (ha)	1.0	1.6	1.1	1.8
Age of household head (years)	52.0	12.3	52.5	11.9
Household head's highest completed grade	7.6	3.1	7.7	3.1
Household size	4.0	1.7	4.0	1.7
Annual income (in million VND)	144.4	128.4	157.0	132.1
Annual consumption (in million VND)	92.2	229.4	59.3	176.7
Commune is labeled as poor (%)	24.6	43.1	-	-
Main road is asphalt (%)	78.4	41.2	-	-
Distance to wholesale market (in km)	14.3	24.5	-	-
Distance to extension center (in km)	12.6	11.8	-	-

Note: In 2022, consumption data were collected using a standardized recall module that collects detailed information on household expenditures on food items, non-food items, and durable goods over specified recall periods. In 2023, the variable only captures households' production expenses across categories such as cultivation, livestock, hunting and wildlife domestication, agricultural services, forestry, aquaculture, and non-agricultural sectors like manufacturing and processing.

- = Data not collected in this survey year.

Data source: VHLSS 2022 and 2023.

[35] Defined as non-Kinh household heads.

4. Overview of Results

This section presents an overview of the key findings from the analysis of CGIAR-related innovation adoption in Viet Nam. Following the stocktaking exercise, the following 19 innovations were identified for data collection. A summary table of these innovations is presented in Table 6. Additional details on each of these innovations can be found in the Repository.

Table 6: Overview of CGIAR-related innovations included in nationally representative survey

Core domain (section)	Innovation
Aquaculture and Capture Fisheries (Section Five)	Genetically Improved Farmed Tilapia (GIFT)-derived strains
Breeding Innovations (Section Six)	CGIAR-related Cassava varieties Cassava Mosaic Disease (CMD)-resistant Cassava Varieties CGIAR-related Rice Varieties Salt-tolerant Rice Varieties (STRVs) Submergence-tolerant Rice Varieties CGIAR-related Potato varieties *
Climate Change Adaptation Options (Section Seven)	Agro-Climatic Bulletins (ACBs) * Climate-Smart Mapping and Adaptation Planning (CS-MAP)
Environmental Conservation (Section Eight)	Payments for Forest Environmental Services (PFES)
Mechanization (Section Nine)	Laser Land Leveling (LLL) Combine Harvester (CBH) Mini-Combine Harvester (MCBH) Rice Straw Baler (RSB)
Sustainable Intensification Practices (Section Ten)	'Three Reductions, Three Gains' (3R3G) and 'One Must Do, Five Reductions' (1M5R) Alternate Wetting and Drying (AWD) Drum Seeder Off-field Straw Management Practices Sustainable Water Use for Coffee Production

Note: * Results on CGIAR-related potatoes are not presented in this report due to limited sample size (n=32). Additionally, results for ACBs are preliminary, and no adoption estimates are provided.

Table 7 utilizes new survey modules integrated into the VHLSS 2022, 2023, and 2024, as indicated in Column 1. It reports nationally representative estimates at the enumeration area (EA) and household levels, expressed as percentages, in Columns 2 and 3. Column 4 shows the adoption rates calculated for the subpopulation that is most relevant for each innovation.

An EA is considered an adopter if at least one sample household is an adopter of the innovation. Collectively, these EA-level and household-level adoption estimates provide a nuanced understanding of geographical variation and adoption intensity across the country. Finally, Column 5 reports the total estimated number of households that adopted this innovation using the VHLSS sampling weights to estimate the number in the larger population. These absolute figures are directly comparable between different innovations, and they represent the estimated total number of households in Viet Nam reached by each innovation.

Table 7: Adoption rate at enumeration area (EA) and household levels (in %), and estimates for the absolute numbers of households

	VHLSS survey round	% of EAs	% of households with innovation (among households defined in column 4)	Conditions applied for survey questions	Estimated number of households
	(1)	(2)	(3)	(4)	(5)
Aquaculture & Capture Fisheries					
Genetically Improved Farmed Tilapia (GIFT)-derived Strains	2023	77.2	29.7	Tilapia-growing households	27,291
Breeding Innovations					
CGIAR-related Cassava Varieties	2023	62.5	54.4	Cassava-growing households selected for leaf sampling	270,869
Cassava Mosaic Disease (CMD)-resistant Cassava Varieties*	2023	50	29.7		147,892
CGIAR-related Rice Varieties	2022	5.8	25	Rice-growing households selected for leaf sampling	1,926,902
Submergence-tolerant Rice Varieties (Sub-1 QTL)*	2022	3.2	1.5		114,906
Salt-tolerant Rice Varieties (Saltol QTL)*	2022	49.2	30.8		2,354,528
Climate Change Adaptation Options					
Climate-Smart Mapping and Adaptation Planning (CS-MAP)	2023	49.6	27.4	Households who planted rice in the last 12 months (MRD only)	171,561
Environmental Conservation					
Payment for Forest Environmental Services	2024	11.6	NA	Communes in 41 provinces that have legally implemented PFES	227,331
Mechanization					
Laser Land Leveling	2023	13.9	5.4	Households that planted rice in the past 12 months	409,359
Combine Harvester	2023	81.7	74		5,621,020
Mini-combine Harvester	2022	26.9	10.3		800,280
Rice Straw Baler	2023	12.8	4		303,644
Sustainable Intensification Practices					
Components of 'One Must-Do, Five Reductions' (1M5R):					
1M: Certified Seeds (lenient)	2023	95.1	89.2	Households that planted rice in the past 12 months	6,777,472
1R: Seed Rates (lenient)	2023	76.8	75.8		5,428,344
2R: Fertilizer (lenient)	2023	87.7	62.8		4,718,949
3R: Pesticide (lenient)	2023	46.7	21.4		1,611,585
Three Reductions, Three Gains (3R3G)	2023	27.4	10.5		787,775

	VHLSS survey round	% of EAs	% of households with innovation (among households defined in column 4)	Conditions applied for survey questions	Estimated number of households
	(1)	(2)	(3)	(4)	(5)
Alternate Wetting and Drying	2023	14.7	5.4		408,689
Drum seeder	2023	5.6	1.7		127,955
Off-field rice straw management	2022	0.8	0.2		4,949
Sustainable Water for Coffee Production	2023	78.9	62.6	Coffee-growing households in the Central Highlands	491,393

Note: Estimates of adoption rates of Genetically Improved Farmed Tilapia (GIFT)-derived strains, improved rice varieties, submergence-tolerant rice varieties, salt-tolerant rice varieties, improved cassava varieties, and CMD-resistant cassava varieties are genetically identified through DNA fingerprinting. Breeding innovations refer to CGIAR-related varieties only. *Traits related to cassava-mosaic disease tolerance, salt tolerance, and submergence tolerance are also found in landraces/non-CGIAR-related varieties. 1M: Certified seeds (lenient) rely on farmers' self-reports on the seed type they planted. For the 1M5R/3R3G innovation, we present estimates on the components of the package. Certified seeds (lenient): A combination of certified and farmers' seeds are planted. Fertilizer (lenient): A maximum of 110 kg of nitrogen is applied per ha, across at least two applications. Pesticide (lenient): A maximum of six applications, with no applications before the panicle initiation or after the dough stages. Results on Agro-Climatic Bulletins (ACBs) are not presented in this table due to a mismatch between the nationally representative data collected in the VHLSS and the location of the project intervention.

QTL= Quantitative Trait Locus

Table 8: Summary of adoption rates by regions at the EA and household levels (%)

	Viet Nam		Red River Delta		Northern Midlands and Mountains		Northern and Central Coast		Central Highlands		Southeast		Mekong River Delta	
	N	Panel	%EA	%HH	%EA	%HH	%EA	%HH	%EA	%HH	%EA	%HH	%EA	%HH
Aquaculture & Capture Fisheries														
Genetically Improved Farmed Tilapia (GIFT)-derived Strains	194	2023	-	-	100	90.2	-	-	-	-	-	-	31.6	7.3
Breeding Innovations														
CGIAR-related Cassava Varieties	738	2023	-	-	45.5	34.1	74.7	68.5	90	68.5	-	-	-	-
Cassava Mosaic Disease (CMD)-resistant Cassava Varieties*	738	2023	-	-	55.6	36.6	50.7	30.5	32.5	14.3	-	-	-	-
CGIAR-related Rice Varieties	766	2022	15.8	10.8	32.6	15.4	13.3	3.9	63.6	45.2	-	-	73.2	59.1
Submergence Tolerant Rice Varieties (Sub-1 QTL)*	766	2022	-	-	-	-	6.7	2.3	18.2	4.5	-	-	3.7	3.1
Salt-tolerant Rice Varieties (Saltol QTL)*	760	2022	40.4	26.3	47.8	26.6	46.7	22.6	27.3	12.7	-	-	59.3	46.5
Climate Change Adaptation Options														
Climate-Smart Mapping and Adaptation Planning (CS-MAP)	1069	2023	-	-	-	-	-	-	-	-	-	-	49.6	27.4
Environmental Conservation and Ecosystem Services														
Payment for Forest Environmental Services (PFES)	1,539	2024	-	-	38.4	-	8.6	-	23.6	-	0.9	-	-	-
Mechanization														
Laser Land Leveling	13,217	2023	18.2	7.9	9	2	15.9	5.6	20.4	12.1	12	11.5	10.8	3.6
Combine Harvester	13,217	2023	98.5	96.5	51.7	35.6	89.2	80.6	67.3	49.8	96	97.7	96.2	93
Mini-combine Harvester	13,986	2022	24.5	8.4	40.2	13.1	27.4	13.3	45.4	13.3	12.1	4.9	5.2	1.2
Rice Straw Baler	13,217	2023	8.7	2.2	9.8	2.2	18.1	6.5	10.2	3.1	24	11	14.3	5.7

	Viet Nam		Red River Delta		Northern Midlands and Mountains		Northern and Central Coast		Central Highlands		Southeast		Mekong River Delta	
	N	Panel	%EA	%HH	%EA	%HH	%EA	%HH	%EA	%HH	%EA	%HH	%EA	%HH
Sustainable Intensification Practices														
Components of 'One Must-Do, Five Reductions' (1M5R)														
1M: Certified Seeds (lenient)	13,216	2023	98.5	95.7	96.9	87.2	93.8	89.6	86.7	72.4	92	92.6	93	83.6
1R: Seed Rates (lenient)	12,244	2023	99.5	97.6	96.8	93	72.1	71	37.2	19.5	42.1	26.2	40.1	22.9
2R: Fertilizer (lenient)	13,061	2023	88.2	67.6	86.7	57	89	61.5	83.7	52.9	65.4	39	89.5	71.8
3R: Pesticide (lenient)	13,087	2023	36.8	17.9	65.9	24.6	53.2	25.3	52.5	24.4	15.4	6.5	22.4	13
'Three Reductions, Three Gains'	12,925	2023	26.4	12.4	41.2	12.1	31.5	11.6	13.1	4.7	3.8	0.3	9.5	3.1
Alternate Wetting and Drying	13,112	2023	12	8.2	23.4	6.4	11.8	2.9	19.2	4.8	16	2.8	8.5	3.6
Drum Seeder	13,217	2023	3.7	1	0.2	0	1.5	0.5	3.1	0.2	4	0.8	22.5	10
Off-field Rice Straw Management	4,313	2022	-	-	0.4	0.1	0.3	0.2	-	-	-	-	3.5	0.9
Sustainable Water for Coffee Production	1,272	2023	-	-	-	-	-	-	79.4	63.2	-	-	-	-

Note: Estimates of adoption rates of Genetically Improved Farmed Tilapia (GIFT)-derived strains, improved rice varieties, submergence-tolerant rice varieties, salt-tolerant rice varieties, improved cassava varieties, and CMD-resistant cassava varieties are genetically identified through DNA fingerprinting. Breeding innovations refer to CGIAR-related varieties only. *Traits related to cassava-mosaic disease tolerance, salt tolerance, and submergence tolerance are also found in land races/non-CGIAR-related varieties. 1M: Certified seeds (lenient) rely on farmers' self-reports on the seed type they planted. For the 1M5R / 3R3G innovation, we present estimates on the components of the package. Certified seeds (lenient): A combination of certified and farmers' seeds are planted. Fertilizer (lenient): A maximum of 110 kg of nitrogen is applied per ha, across at least two applications. Pesticide (lenient): A maximum of six applications, with no applications before the panicle initiation or after the dough stages. Results on Agro-Climatic Bulletins (ACBs) are not presented in this table due to a mismatch between the nationally representative data collected in the VHLSS and the location of the project intervention.

- = not estimated due to small sample size.

Estimate for Payment for Forest Environmental Services (PFES) is only based on the first three quarters of VHLSS 2024 and is measured through the commune-level questionnaire.

HH = household

Finally, Table 9 provides an overview of the key socioeconomic variables associated with the adoption of CGIAR-related innovations. As mentioned in Section 3.5.2, we draw on a set of household-level correlates from the VHLSS. The selection of these variables reflects key characteristics relevant to smallholder farmers. The analysis provides an initial understanding of whether CGIAR's innovations are reaching the relatively deprived sections of the farming population.

Each cell in the table displays the coefficient estimate from a multivariate regression of the row variable on all column variables. The dependent variable is a dummy variable equal to one if the household is an adopter. Standard errors were clustered at the EA level. Cells highlighted in green indicate a positive relationship, and those highlighted in red show a negative relationship. All estimates were based on data from the most recent year when the adoption of the innovation was measured in the VHLSS (dates are shown in Table 7).

Importantly, note that regional variations in landholdings, access to infrastructure, and other such factors may also drive the associations we see in this table. To control for these confounding factors, in Appendix E, we present results from the same regression specification as in Table 9, but with controls for region fixed effects. Below we mainly interpret the coefficients that remain consistently significant across both specifications.

Our results show significant heterogeneity across innovations in the types of households that adopted CGIAR-related innovations. Some major patterns that emerge are as follows.

While CGIAR may hope to reach the relatively poor farmers with their innovations, within a country we may expect farmers who own or operate more land to be better able to adopt these new technologies. We do see a positive association of household income with the adoption of some mechanization innovations, specifically, laser land leveling and combine harvesters. Regarding income, the size of agricultural land is negatively associated with the adoption of these two innovations – which is a puzzling result that would benefit from further investigation. Yet, while income does not seem to matter consistently for the adoption of drum seeders, farmers with more agricultural land are more likely to adopt them. If we interpret internet access as a measure of relative privilege, then it seems to correlate positively with the adoption of CGIAR-related cassava, salt-tolerant rice as well as combine harvesters.

There is some evidence that relatively poor farmers may have been more likely to adopt sustainable intensification practices – ethnic minority households are less likely to adopt mechanization innovations but more likely (and households with internet access are less likely) to follow sustainable intensification practices such as reducing pesticide use, and 3R3G more broadly. Gender as indicated by the household having a female head is associated with the adoption of some of the innovations we study – female-headed households are more likely to be growing CMD-resistant cassava, although less likely to be growing CGIAR-related cassava. We also see in Appendix E that female-headed households are more likely to be using combine harvesters. Further research is needed to understand what drives these associations.

Ethnic minority[36] households were more likely to be cultivating GIFT-derived tilapia strains. They were also more likely to report practices in line with the 'Three Reductions, Three

[36] Defined in this report as household head from a non-Kinh ethnic background.

Gains' sustainable rice intensification package. However, they were less likely to report using mechanized tools such as laser land leveling and the drum seeder.

Considering the indicator of gender, we also see inconsistent association patterns with adoption. On the one hand, there is suggestive evidence that female-headed households are more likely to be practicing sustainable intensification practices in coffee production and more likely to be growing cassava varieties resistant to cassava mosaic disease. On the other hand, they are less likely to grow CGIAR-related cassava varieties. We do not estimate a gender differential in adoption for any of the other innovations.

Table 9: Overview of variables associated with the adoption of agricultural innovations

Innovation	Age of HH head (std)	Annual income (std)	HH head from an ethnic minority	Highest completed grade (std)	HH head is female	Household has internet	Household size (std)	Main road is asphalt	Total agricultural land (in ha)
Aquaculture and capture fisheries									
GIFT-derived Tilapia Strains	0.01	0.03	0.53 ***	0.12 **	-0.06	-0.01	-0.01	NA	0.00
Breeding innovations									
CGIAR-related Cassava Varieties	-0.06 *	-0.08	-0.06	-0.04	-0.18 **	0.15 **	0.04	NA	0.00
Cassava Mosaic Disease (CMD)-resistant Cassava Varieties	0.11 **	-0.01	0.07	0.04	0.13 *	-0.06	0.02		-0.01
CGIAR-related Rice Varieties	0.00	0.34	-0.09	-0.05 **	0.05	0.05	-0.02	-0.16 **	0.07 ***
Salt-tolerant Rice Varieties~	0.00	-0.14	-0.06	-0.04	-0.06	0.10 *	0.00	-0.14 **	0.04 **
Climate Change Adaptation Options									
Climate-smart Mapping and Adaptation Planning (CS-MAP)	0.00	0.02	0.01	-0.01	-0.05	0.02	0.05 *	NA	-0.01
Mechanization									
Laser Land Leveling	-0.01 *	0.01 *	-0.04 ***	0.00	-0.01	0.00	0.00	NA	-0.01 **
Combine Harvester	0.03 ***	0.05 ***	-0.54 ***	0.00	0.02	0.02 **	-0.02 **	NA	-0.03 ***
Rice Straw Baler	0.00	0.00	-0.02 *	0.00	-0.01	0.00	0.00	NA	0.00
Sustainable Intensification Practices									
Components of 'One Must-Do, Five Reductions'									
1R: Seed Rate	0.03 ***	0.02 **	0.13 ***	0.08 ***	0.02	0.03 **	-0.02 ***	NA	-0.08 ***
2R: Fertilizer Use	0.01	0.02 **	-0.07 **	0.01	0.02	-0.02	0	NA	0
3R: Pesticide Use	-0.01 **	-0.01	0.1 ***	0.01	0.02	-0.04 **	0.01 **	NA	0
'Three Reductions, Three Gains'	0.00	0	0.04 **	0.01 **	0.01	-0.02	0	NA	-0.01 *
Alternate Wetting and Drying	0.01 **	0.01	0.02 **	0.01 **	-0.01	0.01	-0.01 **	NA	0
Drum Seeder	0	0	-0.03 ***	-0.01 **	0	0	0	NA	0.01 ***
Sustainable Water for Coffee Production	-0.04	0.09	0.2 **	0.05	0.19 **	-0.13	-0.05	NA	-0.01

Note: *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. NA = Non-available in VHLSS 2023. ~ = Traits related to cassava-mosaic disease tolerance, salt tolerance, and submergence tolerance are also found in land races/non-CGIAR-related varieties. Each cell displays the coefficient estimate from an OLS multivariate regression of the row variable on all column variables. The dependent variable is a dummy variable equal to one if the household is an adopter. Standard errors were clustered at the EA level. Cells are colored if the estimated coefficient is statistically different from zero. Green cells indicate a positive relationship, whereas red cells show a negative relationship. All estimates are based on the most recent year for which this innovation was collected in the VHLSS. Annual income and total agricultural land were winsorized at the 99th percentile. Age, annual income, education, and household size were standardized using z-scores. The analysis excludes innovations adopted by fewer than 3% of households.

HH = household

5. Aquaculture and Capture Fisheries

Viet Nam's aquaculture sector has expanded significantly over the last two decades. The contribution of aquaculture and fisheries to GDP increased from 10.5% in 2000 to 22.2% in 2023. In parallel, the proportion of aquaculture and fishery workers in the labor force increased from 4% to 11% during the same period (GSO, 2023). These changes are accompanied by a four-fold increase in the value of exports of aquaculture and fishery products, from USD 2.2 billion in 2000 to USD 9 billion in 2023 (GSO, 2023).

Targeted investments along the aquaculture value chain and incentives for households to shift from fisheries to aquaculture have likely contributed to this expansion. Since the 1990s, there has been an emphasis on small-scale aquaculture as a vehicle for poverty alleviation. The Sustainable Aquaculture for Poverty Alleviation project outlined a strategy to better support vulnerable groups that depend on or could make use of aquatic resources (Ministry of Fisheries, 2001). Under this scheme, households in the Mekong River Delta (MRD) and North Central Coastal (NCC) provinces received financial support to transition from fishing to aquaculture. More recent policies place more emphasis on the industrialization of the sector, while also mentioning the poverty reduction potential of aquaculture in the North Central and Central Coastal Areas (NC) and the Mountainous, Midland, and Central Highlands regions (Decision 1690/QĐ-TTg, 2010)[37].

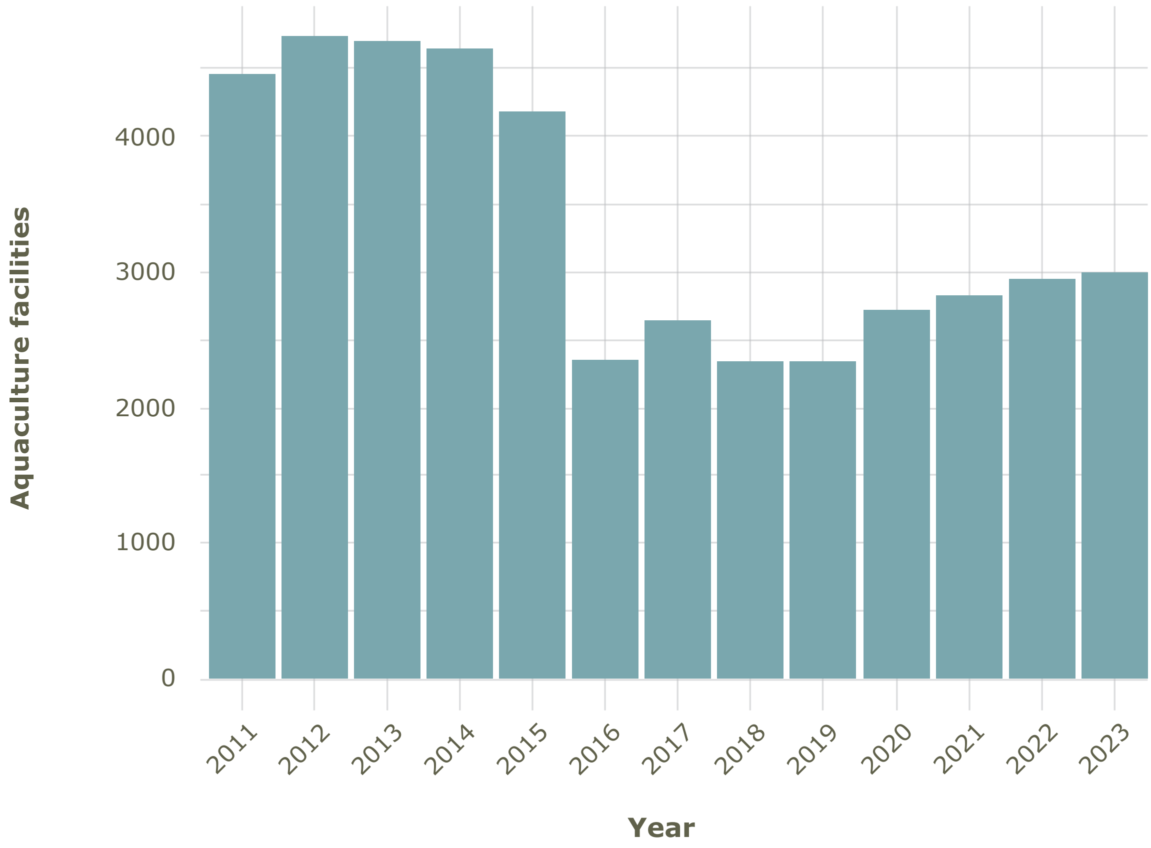
The total area under aquaculture in Viet Nam expanded by 43% in the two decades since 2000, reaching 1,100,000 ha in 2020[38]. In addition, following a large reduction of aquaculture facilities in the MRD in 2016, possibly due to drought, there has been a steady increase in the number of large-scale aquaculture facilities (Figure 8)[39]. Three-quarters of these large-scale farms are located in MRD. The most farmed species in Viet Nam are pangasius, shrimp, tilapia, carp, mollusks, and crabs.

[37] Decision 1690/2010/QĐ-TTg dated on 16 Sep 2010 on the approval of Vietnam's fisheries development strategy to 2020. https://chinhphu.vn/?pageid=27160&docid=96770&tagid=6&type=1

[38] Author's compilation using GSO, Statistical Yearbook, from 2010 to 2020

[39] These are defined as aquaculture farms with "an average production value of at least VND 2.0 billion/year (equivalent to USD 87,925) and a total production land area superior to 1 ha or more" (Circular 02/2020/TT-BNNPTNT, Article 3)

Figure 8: Number of large-scale aquaculture facilities in Viet Nam (2011-2023)



Data source: General Statistics Office, 2023.

A total of eight aquaculture and fisheries innovations were identified in the Viet Nam stocktake. The first group of innovations is related to breeding: Genetically Improved Farmed Tilapia (GIFT)-derived strains, genetically improved common carps, and sea cucumber breeding methods. WorldFish has also conducted research on aquaculture management, with innovations such as nutritious-system pond farming and integrated Agriculture-Aquaculture (IAA) systems: shrimp-tilapia-seaweed. A third group of innovations is more oriented toward the collective management of resources: community-based fish culture (CBFC) in seasonal floodplains, area-based management (ABM) of aquaculture, and fisheries resource co-management (FRC) or Community-Based Fisheries Management (CBFM).

Among these innovations, we concluded that only GIFT-derived strains could potentially be at scale in 2023[40]. This section presents the results of the data integration and follow-up survey designed to measure the adoption of GIFT-derived strains in Viet Nam. This innovative DNA fingerprinting study was conducted at the household and hatchery levels in 2023.

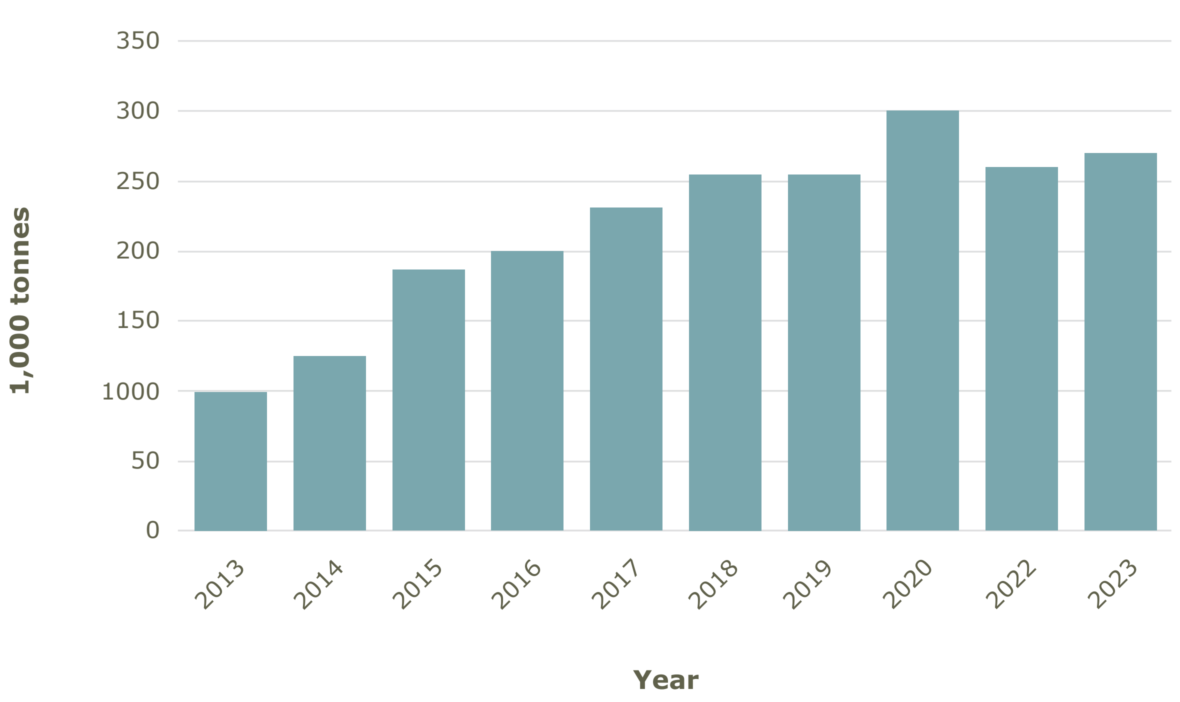
[40] The Vietnamese stocktake provides details on the potential for each of these eight innovations to be at scale in 2023.

5.1 Genetically Improved Farmed Tilapia-Derived Strains

Tilapia is a member of the Cichlidae family, one of the largest families of freshwater fish. It is non-native to Viet Nam and is believed to have been first introduced in the late 1950s (Xuan & Hiep, 2005).

Tilapia production in Viet Nam has clearly increased over the years, with figures from FAO suggesting that in 2018 it was the seventh largest tilapia-producing country in the world (FAO, 2020). As Figure 9 suggests, tilapia production has increased by a factor of 2.7 over the past 10 years, from 100,000 tonnes in 2013 to 270,000 tonnes in 2023. In 2017, Viet Nam exported USD 45 million worth of tilapia to 68 markets (MARD, 2019). Data from Vietnamese customs show that the largest importers of Viet Nam's tilapia were the EU (26%), the USA (16%), and South Korea (13%). However, despite the expanding nature of the sector, tilapia accounted for less than 1% of Viet Nam's total aquaculture production in 2023. The production of pangasius (Pangasius hypophthalmus), the most widely farmed freshwater fish, is four times higher (1.1 million tonnes in 2020).

Figure 9: Tilapia aquaculture production in Viet Nam (in thousand tonnes), 2013- 2023



Data source: MARD Department of Aquaculture, 2023

The increase in tilapia production since the early 2000s has occurred concurrently with an increased policy emphasis on commercial tilapia farming and exports (Decision 224/1999/QD-TTg)[41]. The recent Decision 1639/2016/QD-BNN-TCTS[42] (2016) on MARD's plan to develop tilapia production (2020-2030) sets an annual target of 400,000 tonnes of tilapia output by 2030, with 45-50% expected to be exported. The plan also states that 100% of tilapia fingerlings for commercial production would be produced domestically. Accordingly, Decree 66/2016/ND-CP[43] also envisions the promotion of tilapia breeding for the 2020-2030 period.

Genetically Improved Farmed Tilapia (GIFT) is a faster-growing strain of Nile tilapia (*Oreochromis niloticus*) improved through selective breeding, made available as a public good by WorldFish since 1993[44]. GIFT strains were originally pure-bred lines of male tilapia with two Y chromosomes, thus producing only male progeny (monosex). Monosex tilapia are used in aquaculture because they grow faster and are more efficient than mixed-sex populations. GIFT is viewed as a unique International Public Good that has helped advance the tilapia sector and is a technology that is suitable for small-scale commercial aquaculture (Gupta & Acosta, 2004). In 2004, the Prime Minister issued Decision 112/2004/QG-TTg[45] to prioritize the transfer of GIFT tilapia technology to large-scale hatcheries and increase the supply of fingerlings.

GIFT has been disseminated globally in at least 14 countries across 5 continents (Etherington et al., 2022; Gupta & Acosta, 2004). In Viet Nam, GIFT tilapia were obtained from the Research Institute for Aquaculture No. 1 (RIA1) in 1994, 1996, and 1997 and by the Research Institute for Aquaculture No. 2 (RIA2) in 1996 and 2006. The last GIFT stock received by RIA2 comprised approximately 1,500 fingerlings from 50 families.

The GIFT strain has since been maintained and used for breeding RIA1 and RIA2 strains. The first GIFT-derived strain released in Viet Nam was the cold-tolerant tilapia, selected by RIA1 in 1999. This was followed by the NOVIT-4 Nile tilapia (2004), a cross between GIFT and the Red tilapia *Oreochromis spp*. The strain was selected over seven generations for its rapid growth in freshwater environments at RIA1 from 1998 to 2006 (Tran et al., 2008). In 2014, a saline-tolerant Nile tilapia was released from a selective breeding programme formed of three strains of Nile tilapia: GIFT, a Taiwanese strain, and NOVIT-4. Four generations were selected for high growth in 15–20ppt brackish water (2007 to 2011) at RIA1 (Ninh et al., 2014b) The last released GIFT-derived strain is 'Phu Ninh', which was bred to be resistant to the Tilapia Lake Virus (TiLV).

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[41] Decision No. 224/1999/QD-TTg dated December 8, 1999 on approving the aquaculture development program for the 1999-2010 period. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Quyet-dinh-224-1999-QD-TTg-phe-duyet-chuong-trinh-phat-trien-nuoi-trong-thuy-san-1999-2010-45998.aspx

[42] Decision No. 1639/2016/QĐ-BNN-TCTS dated May 6, 2016 on approving the planning on development of tilapia farming until 2020, driven by 2030. https://datafiles.chinhphu.vn/cpp/files/vbpq/2016/06/1639.signed.pdf

[43] Decree No. 66/2016/ND-CP dated July 1, 2016 on regulations on requirements for investment in protection and quarantine of flora, plant varieties; common wild animals; aquatic animals; foods and husbandry. https://thuvienphapluat.vn/van-ban/Dau-tu/Nghi-dinh-66-2016-ND-CP-dieu-kien-dau-tu-kinh-doanh-bao-ve-kiem-dinh-thuc-vat-giong-cay-trong-thuy-san-316252.aspx#:~:text=Ng%C3%A0y%2001%2F7%2F2016%2C,c%C3%B3%20ho%E1%BA%A1t%20%C4%91%E1%BB%99ng%20li%C3%AAn%20quan.

[44] The project "Genetic Improvement of Farmed Tilapia (GIFT)" was funded by the UNDP and ADB in 1988. The project ended in 1997 after completing six generations of selection (Gupta & Acosta, 2004).

[45] Decision No. 112/2004/QD-TTg of June 23, 2004 approving the program on development of aquatic seeds until 2010. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Quyet-dinh-112-2004-QD-TTg-Chuong-trinh-phat-trien-giong-thuy-san-den-2010-52170.aspx.

To our knowledge, the breeding and release of GIFT-derived strains in Viet Nam has been led by RIA1, with technical support from NORAD projects (1999-2006). WorldFish's role has primarily been to disseminate GIFT families to the NARS. More recently, CGIAR projects aiming at the promotion of climate resilience have integrated GIFT-derived strains. This includes Enhancing community resilience to climate change by promoting smart aquaculture management practices along the coastal areas of North Central Viet Nam (2015-16).

GIFT-derived strains were also supplied by the Norwegian company GenoMar, which acquired commercial rights to the GIFT strain in the early 2000s. The company opened two hatcheries in Viet Nam in 2021. Their main product is GenoMar GAIN, which originates from GIFT (Ponzoni et al., 2010).

At the start of the dissemination process is a breeding nucleus that has been selected for the superiority of specific traits, commonly growth rate. The aim is to achieve genetic gains in small fish populations using selective breeding. In 2023, the selection of a breeding nucleus for tilapia in Viet Nam was undertaken by RIA1 and GenoMar. It is possible that nuclei tilapia populations have been imported into Viet Nam, but this has not been documented.

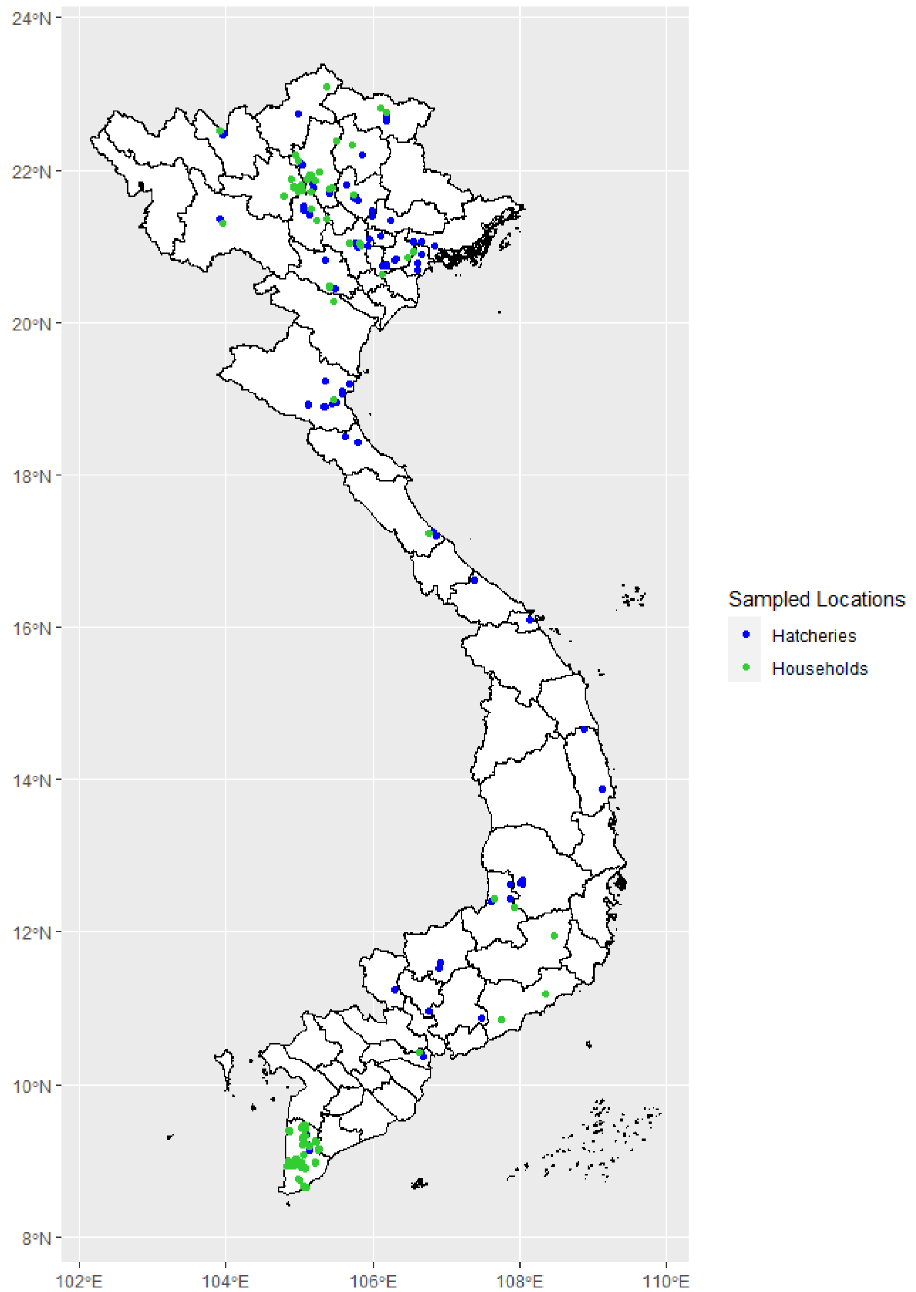
From this level, the gene flow moves downwards, and the number of fish increases as we move down the pyramid. In the next stage, improved fish are multiplied by hatcheries to produce large quantities of fingerlings. A network of Vietnamese hatcheries throughout the country performs this task, mainly using hormone treatments to produce monosex tilapia. Estimates from 2019 suggest that 250 facilities were involved in producing and trading tilapia fingerlings, of which 50 facilities kept broodstocks (Vietfish Magazine, 2024). Roughly every 2-3 years, hatchery broodstocks need to be replaced with new generations of fish that have undergone further selection. Commercial farms and households purchase fingerlings from hatcheries at the bottom of the pyramid. In the case of monosex tilapia, the farmed fingerlings grow to a marketable size of 100-150 g about three months after purchase.

Some studies have documented the links between aquaculture and rural household income in Viet Nam. In 2020, 13% of households in Viet Nam were engaged in aquaculture. However, most of these households diversified their earnings from different sources; only 6% of these households were fully specialized in aquaculture (Tran et al., 2023). Betcherman & Marschke's (2016) survey of 599 households in 12 coastal communes in Hue and Ca Mau provinces found that fewer households relied on aquaculture as their primary income source in 2012 than in 2002. The authors suggest that, for most, aquaculture did not generate a high income, so households made it a less important aspect of their portfolio.

The literature on tilapia farming in Viet Nam is scarce. (Huy et al., 2003) describe tilapia seed production in one district in Ho Chi Minh city. Households used a self-sustaining sewage-based system, with a total of 200 million fry produced annually in the district. There is limited existing evidence on the adoption rate of GIFT tilapia in Viet Nam. A study by the Asian Development Bank calculated that in 2003, GIFT and GIFT-derived strains accounted for 17% of tilapia production in Viet Nam (ADB, 2005). Ponzoni et al. (2010) reported hatchery production data from 2021 when RIA1 was supplying approximately 200 million fingerlings of the GIFT-derived NOVIT-4 strain to almost 100 hatcheries. Other sources point to an annual production of 1.1 billion fry and over 600 million fingerlings (Vietfish magazine, 2020).

We present the results from the SPIA follow-up survey. The obtained sample consisted of fish fin-clip samples from 204 households and 87 hatcheries. While the sample comes from 20 different provinces (Figure 10), 72% of households are in Ca Mau province in the southern part of MRD. Households in the provinces of Tuyen Quang and Yen Bai, both in the Northern part of the country, represented 9.3% and 4.4% of the sample, respectively.

Figure 10: Map of Sampled Tilapia Households and Hatcheries in 2023



Data source: VHLSS 2023 and follow-up survey, 2023.

Tilapia-farming households operated on a small scale, with an average of 1.1 (SD = 1.3) hectares of land dedicated to aquaculture (Table 10). This figure, however, masks large disparities: the average size of land under aquaculture (1.56 ha) was much larger in Ca Mau than in other provinces (0.1 ha), possibly because of large infrastructure investments. Nearly all (94%) households practiced polyculture. In the North, the most common facilities were ponds. Households in Ca Mau (MRD) used paddy fields irrigated through canals. On average, households had been farming tilapia for 15 years (SD = 18). Tilapia consumption was widespread, with close to three-quarters of households consuming the produced tilapia and one-third selling part of their harvest. Fish were generally fed using farming outputs, such as cassava or maize leaves.

Among the surveyed households, close to one-third had purchased tilapia fingerlings in the last three years. Other households obtained tilapia from their friends or relatives. or had tilapia conserved in their ponds over several generations. On average, households who purchased from a hatchery or broker stocked 1,410 SD = (SD = 8,115) fingerlings for a mean price of USD 103 (SD = USD 444)[46], but large variations exist. The highest expenses for purchasing fingerlings were recorded among households from Ca Mau (4.6m), followed by Quang Tri (2.5m) and Yen Bai (2.4m).

Table 10: Characteristics of tilapia-farming households in Viet Nam

	Obs	Mean	SD	Conditions applied
Production scale				
Size of land under aquaculture (in ha)	203	1.13	1.27	-
Number of ponds	204	1.14	0.48	-
Experience of tilapia farming (in years)	203	15.05	7.96	-
Diversification				
Tilapia monoculture production (in %)	204	5.66	23.11	-
Monosex tilapia production (in %)	62	14.73	33.23	HH purchased fingerlings in the last 3 years
Household consumes tilapia (in %)	204	73.88	43.93	-
Household sells tilapia (in %)	204	35.25	47.77	-
Tilapia stocking practices				
Year of last purchase	62	2021	-	HH purchased fingerlings in the last 3 years
Size of fingerlings at purchasing (in cm)	62	1.55	2.19	HH purchased fingerlings in the last 3 years
Quantity at stocking	62	1410.47	8114.88	HH purchased fingerlings in the last 3 years
Size at sampling (cm)	204	16.04	5.17	-

Note: HH = households

[46] Here, and along the report, the conversion from Vietnamese Dong (VND) to US Dollars (USD) was made using the 2022 average exchange rate of USD 0.00004274 per VND. This rate reflects nominal exchange values and does not account for differences in purchasing power between countries.

Data suggest that tilapia growers in Viet Nam practice an extensive form of aquaculture, purchase new broodstock occasionally, and rely on natural feed. The intensive farming of tilapia – with growth cycles typically lasting 4-6 months before the fish can be marketed – was not the norm.

At the hatchery level, the follow-up survey gave us information about the businesses and their scale of operations, the origin of their broodstock, and the strain names and origins. Close to two-thirds of hatcheries were private companies, 26% were public, and 8% were farmers' cooperatives. At the time of the survey, 78% of the hatcheries had only one strain for sale. Only 16% of the hatcheries produced monosex tilapia, mostly using hormone treatments. There were frequent business transactions between hatcheries, with 59% reporting that they sold fingerlings to other hatcheries, and only 21% sourcing their fingerlings within the same province. Over the past 12 years, the hatcheries reported selling an average volume of 1.16 (SD = 4.5) million fingerlings, with those located in the Southeast and Central Highlands supplying significantly larger volumes annually (6.7m and 2.9m, respectively). Going by the strain name they provided, it would appear that 15% of hatcheries were selling GIFT-derived strains.

In what follows, we discuss the genetic identification of tilapia strains. The results at the household and hatchery levels are presented in Table 11. Column 1 details the 12 core population strains that were used as references to assign the field samples. Two were pure GIFT strains, six were GIFT-derived (including the Vietnamese strains sampled)[47] and four were non-GIFT. Additional information is presented on the strains' country of origin, breeder/maintainer, and species. The last three columns show the percentage of the sample whose strains matched the given reference strain for three different samples: all surveyed households; households that purchased fingerlings in the last three years, and all hatcheries.

[47] The six Vietnamese strains sampled at RIA1 were genetically indistinguishable and so were clustered for analysis (Hamilton, 2024). We refer to this cluster as "RIA1 lineage".

Table 11: Percentage match of hatcheries and household tilapia samples to modal core populations

Strain	Group	Country	Breeder/maintainer	Species	Households		Hatcheries
					All	Purchased fingerlings in last 3 years	All
GIFT-WF	GIFT	Malaysia	WorldFish	O. niloticus	-	-	-
GIFT-FF	GIFT	Philippines	BFAR NFFTC	O. niloticus	-	-	-
BEST	GIFT-derived	Philippines	BFAR NFFTC	Hybrid	2.0	4.8	1.1
GET-ExCEL	GIFT-derived	Philippines	BFAR NFFTC	O. niloticus	-	-	-
Molobicus	GIFT-derived	Philippines	BFAR NIFTDC	Hybrid	0.5	3.2	1.1
Nile × Moss	GIFT-derived	Philippines	BFAR NIFTDC	Hybrid	-	-	-
RIA1 lineage	GIFT-derived	Viet Nam	RIA1	O. niloticus	25.0	64.5	94.3
GenoMar GAIN	GIFT-derived	Viet Nam	GenoMar	O. niloticus	-	-	2.3
Abbassa	Non-GIFT	Egypt	WorldFish	O. niloticus	-	-	-
Chitralada	Non-GIFT	Thailand	AIT	O. niloticus	-	-	-
FaST	Non-GIFT	Philippines	FAC CLSU	O. niloticus	-	-	-
O. mossambicus	Non-GIFT	Philippines	BFAR NIFTDC	O. mossambicus	71.1	27.4	-
Unassigned					1.5	-	1.1
Obs.					204	62	87

Note: The reference library included 10 core global populations from Hamilton et al., (2020) and 7 Vietnamese core populations (RIA1 lineage and GenoMar GAIN). The RIA1 lineage includes a group of closely related strains (GIFT 13th, Philippines, ProGIFT China, Taiwan, NOVIT4 12th, and Phu Nem) that have a shared provenance and formed a distinct genetic cluster. GenoMar GAIN samples were obtained from a hatchery supplied by GenoMar at the reception.

AIT = Asian Institute of Technology; BFAR NIFTDC = National Integrated Fisheries Technology Development Center; BFAR NFFTC = Bureau of Fisheries and Aquatic Resources, National Freshwater Fisheries Technology Center; FAC CLSU = Freshwater Aquaculture Centre, Central Luzon State University; RIA1 = Research Institute for Aquaculture No. 1.

Several insights emerge from assignments at the household and hatchery levels.

First, our data indicate that one-quarter of tilapia-farming households in Viet Nam raised tilapia that genetically matched a cluster of strains sampled at RIA1 and are GIFT-derived. Second, 2% farmed BEST and 0.5% farmed Molobicus, which are also GIFT-derived hybrid strains. Overall, our data indicate that 30% of the tilapia-growing households in our sample, representing 27,300 households overall, have benefited from GIFT tilapia genetic enhancements. As expected, farming of GIFT-derived strains was more prevalent among households that had purchased fingerlings in the last three years. Seventy-three percent of these households farmed GIFT-derived strains.

Overall, 71% of strains identified at the household level were assigned to the O. mossambicus species[48]. The majority of these O. mossambicus samples were found in the province of Ca Mau in MRD in the south (Figure 11). Ca Mau stands out in the realm of aquaculture in Viet Nam because of its concerted efforts starting in early 2000, to convert the agricultural production structure from rice to aquaculture (Decision No. 1116/QD-CTUB)[49]. Through investments in infrastructure, the province has specialized in the intensive farming of black tiger shrimp, white-leg shrimp, and crabs. In 2023 Ca Mau province had 303,320 ha of land under aquaculture, the most of any province in the country (DARD Ca Mau, 2023).

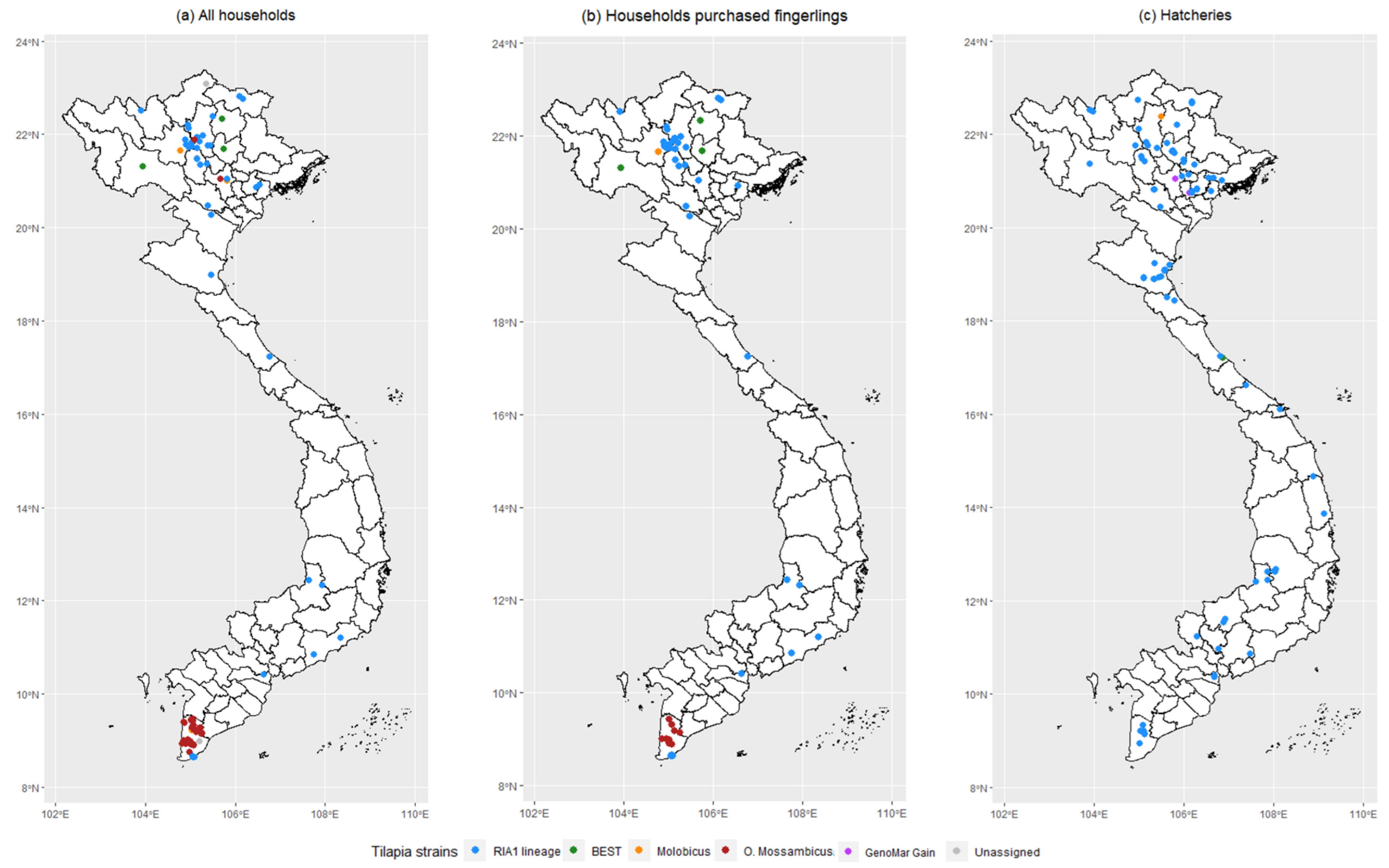
A subset of the authors of this report organized a field trip to Ca Mau in September 2023 to understand the nature of tilapia farming there. Through accompanying enumerators on their field visits and conversations with sample households, it became clear that tilapia farming in the province is generally incidental. Households in Ca Mau co-cultivate rice and shrimp on large plots that were dug to accommodate aquaculture. Farmers told us that when water is pumped from the canal to flood the plots for shrimp farming, it also brings in tilapia. Tilapia have been present in the canal ecosystems for several decades. This echoes several cases reported in the literature of tilapia strains becoming invasive in other contexts as well (Xiong et al., 2023). In such cases, we learned that although tilapia farming is not the household's primary goal, it can add significant value if consumed or sold either raw or processed (such as in fish cakes).

Turning to results at the hatchery level, we see that GIFT-based fingerlings dominate the sample. Strains originating from the RIA1 lineage made up 94% of the hatchery-strain samples, while GenoMar GAIN strains were in 2% of the samples. This finding suggests that commercial farms, not smallholder households, are the main buyers of GIFT-derived fingerlings.

[48] Sampled fish shared part of the O. mossambicus genome but are not necessarily pure O. mossambicus.

[49] https://www.camau.gov.vn/wps/portal/?1dmy&page=trangctt&urile=wcm%3Apath%3A/camaulibrary/camauofsite/gioithieu/thiduakhenthuong/vanbantinhkhenthuong/1116qd2021

Figure 11: Map of tilapia strain assignments on three different samples: (a) all tilapia-farming households (n=204), (b) households that purchased fingerlings in the last 3 years (n=62), and (c) hatcheries (n=89)



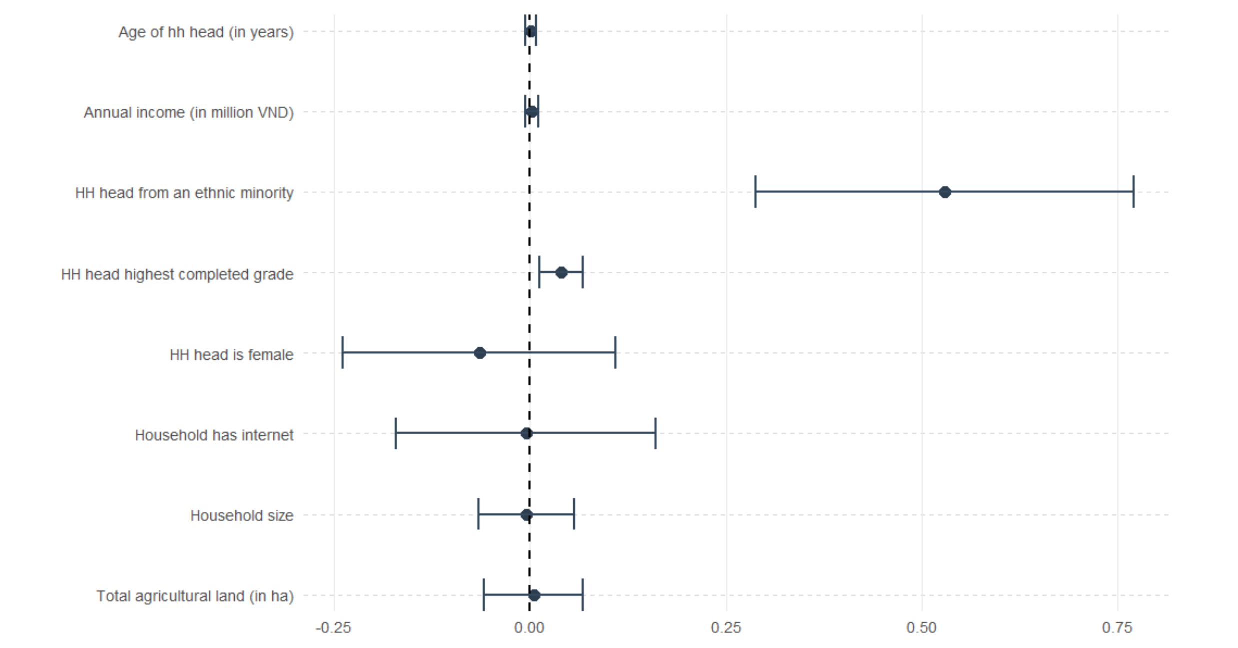
Data source: VHLSS and follow-up survey, 2023.

We observe that survey data hint that hatcheries sell a very different number of fingerlings than the national production statistics on tilapia (FAO, 2020)[50]. A possible reason is that, as explained above, the follow-up survey focused on Nile tilapia, whereas the official production statistics include all tilapia species. Given that the survey data only captures part of the tilapia production, it suggests that other species, like red tilapia (*Oreochromis spp*.), are likely to be more prevalent in production systems not captured by the survey. This is supported by previous studies (Boerlage et al., 2017), which indicated that red tilapia are commercially farmed in Viet Nam. This strain is recognized as less productive (Gupta & Acosta, 2004). The wider adoption of red tilapia may be linked to cultural factors (red is a lucky color in Vietnamese culture that symbolizes prosperity, joy, and good fortune; consumer acceptance is higher due to its resemblance to marine species) as well as environmental factors (red tilapia is better adapted to higher temperatures.)

Finally, we ask what characteristics of households predict adoption. The results of an OLS multivariate regression model examining sociodemographic predictors of adoption for GIFT-derived strains are displayed in Figure 12 We find that households, where the head belongs to an ethnic minority, were associated with an increased likelihood of adopting GIFT-derived strains, with a coefficient of 0.53 ($p < 0.01$), indicating a strong, statistically significant positive effect. Additionally, the highest completed education grade of the household head was also positively related to adoption, with a coefficient of 0.12 ($p < 0.05$), though the effect is smaller. Other sociodemographic characteristics in the model were not found to have statistically significant effects on adoption.

[50] The follow-up survey data indicated that 100m fingerlings were sold by hatcheries in the last 12 months. In the most optimist scenario, assuming an harvest size of 150 gr per fish, this is the equivalent of 15,000 tons of tilapia produced. Official statistics, by contract, indicate an amount of 260,000 tons of tilapia exported in 2018 (FAO, 2020). While the survey data may be subject to under-reporting bias, the difference appears to be so large that some other explanation is called for.

Figure 12: Estimated associations between household characteristics and adoption of GIFT-derived tilapia strains



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines. Data source: VHLSS 2023 and follow-up survey.

HH = household

6. Breeding Innovations

The stocktake identified a total of 17 breeding innovations in Viet Nam. Over the past two decades, CGIAR centers have collaborated with Vietnamese National Agricultural Services (NARS) on rice, cassava, maize, groundnut, potato, sweetpotato, banana, and forages. Following the review of evidence on the potential scale of adoption, it was recommended that we collect data about the cultivation of improved rice and casava varieties by integrating questionnaire modules into the VHLSS[51]. In this section, we present the results of varietal identification and the presence of four key Quantitative Trait Loci (QTLs) in the rice and cassava samples collected from VHLSS 2023 sample farmers[52].

6.1 CGIAR-Related Cassava Varieties

Cassava (Manihot esculenta) was introduced into Viet Nam in the 17th century (Kawano et al., 1978). With 530,000 ha of land under cassava in 2022 (GSO, 2023), it is an important crop for Viet Nam.

In some parts of the country, it provides smallholder farmers' income and food security. However, since the Đổi Mới (1986), it has increasingly become a cash crop for industrial processing. This is especially true in the Central Highlands, Southeast, and Northern Midlands, where farmers sell their produce to large facilities that process it into starch, dried root chips, or ethanol.

Cassava production increased from 1.9 million tonnes in 2000 to 11 million tonnes in 2015 (Agency of Foreign Trade, 2017). This period of growth was also marked by increased cassava yields, thanks to the adoption of new high-yielding varieties (Howeler & Ceballos, 2006). From 2010 to 2023 (prel), cassava yield increased from 172.6 to 205.8 qt/ha (GSO, 2024). In parallel, the Vietnamese government has supported the development of the agro-processing industry. In 2020, 120 industrial-scale cassava factories in Viet Nam, many located in Tay Ninh province in Southeast Viet Nam, produced starch, ethanol, and animal feed.

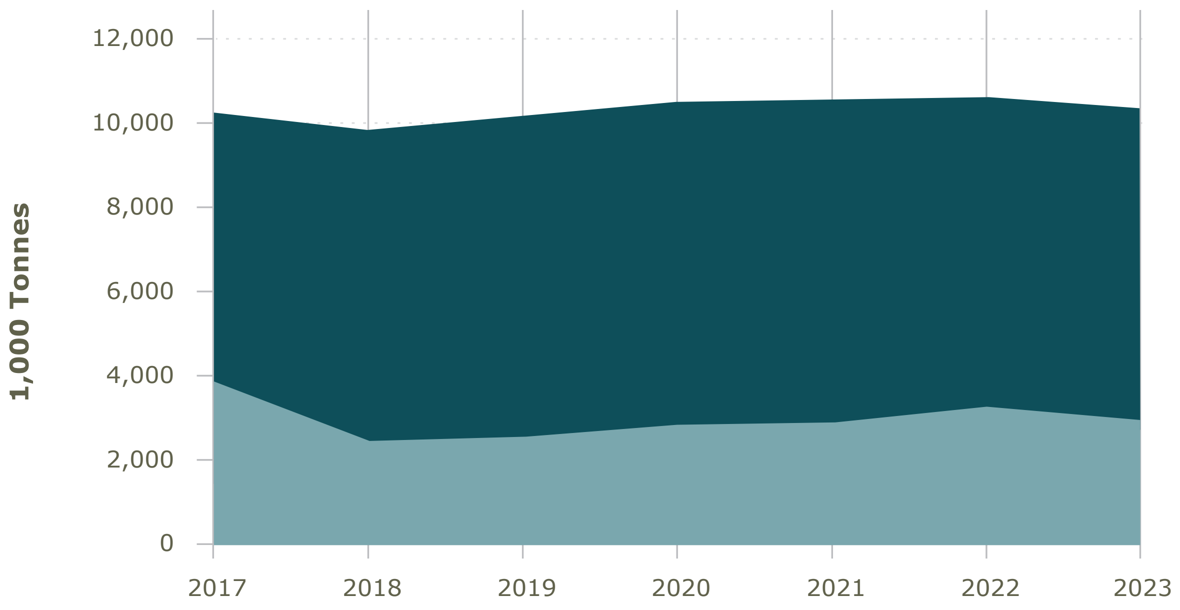
These developments, combined with an ideal geographic position, have allowed Viet Nam to become a major exporter of cassava products. Cassava starch and dried chips are exported mainly to China, South Korea, and the Philippines. In 2020, Viet Nam exported over 2.5 million tonnes of cassava starch, earning approximately USD 1 billion in revenue (Viet Nam times, 2024). An epidemic of cassava mosaic disease (CMD) in 2018 reduced both production and exports. Since then, production appears to have regained steady growth, but exports in 2023 continue to be 24% below what they were in 2017 (Figure 13).

[51] A module on improved potato varieties was also included in the VHLSS 2023. However, only 32 households in the entire VHLSS 2023 sample reported that they grew potatoes. We are thus unable to document the adoption of improved potato cultivars in Viet Nam.

[52] This report focuses on two rice QTLs and two cassava QTLs that have been a focus of CGIAR breeding teams. For a descriptive analysis of 28 QTLs identified by the RiCA v4 platform, see Kosmowski et al.(2023).

At the same time, Vietnamese starch producers also import cassava roots from within the region, in particular, from Cambodia. The exchange of planting materials is also common across the borders of Laos, Cambodia, and Viet Nam.

Figure 13: Evolution of cassava production and exports in Viet Nam, from 2017 to 2023, in thousand tonnes



Data source: General Statistics Office, 2023

The cassava seed market is unregulated: non-certified seeds account for 90% of cassava stem plants. Seed multiplication is performed by national research institutes (Root Crop Research and Development Center and the Experimental Centre of Agriculture Hung Loc Research Institute, the Institute of Agricultural Sciences for Southern Viet Nam, and universities including Thai Nguyen University of Agriculture and Forestry, Ho Chi Minh City, and the University of Agriculture and Forestry). Provincial Agricultural Extension Centers together with the Sub-Department of Crop Production and Plant Protection are also engaged in varietal testing, seed production, and multiplication. Decentralized multipliers consisting of locally organized farmers, groups, and cooperatives also multiply and sell seeds to local farmers.

CIAT[3] maintains the main global, publicly accessible collection of cassava germplasm, consisting of 67,000 accessions from 28 countries. It has been active in disseminating this germplasm around the world, having shipped 30,847 cassava samples to 66 countries between 1979 and 2007 (Mafla et al., 2007).

Research has concentrated on breeding cassava with a high dry matter content (DMC), in accordance with the needs of the food processing industry (Ceballos et al., 2021). For international exports, the benchmark root price is set for a 30% starch content. Hoang et al. (2024) noted that during 2000-2010, the primary objective of cassava breeding efforts in Viet Nam was to help meet the demand of starch and cassava chip producers. Accordingly, the germplasm deployed in Viet Nam and released directly as varieties (such as KM94) or as parents following NARS breeding efforts, has generally had high and stable DMC. It has been suggested that the growth in cassava starch production may have been facilitated by high-starch varieties originating from the CIAT genebank (Labarta et al., 2017).

Several CGIAR projects in Viet Nam have also focused on improving the livelihoods of cassava-growing smallholders through better varieties and seed system interventions. These include the following programs: Enhancing the Sustainability of Cassava-based Cropping systems in Asia (1994-2003); Cassava Value Chain and Livelihood Program (2016-19); Development and Dissemination of Sustainable Production System Based on Invasive Pest Management of Cassava' (2016-2021); Establishing Sustainable Solutions to Cassava Diseases in Mainland Southeast Asia (2019-23); and Developing Value-chain Linkages to Improve Smallholder Cassava Production Systems (2016-2020). The CGIAR Research Program on Roots, Tubers, and Bananas (2012-2020) also fostered collaboration between the breeding programs at research institutes, and cassava processing factories in Viet Nam.

A handful of studies have documented the adoption of improved cassava varieties in Viet Nam. Using data from GSO and MARD, Kim et al. (2005) reported that 52-60% of Viet Nam's cassava areas are improved varieties. Howeler & Ceballos (2006) estimated that 67% of the cassava area (250,000 hectares) is planted with improved varieties and that KM94 was the dominant variety. In a review of how the cultivation of different cassava varieties has changed over the years in Viet Nam, Hoang et al. (2024) reported that KM94 covered 75% of the nationwide cassava area in 2010. In 2015, a CIAT-led DNA fingerprinting exercise estimated that more than 85% of cassava farmers were growing improved varieties (Le et al., 2019) and that KM94 and KM419 represent approximately two-thirds of all cassava grown in the country. They also reported that CIAT-related varieties accounted for 91% of the adopted varieties, and 11% were landraces.

We started by compiling information on the officially released cassava varieties and their pedigrees (Table 12). From 2003 to 2023, 25 varieties were released, of which 16 were CIAT-related. Remarkably, 11 varieties were released in the 3 years from 2020 to 2023, the same number that were released in the 9 years between 2010 and 2019. This underscores the dynamism of the cassava sector in Viet Nam, and the effort to release new high-starch and CMD-resistant varieties.

Table 12: Number of cassava varieties released, by germplasm origin, 1990–2023

Germplasm origin	1990 - 1999	2000 - 2009	2010 - 2019	2020-2023
CIAT-related	6	3	6	7
Other	0	0	5	4
Total	**6**	**3**	**11**	**11**

In Table 13 we present the adoption rate of different varieties, as identified through our DNA fingerprinting exercise in the sample of 738 cassava-growing households collected as part of the VHLSS 2023. The identified varieties were classified as either improved or landraces. Columns (6) and (7) report the fraction of samples belonging to a given variety that contained the QTLs for dry matter content and CMD resistance (detailed in Section 3.4.4).

Table 13: Overview of cassava varietal adoption in Viet Nam

Variety	Number of samples	% samples	Age (years)	CGIAR-related	Dry matter content QTL (in %)	CMD-resistant QTL (in %)
Improved						
KM94	179	27.5	28	Yes	97	1
KM98-5	114	15.3	18	Yes	39	37
KM57	66	7.7		No	100	100
KM140	56	7.4	13	Yes	98	0
KM419	14	2.1	7	No	93	0
KM297	7	1.3	21	Yes	0	0
KM7	5	1.1	7	Yes	100	0
HL-S11	4	0.9	8	Yes	100	0
KM98-1	4	0.4	18	Yes	100	0
SC9	3	0.1		No	0	0
KM60	2	0.7	28	Yes	0	0
HN2	1	0.4		No	100	100
KM95	1	0.1	28	Yes	100	100
Pirun2	1	0.1		No	100	100
R1/TAI1	1	0.3		No	0	0
VNM1	1	0.6		No	0	0
Landraces						
Cao San	78	10.4		No	74	19
Dịa phương	65	7.6		No	55	15
Sắn tre	35	3.0		No	94	43
Ba Trăng	7	0.8		No	86	100
Other landraces	102	11.9		No	90	87

Note: To determine the percentage of varieties that contain alleles associated with the dry matter content QTL, the homozygous favorable allele (CC) was used. For the percentage of varieties that contain alleles associated with the CMD-resistant QTL, the homozygous favorable allele (TT) or heterozygous allele (TG) was used.

CMD = cassava mosaic disease QTL = Quantitative Trait Locus

Data source: VHLSS 2023.

From the samples taken from farmers' fields, 87 different genotypes were identified. After clustering the genotypes that had similar names (for instance, km94 was re-coded as KM94)[53], we found 16 improved cultivars and 6 landraces. Overall, 60% of the farmers' samples were identified as improved cultivars, and 38% matched the genetic profile of landraces. Two percent of the samples did not match any reference and thus could not be identified.

In line with prior research, we found that in 2023, the most common improved variety was KM94 (27% of households). It was found in all agroecologies of the country. This was followed by KM98-5 (15% of households), KM57 (8% of households), and KM140 (7% of households). All other improved cultivars were identified on the plots of less than 2% of farmers.

The KM94 cultivar was originally released in Thailand in 1993 and has since spread throughout

[53] The CIAT reference library named the samples received according to their passport data. Several references of a similar cultivar can thus happen to be registered under different names.

Southeast Asia. It also goes by the names Kasetsart 50, KU50, TAI16, and MKUC 28-77-3, and is a cross between Rayong 1 and Rayong 90. It has previously been called the "most successful cassava variety in the world" (Howeler & Ceballos, 2006). Its high yield and starch content (Kawano, 2003) were confirmed by genetic analysis: 97% of samples identified as KM94 contained the high-starch content allele. Although KM94 continues to be the most cultivated cultivar, disadoption may have occurred when compared to previous estimates found in the literature (previous studies mentioned above point to 33–75% of the cassava growing area).

The second-most adopted cultivar, KM98-5, is a South American landrace. It is registered in the CIAT genebank as CR63 and TAI9 but is referred to as KM98-5, belonging to the genebank collection from Viet Nam. This cultivar was mainly found in the Northern Midlands and Mountains Area, suggesting that it is used for household consumption and income. The cultivar had a lower proportion of the high-starch allele than the other widely adopted cultivars.

KM57 is a Vietnamese landrace suitable for fresh consumption. These farmer samples matched the references collected at the Root Crop Research and Development Center (RCRDC) and the Agricultural Genetics Institute (AGI) centers in Viet Nam. The adoption of KM57 is concentrated in the NM and SCC regions. Notably, all samples from this cultivar contained both high dry matter content QTL and CMD-resistant QTLs.

KM140 is both high-yielding and suitable for fresh consumption. Identified in 7% of household plots, these samples matched references collected at the RCRDC and HLARC centers in Viet Nam. The cultivar was mainly adopted in the Central Highlands.

We found that 54.4% of cassava-growing households had CIAT-related accessions. These breeding innovations reached the equivalent of 270,900 households in 2023. CIAT-related cultivars were more widely adopted in the southeast (78%), Central Highlands (68%), and North Central and Central Coastal Areas (68%) regions.

The adoption of CIAT-related germplasm correlated with only a few household characteristics. Adopters were on average younger than non-adopters. Adopters were also more likely to have accessed the Internet in the last six months, suggesting that digital connectivity might play a role in awareness or uptake of CIAT-related germplasm. No significant differences were reported in inclusion or income.

6.2 Cassava Mosaic Disease-Resistant Cassava Varieties

Viet Nam's cassava sector has recently been challenged by the appearance and spread of the Sri Lanka Cassava Mosaic Virus[54]. The virus is transmitted by the whitefly (*Bemisia tabaci*) and triggers mosaic patterns on leaves, leaf distortion, and stunted growth. First reported in Cambodia in 2015, it is now present throughout the major Southeast Asia-producing regions. An outbreak of cassava mosaic disease (CMD) in 2017 reduced both yields and starch content, and the country has yet to fully recover. In 2022, 120,686 hectares were affected in Viet Nam compared to 72,400 hectares in 2021 (Newby, 2024).

[54] CMD is the disease caused by several viruses in the Begomovirus genus, including the Sri Lanka Cassava Mosaic Virus.

For Viet Nam's cassava sector to remain competitive in global markets it is important to prevent the spread of crop diseases such as CMD. One solution includes integrated pest management strategies to control whitefly populations (Abubakar et al., 2022). Others include the promotion of CMD-resistant cultivars. Following the 2017 CMD outbreak in Viet Nam, MARD issued an urgent dispatch No. 5920/CD-BNN-BVTV to direct Tay Ninh provincial authority to implement the destruction of cassava with CMD. Two days later, on 21 Jul 2017, the MARD Plant Protection Department issued guidance to local authorities named 'Technical Process for the Prevention of CMD in Cassava' (Official Letter No. 1605/BVTV-TV dated 21/7/2017 of the Plant Protection Department)[55]. The Technical Process indicates severely infected varieties (HLS11) and sporadically infected varieties (KM 419, KM 140) and gives recommendations to local authorities and farmers on planting CMD-resistant cultivars, and not the infected ones.

In May 2017, in cassava plants in Tay Ninh province, Viet Nam, a team of CIAT scientists found typical CMD symptoms, including chlorotic mosaic, leaf distortion, and stunted growth (Uke et al., 2022). The CIAT task force took advantage of a DNA fingerprinting dataset collected in Viet Nam in 2015-16 to test for CMD in different production areas of Viet Nam, including Tay Ninh province, which borders Cambodia. The results confirmed that SLCMV was already present in 2016 in Viet Nam. Results also demonstrated that the infected varieties were bred in Viet Nam and thus were not imported from South Asia. The Developing an Emergency Response and Long-term Management Strategy for Cassava Mosaic Virus in Cambodia and Viet Nam project (2016-2018) additionally found that KM94 and KM419 were moderately resistant to CMD. In Tay Ninh province, KM419 was considered the safest and most economical solution given the CMD situation at the time (Directive 1068/BTV-TV, 2019)[56].

To produce commercially competitive and CMD-resistant cultivars, researchers have used best-bet CMD-resistant clones from CIAT and IITA as breeding material. The Establishing Sustainable Solutions to Cassava Diseases in Mainland Southeast Asia project' (2019-2023) promoted germplasm exchanges (102 clones and more than 475 CMD-resistant seeds from CIAT, and five varieties from IITA) and screened cultivars for CMD resistance and yield performance. The project relied on a breeding trial network of eight locations in Viet Nam.

At the time of writing, seven CMD-resistant varieties had been released. These varieties included HN1, HN3, HN5, HN97, HN80, HN36, and SDA15. According to Zhang (2020), five of these varieties were prioritized for rapid multiplication in 2023: HN1, HN3, HN5, HN36, and HN80. Variety HN1 (TMEB419) is regarded as the most suitable option, with a CMD-resistant score of 1 and starch content of 27.5% (Hoang et al., 2024).

DNA fingerprinting data analyzed by Intertek was used to assess the presence of alleles associated with a CMD-resistant gene (Rabbi et al., 2022). No samples containing the homozygous favorable allele (TT) were found. Since the heterozygous (TG) allele provides some degree of resistance, we categorized samples with this allele as "resistant". Overall, the CMD-resistant marker snpME0021 was found in 50% of EAs and 29.7% of cassava-growing

[55] Official Letter No. 1605/BVTV-TV dated 21/7/2017 of the Plant Protection Department. https://khuyennongvn.gov.vn/du-lieu-khuyen-nong/van-ban-thong-bao/bo-nn-ptnt/bo-nnptnt--cong-van-so-1605bvtvtv-vv-ban-hanh-quy-trinh-ky-thuat--phong-tru-benh-kham-la-san-15921.html.

[56] Directive No. 1068/BVTV dated May 3, 2019 was issued by the Plant Protection Department of the Ministry of Agriculture and Rural Development.

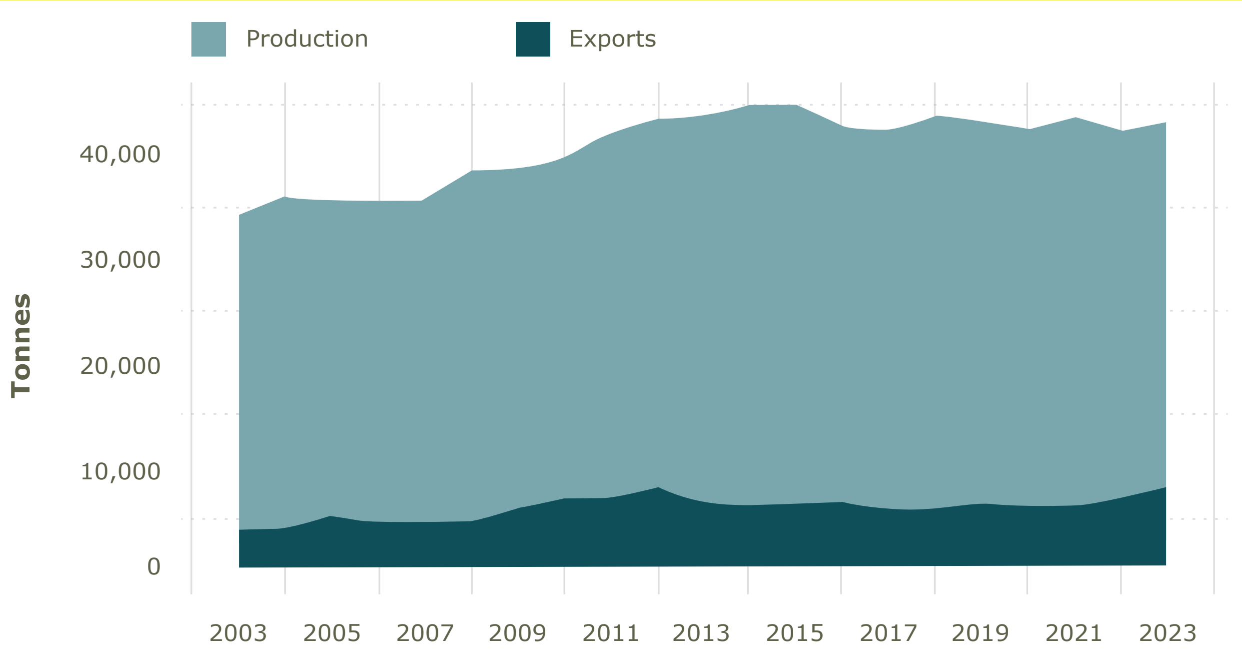
households. We estimated the reach of this CMD-resistance trait to be 147,900 cassava-growing households in Viet Nam.

The recently released CMD-resistant varieties have only been approved in some provinces and therefore it was unlikely that we would find a high prevalence across the country in 2023. One such cultivar is HN2, which was identified in one household. It is also recognized that they have a lower starch content than the current cultivars in use, and more commercially acceptable cultivars are currently under trial. These should be released in the coming years.

6.3 CGIAR-Related Rice Varieties

Rice is of crucial importance to the national economy of Viet Nam. Following the Đổi Mới (1986) reforms[57], Viet Nam made tremendous strides to move away from subsistence rice farming of landraces to become the world's second-largest exporter of rice. In 2022, rice was cultivated on 7,109 thousand hectares (GSO, 2023). Despite a small decrease in the area cultivated with rice over the past twenty years, rice production rose by 23% to reach 43,498 thousand tonnes in 2023. In 2005, Vietnamese rice penetrated markets such as Japan, the EU, and the US, which require high-quality produce. Both production and exports grew rapidly over the following two decades (Figure 14). In 2023, Viet Nam exported 8,132 thousand tonnes of rice (GSO, 2023). Ninety percent of these exports originated in the MRD.

Figure 14: Evolution of rice production and exports in Viet Nam, from 2003 to 2023, in thousand tonnes



Source: General Statistics Office, 2024. 2023 data points were preliminary at the time of writing.

[57] The term "Đổi Mới" or "Renovation" in Vietnamese, refers to the economic reforms initiated in 1986 in Viet Nam, aimed at transforming it from a centrally planned economy to a socialist-oriented market economy.

Viet Nam's Green Revolution in rice began in the mid-1980s. The semi-dwarf genes (sd-1) allowed for shorter stems and stronger roots, and consequently, higher yields[58]. Over the following two decades, there was an increase in the cultivation of modern varieties, and concurrently, an increase in the use of chemical fertilizer, and an expansion of irrigation. Many seed companies – private, foreign, or domestic-foreign joint ventures – were established. Over time, improved cultivars spread to less favorable areas (Thu et al., 2016; Ut & Kajisa, 2006). It is believed that varietal turnover, with its continuous replacement by superior rice varieties, has fueled the momentum of Viet Nam's green revolution (Ut & Kajisa, 2006). Rice yield continued to increase during the study period, from 4.6 tonnes per hectare in 2003, to 6.1 tonnes per hectare in 2023 (GSO, 2023)[59]. Meanwhile, breeding innovation has continued, with new cultivars developed using marker-assisted selection (MAS)[60] introduced into Viet Nam in the 2010s.

Importantly, there are large regional variations in agroecology, irrigation infrastructure, varietal adoption, and productivity across Viet Nam. In the northern regions, production is concentrated in the RRD and the northern highlands. Given the similarity between the agroecology of Southern China and Northern Viet Nam, hybrids originating from Southern China were officially released in Viet Nam in the 1990s, particularly in RRD (Hossain et al., 2003). However, the region is no longer dependent on Chinese rice hybrid seeds as 70-80% of hybrid-certified seeds are now produced locally. Most aromatic varieties in the northern highlands (NH) are of the japonica type, with some unique indigenous landraces (Khanh et al., 2021).

In the southern region, there has been a shift from high-yielding to high-quality rice over the past two decades. There has also been a shift from rice production to meet domestic targets for food security reasons, to production for export. Crop intensification has relied on shorter maturity cultivars and cropping patterns have changed so that instead of only cultivating rice in the winter season, farmers in MRD now also cultivate it in the autumn and spring seasons.

Since the approval of Viet Nam's Strategy for Sustainable Agriculture and Rural Development for the 2020-2030 period[61] in May 2016, there has been an emphasis on increasing the productivity and competitiveness of agriculture by adopting agricultural innovations, including certified rice varieties[62]. Viet Nam's Rice Industry Development Strategy approved in February 2021 spearheaded policy efforts specifically targeted at the production of high-quality rice, specifically, fragrant and specialty rice (Decision No. 555/QD-BNN-TT)[63]. The new plan also recognizes the need to strengthen the resilience of rice production systems to climate change and natural disasters.

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[58] Cultivars IR8, IR36 and IR64 all contain the sd-1 gene.

[59] See also the Statistical Directory (2000). https://www.gso.gov.vn/wp-content/uploads/2020/02/Ni%C3%AAn-gi%C3%A1m-th%E1%BB%91ng-k%C3%AA-2000-%C4%91%C3%A3-n%C3%A9n.pdf

[60] Marker assisted selection in plant breeding involves selecting for specific genetic markers known to be associated with specific desirable traits, rather than selecting upon direct observation of the traits.

[61] Decision No. 1898/2016/QD-BNN-TT dated May 23, 2016 approved initiatives to restructure Viet Nam's rice industry by 2020, with a vision to 2030. https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-1898-QD-BNN-TT-de-an-tai-co-cau-nganh-lua-gao-Viet-Nam-2020-tam-nhin-2030-2016-313302.aspx

[62] A certified rice variety has gone through a breeding process that typically involves the crossing of different germplasms to create cultivars that possess targeted traits. The cultivar then undergoes testing by MARD to ensure its quality, productivity, and suitability before being officially recognized by the government.

[63] Decision 555/2021/QD-BNN-TT approved a restructuring of Viet Nam's rice industry by 2025, with a vision to2030. https://thuvienphapluat.vn/van-ban/Thuong-mai/Quyet-dinh-555-QD-BNN-TT-2021-Phe-duyet-De-an-Tai-co-cau-nganh-lua-gao-Viet-Nam-463761.aspx

Collaboration between the IRRI and the Government of Viet Nam started in 1963. IRRI's improved rice variety IR8 was introduced in 1966 in Tien Giang province under the name 'Than Nong 8' (TN8) and two years later in the North (as 'Nong Nghiep 8', or NN8). IRRI started to collaborate with the CLRRI in 1983, and an IRRI office was established in Hanoi in 1992, to provide support for the production and commercialization of hybrid rice (Cuong, 2014). The stocktake suggests that IRRI-related germplasm was commonly used for breeding efforts in Viet Nam and that IRRI also collaborated with NARS on research on salt-tolerant rice varieties.

IRRI maintains the largest collection of rice germplasm in the world. Research efforts at IRRI headquarters have mainly concentrated on identifying lines with the most favorable traits in terms of yield and grain quality, as well as resistance to biotic and abiotic stressors. In recent decades, IRRI has focused on characterizing and transferring gene technology into locally adapted varieties and elite lines. There are strong indications that some of these materials have been used for breeding in Viet Nam: data from the IRRI Genebank indicate that between 1977 and 2022, it received 8,046 seed requests from NARS in Viet Nam.

Current evidence on rice varietal adoption in Viet Nam relies on farmers' self-reports of the variety they cultivate, or expert opinions, and should accordingly be received with caution. However, estimates from such reports are useful to understand the current state of knowledge on this issue. A report from the Department of Plant Production identified 12 main varieties grown across the country, planted in 47% of the rice-growing area around the country (Khanh et al., 2018). The three main cultivars reported were IR50404 (in 13% of rice growing area), OM5451 (7%), and OM4900 (5%). Only 2 of these 12 varieties were hybrids (Cultivars Nhi Uu 383 and TH3-3), and the rest were inbred rice. A 2021 survey by MARD focused on the southern regions suggests that five main varieties were each planted on more than 100,000 ha: OM5451, OM18, Dai Thom 8, IR50404, and IR4625. In addition, based on self-reported data collected in their annual survey of agricultural crops, the GSO found that the most common varieties planted in Viet Nam are OM5451 (planted on 10.3% of total rice area), Bac Thom 7 (3.4%), and IR50404 (3%) (GSO, 2022). In a representative sample of households in MRD, Paik et al. (2020) used expert elicitation to identify seed varieties[64] and found that 44% of households grew salt-tolerant rice varieties.

A large number of improved rice varieties have been released in Viet Nam. While the first rice certification decision we found dated back to 1984, improved materials were likely used before that date. Since 1984, 565 rice varieties have been certified. However, efforts at introducing new rice varieties have clearly accelerated in the past two decades: 413 of the 565 were released during the study period. Table 14 provides an overview of the number of varieties released by decade.

Table 14: Number of rice varieties released, by germplasm origin, 1990–2023

Germplasm origin	Before 1990	1990 - 1999	2000 - 2009	2010 - 2019	2020-2023
IRRI-related	10	10	66	46	17
Other	3	17	148	138	74
Total	**13**	**27**	**214**	**184**	**71**

[64] According to Paik et al. (2020): "out of the 42 rice varieties grown by the households in either the Dong Xuan or the He Thu season, 6 (14%) were identified as CURE-related rice varieties by experts at the CLRRI"

According to available data, at least 26% of certified rice seeds released from 2003 to 2023 are IRRI-related[65]. Interestingly, the period 2000-2020 witnessed a large increase in the number of varieties developed, with 92% of the Vietnamese rice varieties released since 2000. IRRI-related varieties were 30% of the releases in 2000-2009 and 25% in 2010-2019. Only a small percentage of the seeds released were from pure IRRI lines. Instead, during 2003-2023, IRRI-related seeds comprised those that had IRRI pure lines as parents (P), or grandparents (P2). The main IRRI-related lines used as IRRI parents included CR203 and Jasmine. Notably, the most recent releases from 2020-2023 continue to include IRRI material as a source.

In 2022, SPIA's efforts to measure the adoption of CGIAR-related rice varieties in Viet Nam involved the collection of rice seed samples in partnership with GSO, by visiting the plots of rice growers identified in the VHLSS 2022 sample (Section 3.4.2). DNA fingerprinting results provide an overview of the rice varieties grown, as well as the age of identified cultivars, their pedigree, and origin (Table 15).

[65] This figure provides a reliable lower bound, since a large share of the officially released seeds (61%) had no pedigree data available, or the parents' pedigree were unknown.

Table 15: Distribution of rice by variety planted during the 2022/23 agricultural season

Variety	Found in:		Age (years)	Pedigree	Origin
	Number of rice samples	% of rice samples			
Unidentified	376	47.1	/	/	/
OM4900	59	7.0	13	IRRI-related (P)	CLRRI and Vinaseed Co.
Dai Thom 8	48	5.9	15	IRRI-related (P2)	Vinaseed Co.
BT7	36	7.7	25	Chinese purebred variety	Thai Binh Seed Co.
KD18	33	3.6	23	Chinese purebred variety	Quang Ninh Seed Co. / Vinaseed Co. / Thai Binh Seed Co.
TBR225	30	5.3	7	Parents pedigree unknown	Thai Binh Seed Co.
Thien Uu 8	30	3.7	7	Parents pedigree unknown	Vinaseed Co.
OM5451	25	3.4	11	IRRI-related (P)	CLRRI and Vinaseed Co.
Thai Xuyen 111	17	2.1	12	Parents pedigree unknown	Thai Binh Seed Co. and SAUC
BC15	16	2.0	14	IRRI-related (P)	Thai Binh Seed Co.
IR50404	14	1.6	30	IRRI-related line	IRRI
N98	13	2.0	14	IRRI-related (P)	FCRI
VNR20	11	1.1	2	IRRI-related (P2)	Vinaseed Co.
Huong thom 1	9	1.0	18	Chinese purebred variety	Thai Binh Seed Co.
HUONG UU 98	9	0.9	5	Chinese purebred variety	Vinaseed Co.
J02	7	1.0	3	Japanese purebred variety	AGI
IR17494	5	0.5	34	IRRI-related line	IRRI
N97	5	0.9	18	Parents pedigree unknown	Thai Binh Seed Co. and ASI
ST24	5	0.3	3	Parents pedigree unknown	Ho Quang Tri Co.
Q5	4	0.8	0	Chinese purebred variety	Thai Binh Seed Co.
Jasmine 85	2	0.4	18	Imported from IRRI Genebank	IRRI
LH12	2	0.4	17	IRRI-related line	VAAS
LTH31	2	0.1	3	Parents pedigree unknown	FCRI
RVT	2	0.4	6	Not IRRI-related	Vinaseed Co.
VNR10	2	0.3	2	IRRI-related (P2)	Vinaseed Co.
OM576	1	0.1	32	IRRI-related (P)	CLRRI
OM6162	1	0.1	12	IRRI-related (P2)	CLRRI
OM7347	1	0.1	11	Parent likely imported from IRRI Genebank	CLRRI
SH14	1	0.1	14	IRRI-related (P)	FCRI

Note: Variety pedigree is from official documents from MARD. IRRI-related (P) = At least one of the original parent plants used in the breeding process is IRRI-related; IRRI-related (P2) = Parents of the parent plant contain at least one IRRI-related material used (Parental Generation 2, or (P2), in accordance with Section 3.4.2.1.

AGI = Agricultural Genetics Institute; ASI = Agricultural Science Institute; CLRRI = Cuu Long Rice Research Institute; FCRI = Field Crops Research Institute; IRRI = International Rice Research Institute; SAUC = Sichuan Agricultural University of China; VAAS = Viet Nam Academy of Agricultural Sciences.

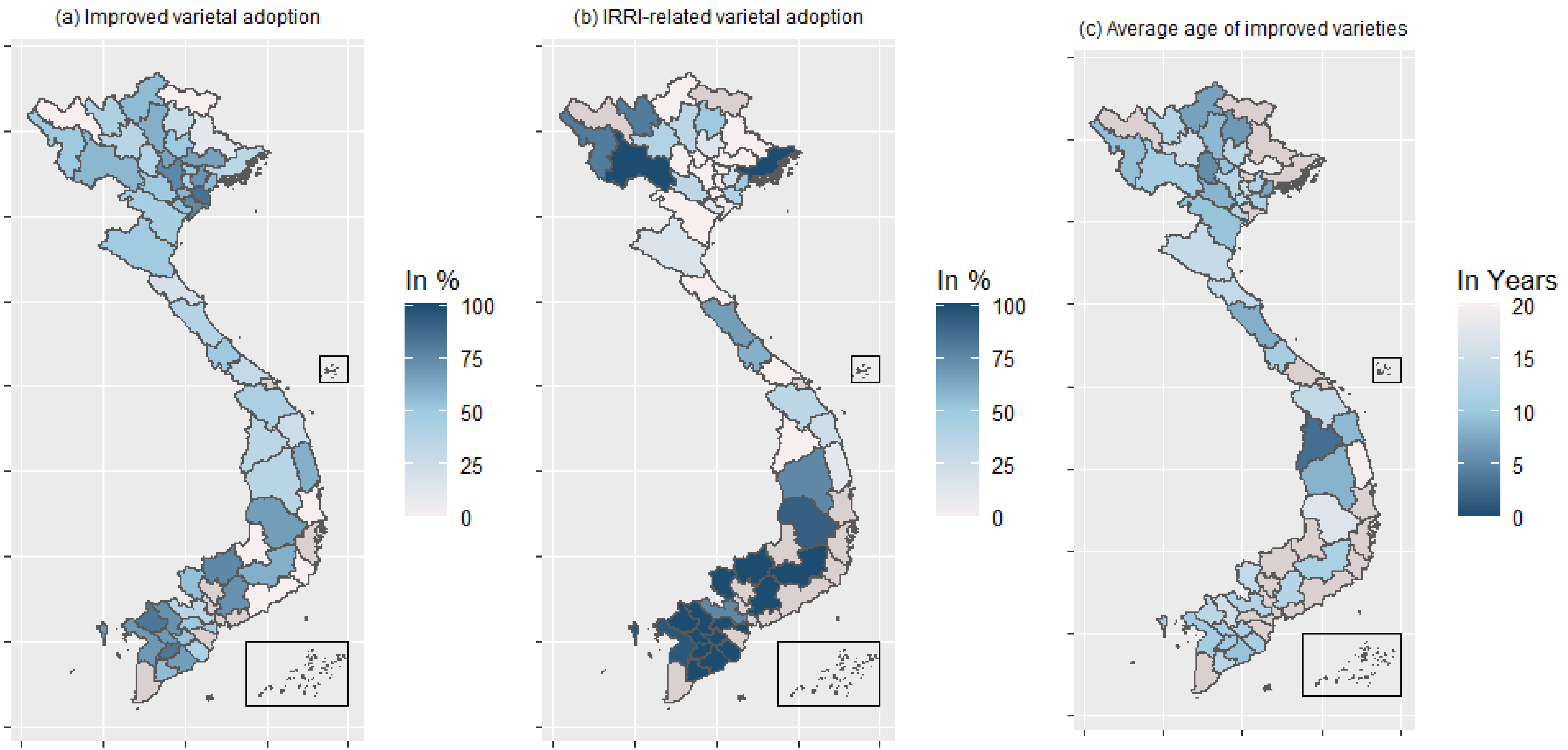
Overall, 53% of the samples taken from households could be identified, and they mapped to 28 different improved rice varieties. The unidentified 49% could have been landraces, or they could have been improved varieties that did not feature in the reference library because they are not currently being sold in markets and so we were unable to obtain seed or grain samples to add to the library. Of the 28 improved varieties identified in farmers' fields, 16 had IRRI parentage. Overall, in our sample, 25% of households had adopted IRRI-related rice varieties. This estimate allows us to infer that IRRI-related rice varieties have reached about 1,926,900 Vietnamese rice-growing households in 2022.

IRRI elite lines have been used as parents to breed improved cultivars, which has led to a diversity of improved varieties currently in use. Users of IRRI materials in Viet Nam have historically included both publicly funded research organizations and commercial enterprises. High-yielding rice varieties such as OM4900, OM5451, OM7347, and OM6162 released by the CLRRI, were developed using IRRI germplasm. Commercial companies have also benefited from the IRRI global public germplasm collection: for instance, Thai Binh Seed Co. selected cultivar BC15 from IR17494. Inbred IRRI lines appear to have almost disappeared: in 2022, we only found lines such as IR50404 and IR17494 that were released in the 1990s in 2.1% of the surveyed households.

There is clearly a large amount of heterogeneity in the improved cultivars being planted in Viet Nam: the cultivar with the highest adoption rate, OM4900, was cultivated by only 7% of sampled households, mainly in the Southern regions, and the second-most frequent cultivar, Dai Thom 8, was cultivated by 5.9% of households from all over the country. Among the seeds that did not originate from the IRRI germplasm collection, 14% were Chinese purebred varieties distributed by private companies such as Thai Binh Seed Co. and Vinaseed Co., mainly grown in the northern provinces.

The spatial distribution of the adoption of improved varieties provides interesting insights. Figure 15 confirms that improved varietal adoption is more prevalent in the deltas where intensive rice cultivation is practiced and in the southeast region. In the Southern regions, cultivars OM4900 and OM5451 were more common. The most common varieties in the RRD were Dai Thom 8 and BC15.

Figure 15: Maps showing the percentage adoption of (a) improved varietal adoption, (b) IRRI-related varietal adoption, and c) average age of improved varieties in Viet Nam



Data source: VHLSS 2022.

Given that most improved varieties have IRRI parentage, the map of the adoption rate of IRRI-related cultivars in Figure 15, (Map b) is similarly varied by region. At the high end, we found that 63% of sampled households in MRD were growing IRRI-related varieties, and at the low end, only 5% of households in the Northern Central Coastal regions were growing them. In northern Viet Nam, we found high adoption rates of IRRI-related cultivars in the northwest and Quang Ninh province in the northeast.

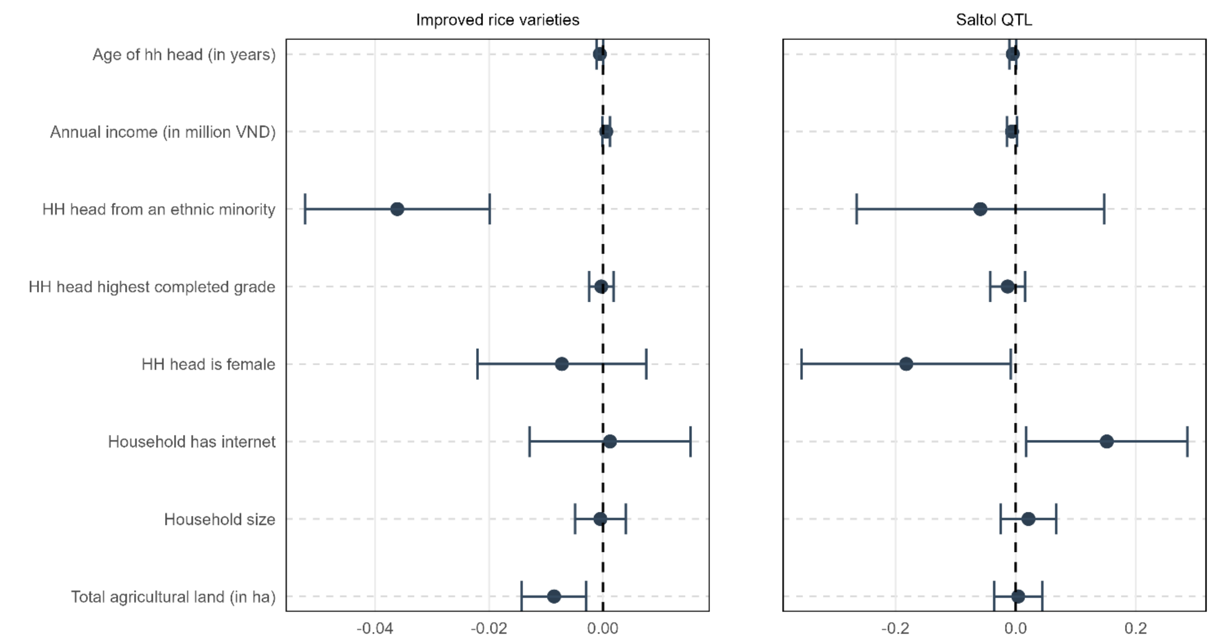
Several donors have been interested in efforts to accelerate the take-up of improved varieties (De Groote & Omondi, 2023; Spielman & Smale, 2017). The capacity of the seed system to supply new cultivars to farmers is a key factor in ensuring farmers have access to alternatives to the landraces and older varieties that are generally vulnerable to environmental changes (Atlin et al., 2017). In 2022, on average the improved rice varieties in farmers' fields in Viet Nam had been released 14 years prior. However, this average masks considerable variation. Four percent of the seeds found on farmer's plots had been released within the previous 5 years (VNR20, J02, ST24, LH12, LTH31, VNR10). These were largely varieties that had been developed by or distributed by large-scale private seed companies. This possibly reflects their greater operational capacity.

On the other end of the timescale, 10% of sampled seeds were from varieties that had been released 20 or more years ago, with some dating from the end of the Green Revolution (IR50404, IR17494, OM576, BT7, and KD18). This suggests a lack of better alternatives for farmers or a lack of access to more recent cultivars. More research is certainly needed to understand the reasons behind this lack of varietal turn-over.

Figure 15, (Map c) displays the mean time since of release of the adopted improved cultivars at the province level. This map is in stark contrast to Figure 15, (Map a) and Figure 15, (Map b). Most provinces are close to the national average age of 14 years for cultivated seeds. A few provinces do stand out, and provinces with the most recent cultivars (dark blue) include Ha Giang, Phu Tho, Quang Binh, and Kon Tum. The cultivars adopted in these provinces are different but are all recently released genotypes.

Next, we turn to examine how adoption rates vary by household characteristics. Figure 16 shows the associations between adopters and non-adopters across a set of variables related to households' socio-economic characteristics and remoteness. The results are provided for both IRRI-related germplasm and the presence of alleles associated with the Saltol gene (Saltol QTL).

Figure 16: Estimated associations between household characteristics and adoption of improved rice varieties, and Saltol QTL



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

HH = household. VND = Vietnamese dong

Data source: VHLSS 2022.

In 2022, households growing IRRI-related germplasms possessed larger land areas than non-adopters. They also had a higher annual income, superior to USD 1,137 on average. These results echo those of Cazzuffi et al. (2020), who found that households that benefited from rice commercialization possessed larger areas of land and were less likely to be poor. Furthermore, households were slightly less educated and less likely to have a main road built with asphalt.

6.4 Salt-Tolerant Rice Varieties

Soil salinity is an important threat to rice crops (Leigh et al., 2020) and climate change is expected to worsen the salinity of coastal agricultural land. According to Viet Nam's Ministry of Agriculture and Rural Development, approximately 15% of Viet Nam's rice area was at risk of salinity intrusion in 2011.

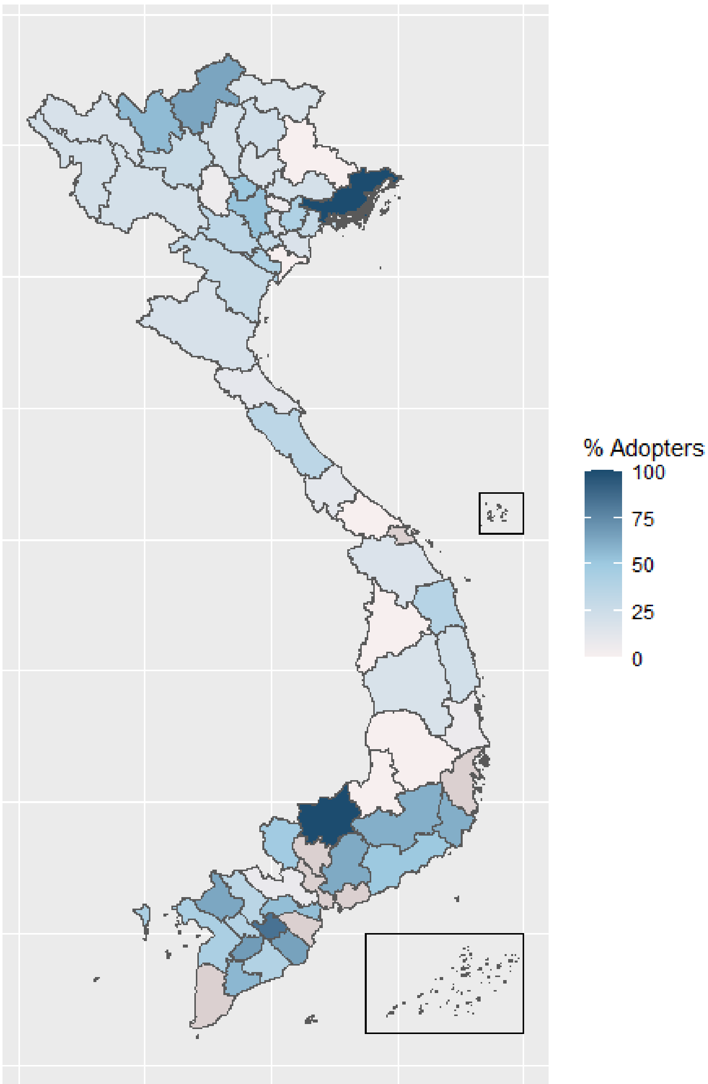
Molecular biologists have identified rice genes and QTLs linked to salt tolerance. The Saltol QTL has been shown to confer salinity tolerance to rice crops at the seedling stage (Ali et al., 2013). Using marker-assisted breeding (MAB), scientists at IRRI in the Philippines have developed multiple lineages containing the Saltol QTL (Ali et al., 2013; Thomson et al., 2010).

In collaboration with NARS, research efforts in Viet Nam have concentrated on breeding new rice varieties that can better withstand saline water intrusion. The Consortium for Unfavourable Rice Environments project (2010-2018) evaluated varietal performance in multi-locational trials and introduced promising varieties into the countries' seed multiplication system. While salt tolerance was a major focus, the released lines also showed tolerance to different types of abiotic stresses.

A second project, Climate Change Affecting Land Use in the MRD: Adaptation of Rice-based Cropping Systems (CLUES) (2011-2013), focused on supporting the transfer of Saltol gene technology into locally adapted varieties and elite lines. There have also been efforts to train farmers in MRD on the cultivation of salt-tolerant varieties.

At least 26 varieties released in Viet Nam between 2002 and 2020 by CLRRI are believed to be salinity tolerant (Figure 17)[66]. All are adapted to the agroecology of MRD.

Figure 17: Map showing the intensity of adoption of alleles associated with the Saltol gene by province in Viet Nam



Data source: VHLSS 2022.

[66] These include OM 1348-9, OM 1352-5, OM1348, OM 2395, OM 3536 (OMCS 21), OM 1252, OM 1350, OM 4059, OM 4900, OM 5199-1, OM 5629, OM 6073, OM 6162, OM 7347, OM 8923, OM 18, OM 5464, OM 5954, OM 5981, OM 6377 (AG1), OM 6677, OM 6932, OM 5953, OM 6976, OM 232, and OM 375.

In our DNA fingerprinting data, favorable alleles associated with the Saltol gene[67] were present in 31% of sampled plots across the country. Accordingly, the potential reach of the salinity tolerance trait is estimated at 2.35 million households. Alleles associated with the Saltol QTL appear to be widely prevalent, and their distribution is very similar to the spatial distribution of rice cultivation. Alleles associated with the Saltol gene are more likely to be found in rice grown in MRD (46.5% of households). It was found less frequently in RRD (26.3% of farmers) and NC regions (22.6% of farmers).

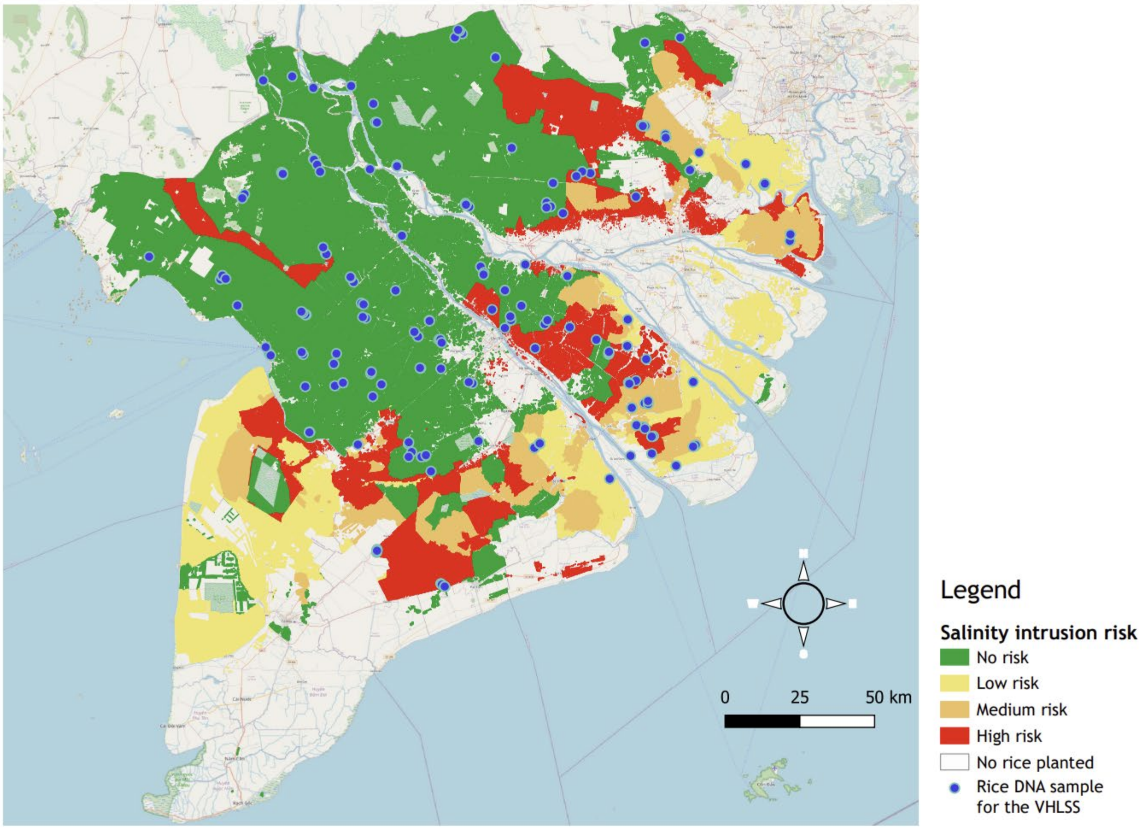
Since we identified the variety that each sample was from, we can examine which rice varieties have this QTL. The Saltol QTL was only found in the seed samples identified as OM5451, TBR225, Thien Uu 8, OM4900, and BC15. Seventy-two percent of the samples where alleles associated with the Saltol was found were improved varieties, and the rest (28%) were unidentified samples, and so could have been landraces. We therefore cannot be sure that the presence of the Saltol QTL in Vietnamese farmers' fields is solely a result of breeding efforts in Viet Nam: this gene may also exist in other non-improved/non-IRRI-related varieties that farmers are growing.

A trait for salinity tolerance is potentially the most impactful for farmers in areas prone to salinity intrusion. As Figure 18 shows, even within MRD, there is considerable geographical variation in the risk of salinity intrusion. Areas in red are those that provincial authorities have classified as facing the highest risk of salinity during the Winter-Spring season[68]. Their classification suggests that 17% of the land area in MRD is at high risk of salinity intrusion, 20% is at medium risk, and 26% is at low risk.

[67] The SNP markers selected during the DNA fingerprinting process act as indirect indicators for inferring the existence of the QTL, meaning the data can only suggest a high probability of the QTL's presence.

[68] This map is an output of the Climate-Smart Mapping and Adaptation Planning (CS-MAP), an innovation documented in Section 7.2.

Figure 18: Map of the Mekong River Delta displaying salinity risk levels and rice-growing households surveyed in VHLSS 2022



Data source: Climate-Smart Mapping and Adaptation Planning (CS-MAP) and VHLSS 2022

Of the sub-sample of VHLSS 2022 rice-growing households for whom we identified alleles associated with the Saltol gene, 156 households were in MRD. One half was located in two provinces: Tra Vinh and Long An, which have medium to high risk of salinity intrusion.

To test the hypothesis that the Saltol QTL is more prevalent in vulnerable provinces, we fitted an OLS model in which the dependent variable was the presence of the alleles associated with the Saltol gene on a household's rice plot in 2022. The independent variables are dummies of the household's salinity risk levels (medium and high risk) based on its location. Our results, available in Table 16, indicate a positive association. We find that compared to households living in a no-risk or low-risk area, those in a high-salinity-risk area were 42% more likely to be growing rice with the Saltol gene. This association approaches significance ($p = 0.068$), providing weak evidence that salinity-tolerant rice is being grown in areas where it is most likely to have a positive impact.

Table 16: Results of the OLS model estimating the relationship between the presence of alleles associated with the Saltol gene on farmer's plot and salinity risk levels in the Mekong River Delta

	Est.	S.E.	t val.	p
Medium salinity risk	0.066	0.158	0.416	0.678
High salinity risk	0.202	0.110	1.836	0.068
Intercept	0.480	0.045	10.546	0.000
Obs.	156			
R2	0.02			

Data source: Climate-Smart Mapping and Adaptation Planning (CS-MAP) and VHLSS 2022.
Standard errors are heteroskedasticity robust.

Our findings have several implications. First, slightly less than one-third of households located in high salinity risk areas were not growing salinity-tolerant rice, suggesting that there is room for greater adoption of the Saltol trait. Second, a large proportion of adopters are in areas where salinity risk is absent or minimal. This result may be understood by examining specific cultivars that contain the alleles associated with the Saltol gene. A variety contains multiple traits, and farmers likely select varieties for multiple reasons, traits possibly being one of them. In MRD, the Saltol QTL was only present in two widespread IRRI-related varieties, OM4900 and OM5451. These varieties are primarily high-yielding, high-quality rice and have high export potential (Bui & Nguyen, 2017). This suggests that the main driver of adoption may not be salinity tolerance. Given the obvious limitations of our sample size, more research is certainly needed on this topic.

The household-economic characteristics associated with growing a rice variety that contains the alleles associated with the Saltol gene include land area and poverty status (Table 9) Households growing a salt-tolerant rice variety were more likely to own larger areas of land. Moreover, several proxies of poverty suggest that adopters were less likely to live in a commune labeled as poor by the authorities ($p = 0.1$) and less likely to be a part of the two lowest quintiles of annual consumption ($p = 0.05$).

6.5 Submergence-Tolerant Rice Varieties

Submergence tolerance, the ability to withstand complete submergence for up to 14 days, has also been the subject of agronomic research. The CLUES project mentioned above (2011-2013) has been a proponent of submergence-tolerant rice varieties. From 2002 to 2020, at least one submergence-tolerant variety was released during the entire period.

IRRI's cultivar IR64 Sub1, which uses the gSub1 gene has led to the submergence-tolerant rice variety OM1490 - Sub1 (Bui & Nguyen, 2017). An impact evaluation in India has shown that farmers who grow this variety also increase the use of complementary inputs, thereby unlocking productivity gains (Emerick et al., 2016).

In our data, the alleles associated with the gSub1 gene were found in 1.5% of surveyed households, equivalent to 114,900 households. These households were in the coastal provinces of Ninh Thuan and Binh Thuan, but also in the Kon Tum and Gia Lai provinces, which are far from the coast. Interestingly, the gene was found only in unidentified rice samples, and so these varieties are of unknown heritage. One of the 14 samples identified as IR50404 also contained alleles associated with the gSub1 gene. It is therefore unclear whether the prevalence of this submergence-tolerant gene can be attributed to breeding efforts.

7. Climate Change Adaptation Options

The Vietnamese stocktake has identified four key innovations that relate to climate change adaptation options. The first, Agro-Climatic Bulletins (ACBs) provide farmers in MRD with tailored agronomic recommendations based on seasonal, monthly, and short-term weather forecasts. The second, Climate-Smart Mapping and Adaptation Planning (CS-MAP), uses participatory processes to blend scientific data with local knowledge to create risk maps identifying vulnerable areas and recommending adaptive farming systems. Third, Agro-Climate Information Services (ACIS) combine local knowledge with scientific forecasts, focusing on gender-inclusive services and scaling access to the service for smallholder farmers. Finally, Climate-Smart Agroforestry Practices promote diverse, sustainable systems combining long- and short-term crops, focusing on testing and scaling best practices across different forest areas.

ACBs and CS-MAP were identified as targets to examine through the integration of new questions into the VHLSS questionnaires. Their implementation in several provinces and the centralized nature of agricultural planning in Viet Nam suggest their potential for large-scale reach. These tools are part of a global effort to deliver climate services that inform farmers about the nature and timing of expected weather changes (FAO, 2013; World Bank, 2016a), to promote adaptation. While CS-MAP employs a top-down approach utilizing province-level agricultural plans as the starting point of dissemination, the ACBs are directly delivered to the farmers. CS-MAPs aim to mitigate the impact of extreme events, whereas ACBs provide continuous, actionable recommendations regarding farming techniques and practices, based on weather forecasts.

7.1 Agro-Climatic Bulletins

Agro-Climatic Bulletins (ACBs) have been developed through a participatory process involving local partners in the districts and communes. They are based on seasonal, monthly, and 10-day weather forecasts and deliver context-specific, ongoing recommendations for agricultural planning and farmers' decision-making over a seasonal (3-6 months) horizon as well as the short-term (monthly and 10-day).

The Applying Seasonal Climate Forecasting and Innovative Insurance Solutions to Climate Risk Management in the Agriculture Sector in Southeast Asia project (2018-2022) piloted ACBs in late 2020 across four communes in Ninh Thuan, Tien Giang, Soc Trang, and Kien Giang provinces. The programme was subsequently expanded to include Ninh Thuan and Tien Giang. By 2022, the project was operational in 351 communes across 8 provinces, with 7 in the MRD and one in the SCC region. Seasonal work plans were issued at the provincial level for the Summer-Autumn 2022 and Winter-Spring 2022-2023 seasons. The scaling of ACBs has occurred through collaboration with MARD, and efforts have been made to institutionalize the approach at the province and commune levels.

In Table 17, we used information gathered through the 2024 VHLSS community-questionnaire on whether farmers receive their commune's Agro-Climatic Bulletins. This allows us to check its association with the monitoring and evaluation (M&E) data on the communes where ACBs are known to be in circulation. By comparing the two independent samples we can get a preliminary sense of the accuracy of the VHLSS data[69].

Across most provinces, the VHLSS commune-level reports tended to overstate the receipt of ACBs compared to the project's M&E reports of the existence of an ACB for that commune. This suggests that the commune-level respondents may have over-reported receipt. This could be because respondents did not understand what the enumerators were referring to when they asked about ACBs. Commune-level extension experts surveyed may be referring to different types of bulletins than those described in the ACB project M&E data. Alternatively, the data may suffer from social desirability bias, where respondents state that ACBs are present in their communes, even if they are not.

Provinces where this overestimation did not occur are An Giang and Tien Giang, where the VHLSS percentages were notably lower than the project M&E data. Additionally, three provinces (marked in blue) showed a relatively close alignment between the two datasets, suggesting that the bias may not be uniform across all regions.

Table 17: Percentage of communes in which ACBs were disseminated in 2024 according to project M&E and VHLSS data

Province	Project M&E data (WS season)	Project M&E data (SA season)	VHLSS data
An Giang	96	96	76
Bac Lieu	6	6	86
Ben Tre	0	3	14
Ca Mau	41	42	39
Can Tho	36	36	33
Dong Thap	0	92	71
Hau Giang	48	48	93
Kien Giang	13	13	63
Long An	3	5	62
Soc Trang	35	38	88
Tien Giang	81	83	46
Tra Vinh	35	41	39
Vinh Long	33	60	65

These results indicate that the community-level protocol used in VHLSS 2024 may not be sufficiently robust to draw conclusions about the reach of ACBs. In the upcoming data collection phases, we recommend considering a more comprehensive piloting phase, incorporating validation of the measurements, to enhance the robustness of the protocol.

7.2 Climate-Smart Mapping and Adaptation Planning

Viet Nam is vulnerable to the El Niño weather phenomenon, which typically causes drier-than-average conditions in Southeast Asia. In Viet Nam El Niño causes higher temperatures, increased

[69] Two important considerations are that the VHLSS sample was designed for province-level representation rather than commune-level, and the analysis excludes survey data collected in Q4 2024, since fieldwork was still ongoing at the time of writing.

evaporation, and reduced river flows. The 2015-2016 El Niño event - one of the strongest on record - reduced rainfall in Viet Nam, which led to a significant drop in groundwater sources. The 2016-2017 drought affected the Central, Central Highlands, and southern regions of Viet Nam.

In response to the Vietnamese government's call to help address future climate risks (Joven, 2016), the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS)'s Southeast Asia (CCAFS SEA) Initiative conducted two assessments in the Central Highlands and MRD in May 2016. Subsequently, they suggested the use of precise forecasting, and the production of hazard maps at the provincial and district levels, which led to the Climate-Smart Mapping and Adaptation Planning (CS-MAP) Initiative (Le et al., 2021).

The initiative was first piloted in Bac Lieu Province (MRD) in 2016 and then scaled up to the entire MRD region in 2017 (Son et al., 2018). In 2020, new maps were designed and given out to provinces in the RRD, Northern Mountainous Midlands (Bac Giang & Phu Tho), and South-Central Coast (Ninh Thuan, Binh Thuan, Phu Yen & Khanh Hoa) (Bernardo, 2020). Maps for the rest of the South-Central Coast (SCC), Central Highland (Dak Lak & Gia Lai), and North Central (NC) Areas were produced in 2021 (CCAFS-SEA, 2021).

The CS-MAPs were designed as a tool to enhance provincial authorities' capacity to deal with climate risk. The hypothetical pathway from CS-MAPs to farmer-level adaptation is described in Section 3.4.7). It relies on the provincial authorities identifying upcoming climate and weather-related risks, consulting the CS-MAPs, and then incorporating the recommended adaptations in their agricultural plans, which are the main policy tool use to pass information on to farmers, from the provinces at the top, down to districts and communes.

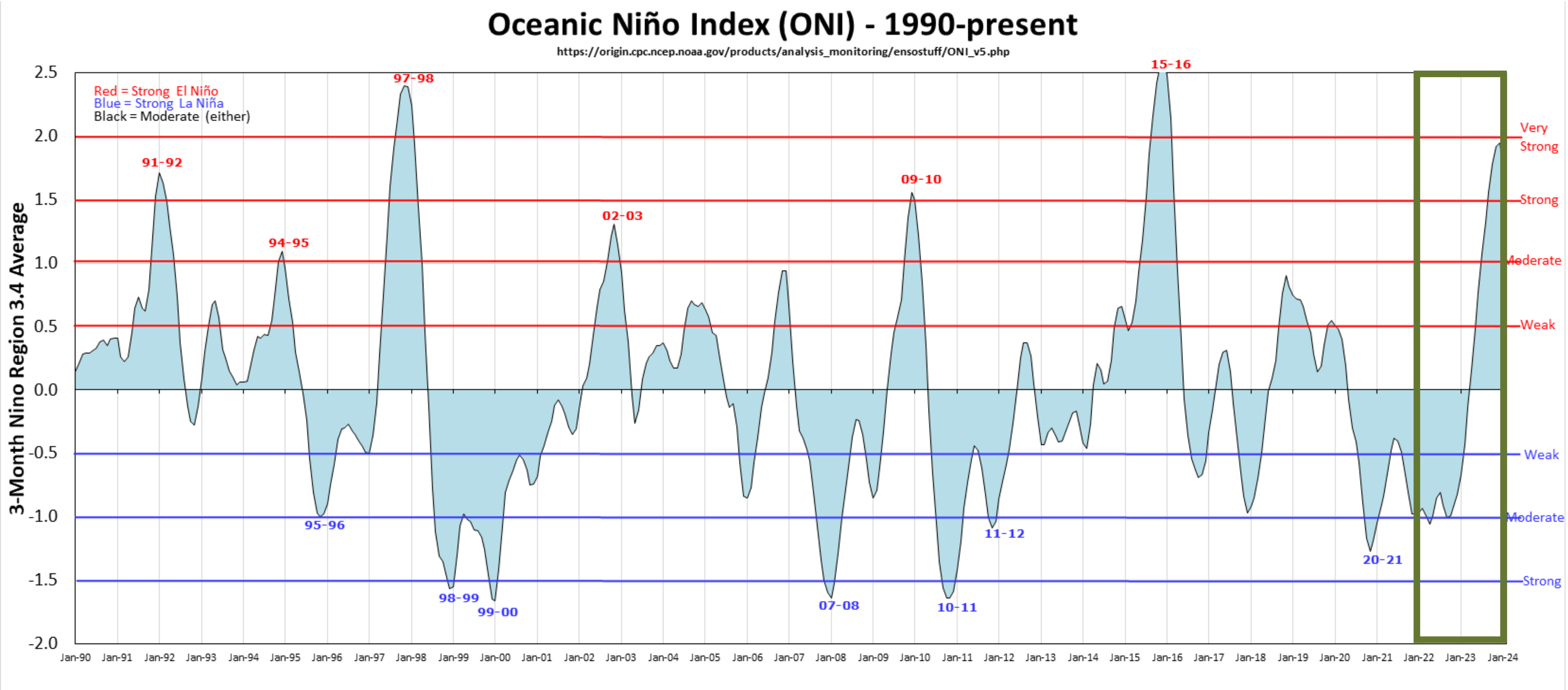
At least two projects have worked on developing the CS-MAP approach. First, CCAFS (2016-2021) developed and tested the participatory approach (Tan et al., 2019) The maps integrate scientific evidence with stakeholders' local knowledge of topography, infrastructure, hydrological management schemes, and land-use plans. Second, the Applying Seasonal Climate Forecasting and Innovative Insurance Solutions to Climate Risk Management in the Agriculture Sector in SE Asia project (2018-2022) supported the scaling of the CS-MAP Initiative to four SSC provinces and twelve Northern Midlands (NM) and RRD provinces.

In 2020, the CS-MAPs approach was recognized in MARD's Decision No. 2559 on initiatives and scientific research projects. To ensure the implementation of the adaptation plans based on the CS-MAPs, the government issued the MARD Official Document No. 8278 to instruct the 12 provinces on using the CS-MAPs to determine the water discharge schedules and cropping calendar for the Winter-Spring season 2020-2021.

CS-MAP's adaptation recommendations are meant to be followed when an upcoming climate event is forecasted. The El Niño-Southern Oscillation (ENSO) is an important, foreseeable factor in the occurrence of drier conditions. According to the CS-MAP's theory of change, most provinces use the Oceanic Niño Index (ONI)[70] to make annual weather forecasts and agricultural plans. Figure 19 shows the 2015-2016 strong El Niño phase, which led to heavy crop losses in Viet Nam, was the strongest event during this period.

[70] The ONI is calculated by averaging sea surface temperature anomalies in the central and eastern equatorial Pacific Ocean, specifically within the coordinates 5°N-5°S, 120°-170°W (NOAA, 2019).

Figure 19: Oceanic Nino Index (ONI) from 1990 to 2024



Source: https://origin.cpc.ncep.noaa.gov/products/analysis_monitoring?ONI_V5.php

We attempt to estimate the reach of CS-MAPs through several approaches, including a household survey question we introduced in the VHLSS 2022 and 2023. Figure 19 indicates that the period from 2022 to early 2023 was characterized by La Niña conditions. The ONI values were neutral and then shifted to moderate El Niño conditions by mid-2023, and strong El Niño conditions toward the end of 2023. These ONI fluctuations support the hypothesis that the CS-MAPs' extreme year recommendations would have been applicable during the second half of 2023, a period which corresponds to the Autumn – Winter cropping season 2023 (August-September) and the Winter-Spring 2023/24 (starting in December).

7.2.1 Phone Survey on the Use of CS-MAPs by Provincial DARDs

In October 2023, a phone survey was conducted with Department of Agriculture and Rural Development (DARD) officials from provinces that designed CS-MAPs. The objectives were twofold: to understand the decision process for recommending adaptation options and to enquire if officials had used the CS-MAPs in the recent past. This information would provide evidence for Steps Two and Three of the hypothetical adoption pathway (Section 3.4.7).

7.2.1.1 Decision Process for recommending adaptation options

We enquired which, if any, risk categories depicted in CS-MAPs were used to inform agricultural plans. Among the 40 respondents involved in the design of agricultural planning, one-half reported using the drought risk category from the CS-MAPs.

Given that the maps provide information at a granular level, it is also important to understand whether they were passed down to the district authorities. In the phone survey, a quarter of the respondents reported that the CS-MAPs were handed over at lower administrative layers (districts), with proper guidance and instructions on how to use them. This was the case for only one province in the Northern Midlands and Red River Delta (NM – RRD), and Central Highlands (CH). Out of 13 provinces in MRD, four reported a handover at the district level.

7.2.1.2 Consultation of the CS-MAPs for Agricultural Planning

When asked whether DARD officials consulted the CS-MAPs before finalizing the first agricultural plan made after the CS-MAPs for their province had been released, 71% of respondents in MRD, 45% in the NM-RRD, 67% in the SCC-CH, and 40% in the NC region responded positively.

Respondents were subsequently asked if they had used CS-MAPS when designing agricultural plans in the preceding three years. As Table 18 shows, their responses showed marked differences by region. Consultation was reported most frequently in MRD, with about two-thirds of respondents there saying that CS-MAPs were consulted. This was followed by SCC-CH where 40-60% of respondents said they were consulted, and then sequentially lower use in the NM-RRD, and NC. The data do not indicate any systematic change in usage frequency over time, or that the CS-MAPs were more or less likely to be used in particular years or seasons.

Table 18: Frequency and percentage of respondents who declared having used CS-MAPs in the last six cropping seasons by region

	MRD (n=13)		RRD-NM (n=12)		SCC-CH (n=10)		NC (n=6)	
	n	%	n	%	N	%	n	%
Winter-Spring 2022/23	9	69	4	33	5	50	1	17
Autumn-Winter 2022	8	62	4	33	4	40	0	0
Summer-Autumn 2022	8	62	5	42	6	60	1	17
Winter-Spring 2021/22	10	77	4	33	5	50	1	17
Autumn-Winter 2021	9	69	5	42	4	40	0	0
Summer-Autumn 2021	9	69	4	33	6	60	1	17

Note: The grey cells indicate the cropping seasons in which no CS-MAPs were designed.

MRD = Mekong River Delta; NM-RRD = Northern Midlands and Red River Delta; SCC-CH = South Central Coast and Central Highlands region; NC = North Central region.

Source: CS-MAPs Phone Survey, 2023.

The phone survey questionnaire asked about agricultural plans for three different cropping seasons: Winter-Spring, Autumn-Winter, and Summer-Autumn. However, not all regions designed separate plans for these three seasons (Table 18 in blue). The intention was to introduce a placebo by asking questions about plans that did not exist. Notably, the results revealed a significant occurrence of false positives, where respondents said they had used CS-MAPs for plans that were never made. Specifically, respondents reported using CS-MAPs in the "Autumn-Winter" season in MRD and the "Autumn-Winter" and "Summer-Autumn" seasons in RRD, which did not exist. This could be due to social desirability bias in the survey responses.

Subsequently, respondents were asked about the specific adaptations they had recommended during the last season when CS-MAPs were used. Nine of the 41 respondents could detail the recommended adaptation options.

7.2.2 Qualitative Content Analysis of Provincial Agricultural Plans (2021-2023)

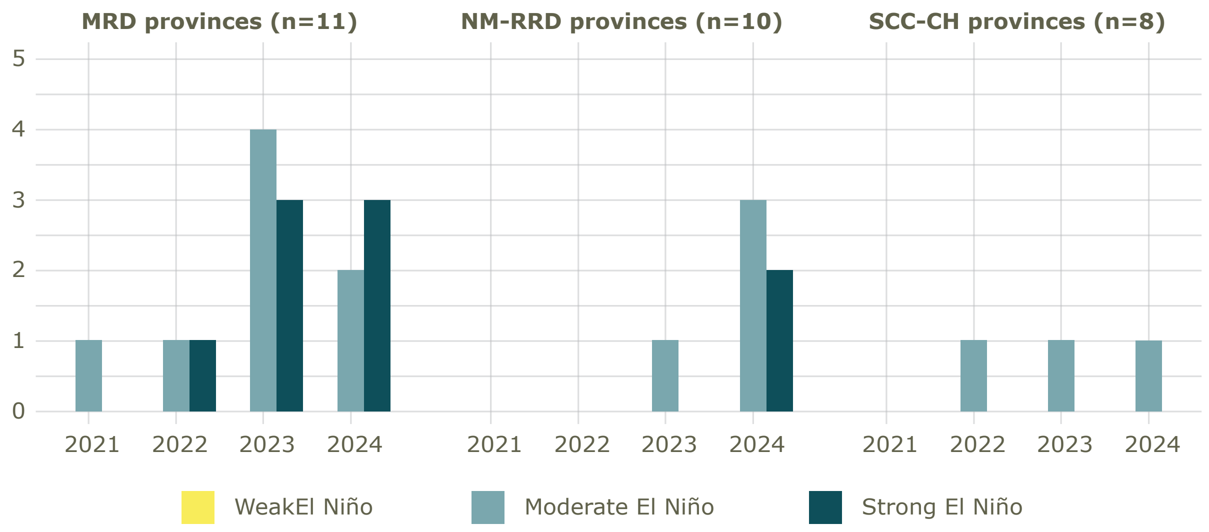
7.2.2.1 Hydrometeorological changes forecast and risk levels assessments

CS-MAP adaptations are only meant to be recommended when an upcoming climate-related event is forecast. Since the second half of 2023 was marked by a stronger El Niño, we expect to find a change in the language used in agricultural plans[71].

As we see in Figure 20, during 2021-2024, El Niño was referenced in three of the four regions that designed CS-MAPs.

[71] When asked about the previous years categorized as severe, phone survey respondents from two provinces, Nghe An, Phu Tho, pinpointed severe conditions in 2023. Positive replies were also collected for seven provinces in 2022 and six in 2021.

Figure 20: Number of Vietnamese provinces referencing the strength of El-Niño in yearly agricultural plans, by region (2021-2024)



Note: MRD = Mekong River Delta; NM-RRD = Northern Midlands and Mountain Areas, Red River Delta; SCC-CH = South Central Coast and Central Highlands. No such occurrence was observed in the North Central and Central Coastal Areas (CH) region.

Source: Author's coding using provincial agricultural plans, 2021-2024.

Agricultural plans written by provinces in MRD showed the highest occurrence of El Niño, particularly in 2023 and 2024. During these two years, moderate and strong El Niño conditions were increasingly mentioned in the agricultural plans. In 2024, strong El Niño conditions are expected in the Ca Mau, An Giang, and Kien Giang provinces. The following quote can be found in the Kien Giang Province's (MRD) sowing schedule plan for Winter-Spring 2023-2024:

"The El-Nino situation is established, continues to strengthen, and is likely to last until the end of 2023 and early 2024 with a probability of 90%."

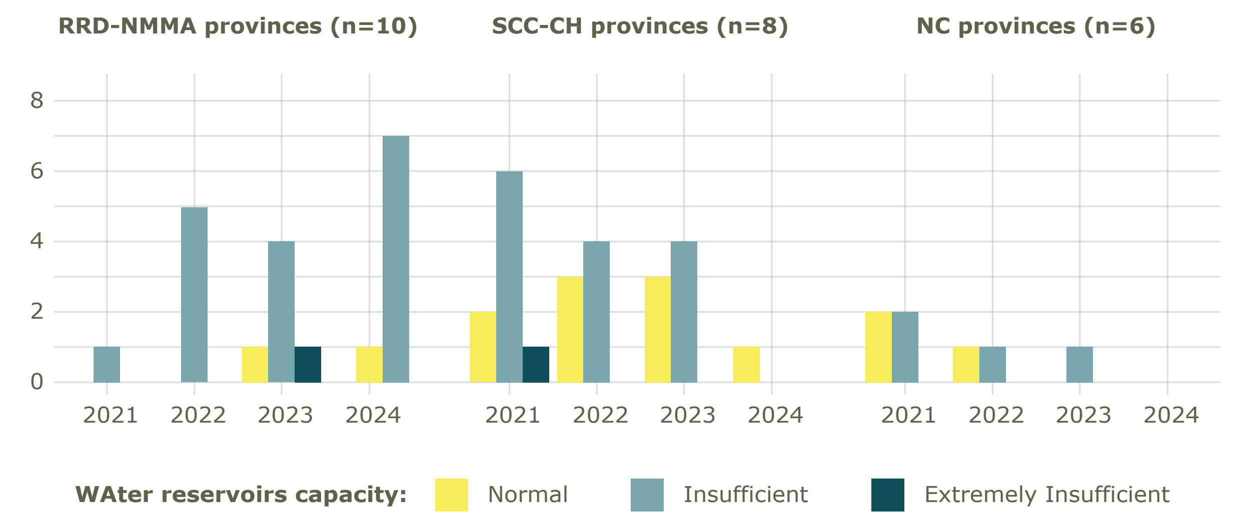
Similarly. moderate and strong El Niño conditions were mentioned in the plans of three provinces: Ha Noi, Thai Binh, and Nam Dinh, in the NM-RRD provinces in 2024.

"The ENSO phenomenon will turn to a neutral state in the months of May-June 2023. Then, in the second half of 2023, it is likely to turn to a warm phase (El Niño) with a probability of approximately 70-80% and may last until 2024." (Nam Dinh Province. Production Plan for Mua 2023)

The plans of only one province in the SCC-CH region, Quang Ngai, mentioned moderate El Niño events. Agricultural plans in the North Central (NC) region did not mention El Niño during the 2021-2024 period at all.

Notably, in three of the four regions, the CS-MAP use process was meant to involve a risk assessment based on the forecasted water levels in reservoirs. We therefore looked at the descriptions of water level in the agricultural plans (Figure 21).

Figure 21: Number of Vietnamese provinces referencing forecasted reservoir water levels in yearly agricultural plans, by region (2021-2024)



Note: NM-RRD = Northern Midlands and Red River Delta; SCC-CH = South Central Coast and Central Highlands; NC = North Central.

Source: Author's coding using provincial agricultural plans, 2021-2024.

In the NM-RRD plans, there is frequent mention of insufficient water levels, particularly in 2024, when seven of the ten provinces mentioned this. An extremely insufficient water level was mentioned only once in the Hung Yen province in 2023:

"Water resources on rivers are forecasted to be 30-50% below average, especially in the lower Red River, to 60-80%." (Hung Yen province, Production Plan for Spring 2022)

Provinces in the SCC-CH region frequently mentioned insufficient water levels, and extremely insufficient water levels were mentioned only in Ninh Thuan province, in 2021. In the NC region, insufficient and normal water levels are both mentioned over the period 2021–2023. This could be either because this region suffers less water scarcity, or because its agricultural planning does not yet account for potential water shortages.

Using coded data from agricultural plans, we then intended to shed light on the recommended adaptation options. We focused on area shifts from rice to other crops in the NM-RRD provinces, and changes in planting dates in MRD provinces.

7.2.2.2 Shift of land from rice to other crops in NM-RRD provinces

In the NM-RRD provinces, CS-MAP adaptations are formulated as a shift of cultivation from the rice crop to other crops during the Winter-Spring seasons. In Table 19, Section (A) outlines the recommended shifts in land area according to the CS-MAPs, categorized according to whether the district is expected to have sufficient water (no risk), insufficient water (medium risk), or extremely insufficient water (high risk). Section (B) shows the cultivated areas for the Winter-Spring seasons from 2021 to 2024 as recommended in the agricultural plans. In the last two columns, we calculate the shift in area, and these are thus directly comparable to the adaptations that would follow from following the CS-MAPs. If provincial authorities' regulations follow the adaptations recommended in the CS-MAPS, then the areas in sections (A) and (B) should match.

Table 19: Recommended shifts in cultivated areas, based on CS-MAPs risk levels and agricultural plans for different regions across the Winter-Spring cropping seasons from 2021 to 2024

Province	(A) CS-MAPs: Recommended shifts in rice cultivated area by risk levels			(B) Agricultural plans				
	Sufficient water (no risk) (1)	Insufficient water (medium risk) (2)	Extremely insufficient water (High risk) (3)	Recommended rice cultivated area in Winter-Spring 2021-22 (4)	Recommended rice cultivated area in Winter-Spring 2022-23 (5)	Recommended rice cultivated area in Winter-Spring 2023-24 (6)	2022-2023 shift (in ha) (7=5-4)	2023-2024 shift (in ha) (8=6-5)
Bac Ninh	0	-2,736	-2,736	31,500	30,800	29,650	-700	-1,150
Ha Noi	-344	-1,029	-2,249	NA	81,128	79,876	NA	-1,252
Hai Phong	-391	-391	-391	28,250	27,680	26,880	-570	-800
Hai Duong	0	0	0	55,000	54,350	NA	-650	NA
Hung Yen	-718	-1,253	-1,565	26,880	25,130	24,154	-1,750	-976
Nam Dinh	0	0	0	72,000	71,200	70,550	-800	-650
Ninh Binh	0	0	0	NA	NA	NA	NA	NA
Thai Binh	-969	-1,069	-1,069	NA	75,000	74,250	NA	-750
Bac Giang	890	890	1,230	48,200	47,000	NA	-1,200	NA
Phu Tho	234	234	234	35,670	35,320	35,300	-350	-20
Ha Nam	194	840	840	NA	NA	NA	NA	NA
Vinh Phuc	495	764	764	NA	NA	NA	NA	NA

Note: NA = Not Available. Source: Author’s coding using provincial agricultural plans, 2021-2024.

In the CS-MAPs from NM-RRD, eight of the ten provinces recommended adaptation options in the context of severe risk (capacity of reservoirs <50% Whi or extremely insufficient water). These provinces were Thai Binh, Vinh Phuc, Hai Duong, Hung Yen, Bac Ninh, Ha Nam, Ha Noi, Hai Phong and Bac Giang.

As we saw in Table 3 on average, agricultural plans recommended a reduction of rice area by 25% or less. The recommended reduction in rice area does not match what the CS-MAPs suggest. Of course, the decision to reduce the rice cropping area likely depends on a variety of reasons, not all of which are related to climate resilience. However, a few provinces' results do stand out and suggest that the regulation reduction in rice cropping areas was consistent with the recommended CS-MAPs options. In Ha Noi province, the CS-MAP adaptation recommendation is that if water is insufficient the rice crop area should be reduced by 1,029 ha, and it should be reduced by 2,249 ha if water is extremely insufficient. The agricultural plan for Ha Noi in 2023-24 indicates that the rice cropping area be reduced by nearly 1,252 hectares and suggests that provincial authorities did follow the spirt of the CS-MAP recommendation by reducing the area under rice.

Other regions, such as Bac Giang and Hung Yen, also exhibit significant reductions in the area under rice cultivation in Winter-Spring 2022-23, of 1,200 ha and 1,750 ha, respectively.

7.2.2.3 Change in cropping patterns in the MRD provinces

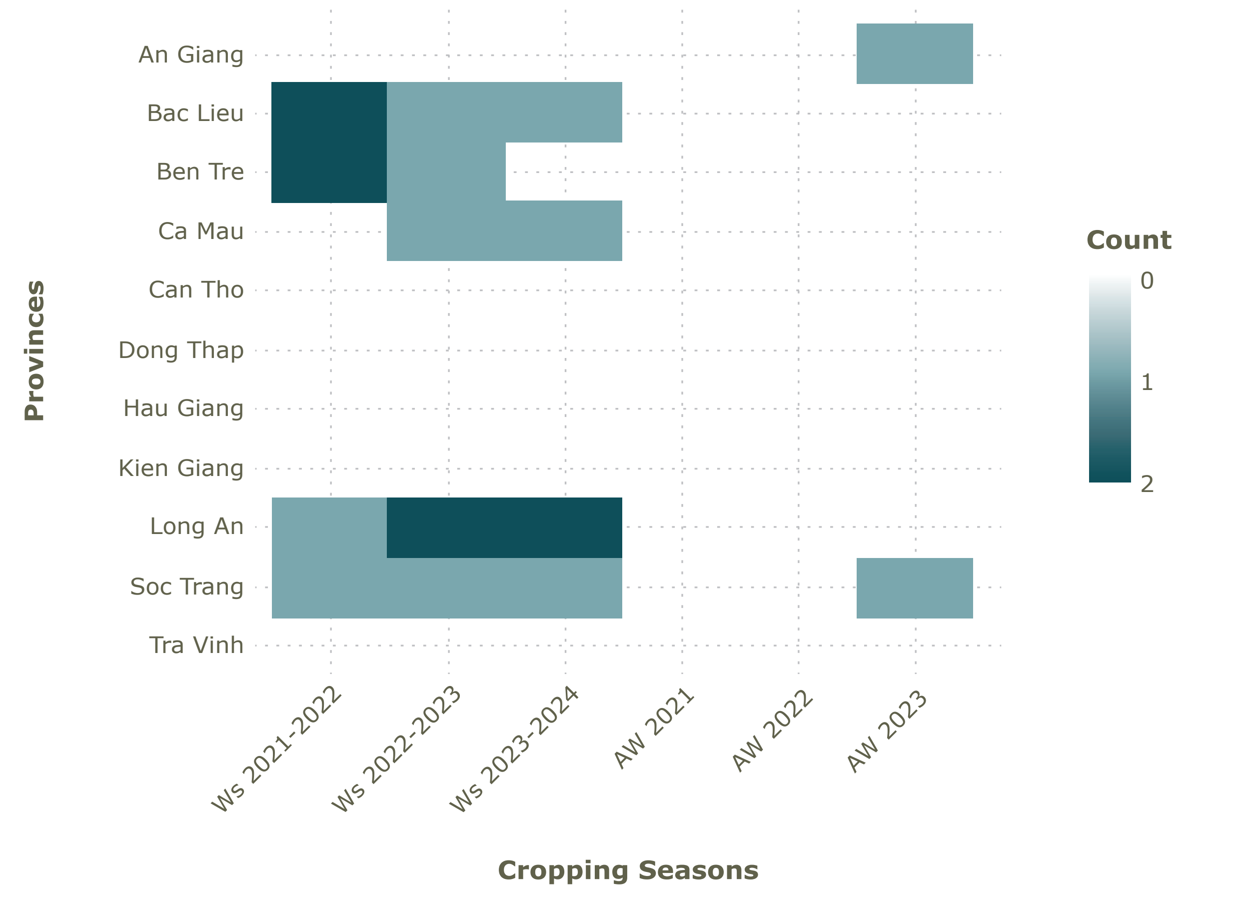
If the year is expected to be extreme, CS-MAPs recommend that provinces in MRD implement location-specific changes in cropping patterns. Depending on the area, the recommendations are to: plant only one, two, or three crops; mix cropping with aquaculture (shrimp-rice farming), or not plant rice. The agricultural plans show that 10 of the 12 MRD provinces, recommended such changes in the event of an extreme year[72].

In the CS-MAPs, the most common recommendation for extreme years is that the farmers do not plant rice. In the heatmap in Figure 22, we list each province on the vertical axis, and on the horizontal axis, we display the occurrence of the "no rice planting" directive in agricultural plans, by cropping season. Province-level regulations that farmers do not plant rice were more frequent during the WS season. Several provinces, such as Bac Lieu, Long An, and Soc Trang, have said that farmers should not plant rice during all Winter-Spring seasons in the past three years. This agricultural plan in Soc Trang province makes the link with extreme weather forecasts particularly clear.

"In case of extreme weather and hydrological developments, with a high risk of freshwater shortage and saltwater intrusion, it is necessary to strongly advise people not to plant late Winter-Spring crops even though rice prices are high because the risk of damage due to saltwater intrusion is very high." (Soc Trang province, Plan for seasons of 2023-2024).

[72] The exceptions are An Giang and Hau Giang provinces.

Figure 22: Heatmap showing the occurrences of recommending no rice cultivation or shift to another crop in a given season from 2021 to 2024 in agricultural planning



Note: WS = Winter-Spring; AW = Autumn-Winter.

Source: Author's coding using provincial agricultural plans, 2021-2024.

Overall, we find one province (Soc Trang) where the CS-MAP recommendation is aligned with the regulation found in the Autumn-Winter agricultural plans. This occurred in 2023, coinciding with stronger El Niño conditions. In five provinces, agricultural plans did not indicate that farmers should not plant rice in any season during the past three years.

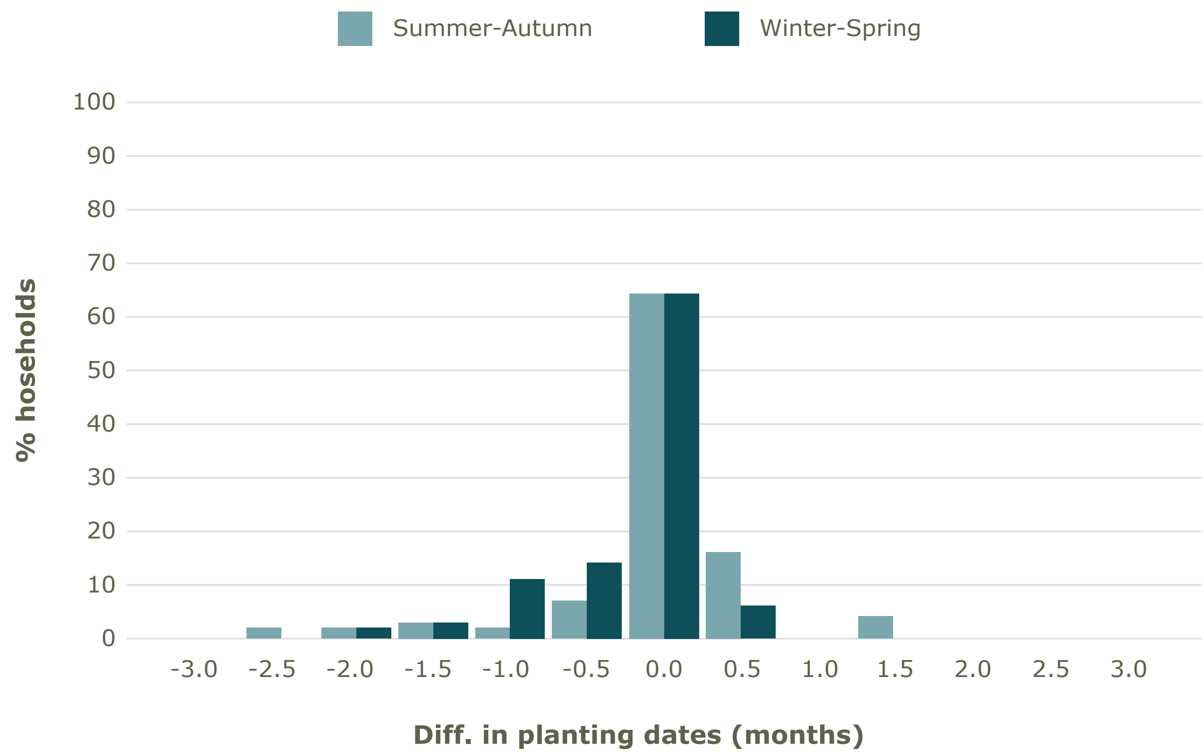
7.2.3 Quantitative analysis of households' planting dates (2022-2023)

The third adaptation option we analyze is the change in planting dates in the MRD region. We quantitatively assessed the matching of household rice planting dates for the 2022 and 2023 cropping seasons with the CS-MAP recommendation.

7.2.3.1 Change in planting dates in the MRD provinces

We started our analysis by comparing the difference in planting dates recommended between the normal and extreme scenarios for both the Winter-Spring (WS) and Summer–Autumn (SA) seasons. The results presented in Figure 23 indicate that for both seasons, approximately 65% of households are in districts for which no change in planting is recommended in the event of an extreme scenario.

Figure 23: Magnitude of change in planting dates recommended by the CS-MAPs in extreme scenarios



We then focused our analysis on households located in districts for which either earlier or later planting dates were recommended in extreme years (n=771 in the WS season and n=865 in the SA season). Notably, WS CS-MAPs typically recommended earlier planting dates, whereas SA CS-MAPs recommended a higher proportion of later dates.

To assess the association of CS-MAPs with household planting dates in the MRD, we first merged rice-growing household planting dates, collected in the VHLSS 2022 and 2023, with the CS-MAP recommended planting dates. We then used an Ordinary Least Squares (OLS) regression approach. The analysis below examines whether these recommendations influence the timing of household planting decisions over a three-year period from 2021 to 2023 across the 13 MRD provinces. We analyze planting dates in the Winter-Spring and Summer-Autumn seasons separately since behaviors may differ.

The OLS method allows us to estimate the average association between CS-MAP recommended planting dates on household planting behaviors. By pooling data across multiple years and controlling for time-related and weather-related factors, we aim to isolate the specific contribution of CS-MAPs recommended dates to household decisions. The results are presented in Table 20.

Table 20: Association of households' planting dates with CS-MAP recommended dates: Winter-Spring and Summer-Autumn seasons

	Winter-Spring season			Summer-Autumn season		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
CS-MAPs planting date	0.011	0.002	0.005	0.013 ***	0.013 ***	0.013 ***
	(0.007)	(0.006)	(0.006)	(0.002)	(0.002)	(0.002)
Year 2022		-0.949 ***	-0.976 ***		-0.314	-0.304
		(0.230)	(0.232)		(0.159)	(0.161)
Year 2023		-9.015 ***	-8.831 ***		-0.629 **	-0.928 ***
		(0.553)	(0.772)		(0.191)	(0.190)
Moderate/Strong El-Nino			6.745			1.570 *
			(4.467)			(0.599)
CS-MAPs planting date × Moderate/ Strong El-Nino			-0.025			-0.009
			(0.017)			(0.005)
(Intercept)	6.630 **	10.479 ***	9.712 ***	3.280 ***	3.617 ***	3.558 ***
	(2.065)	(1.675)	(1.895)	(0.257)	(0.284)	(0.304)
N	1235	1235	1235	1284	1284	1284
R2	0.01	0.32	0.32	0.10	0.12	0.14

Note: *** p < 0.001; ** p < 0.01; * p < 0.05.

Considering the results for the Winter-Spring season on the left-hand side of the table, we see that in Model 1 the association with the CS-MAP recommended date is not statistically significant. Note also that an R-squared value of 0.01 indicates that the model explains a very small portion of the variation in households' planting dates. After adding controls for time-related changes in Model 2, the CS-MAPs planting date variable remains insignificant.

Note that in this model, the coefficient on CS-MAP planting date is the average of the effect across normal and extreme years. In Model 3, the addition of an interaction term allows for a better understanding of how households adjust their planting dates in response to El Niño forecasts, as indicated by agricultural plans. However, under this approach, the CS-MAPs planting date variable is still insignificant. This suggests that there is no association between the recommended planting dates from CS-MAPs and the planting dates chosen by farmers during the Winter-Spring season.

Turning to the Summer-Autumn season, we see across models that households' planting dates correlate with CS-MAP recommended dates. In Model 1, the point estimate is 0.13, indicating a positive correlation with the CS-MAP recommended planting dates. After adding the control and interaction variables in Models 2 and 3, the estimates for δ_1[73] remain around 0.013 ($p<0.01$). These robust point estimates suggest that when CS-MAP recommends later dates, farmers also tend to plant later. Furthermore, the insignificance of the interaction variable in Model 3 indicates that farmers respond similarly to CS-MAP recommendations under both normal and extreme scenarios.

[73] The term δ_1 represents the coefficient of interest in the OLS model. It quantifies the association of the key independent variable (CS-MAPs planting date) on the dependent variable (Farmer's planting dates).

In terms of understanding the reach of CS-MAPs, our analysis began with a phone survey of DARD officials. Half of the provinces reported using drought risk categories in their agricultural planning. In the last Winter-Spring (WS) season of 2022/23, 69% (MRD), 33% (NM-RRD), 50% (SCC-CH), and 17% (NC) of respondents indicated that they had consulted the CS-MAPs. A subset of these respondents, mainly in MRD, could specifically identify the recommended adaptation options. However, the findings also indicated that responses were collected for cropping seasons without corresponding CS-MAPs, raising concerns regarding the possibility of social desirability bias.

Qualitative content analysis of the agricultural plans revealed regional differences in climate resilience planning. It is more prevalent in MRD and NM-RRD but relatively absent in SCC-CH and NC, where few hydrometeorological considerations were found in provincial agricultural plans.

We further examined two adaptation options for agricultural planning through a qualitative content analysis. First, the recommended shift from rice to other crops was assessed in the NM-RRD provinces. We identified three provinces – Hanoi, Bac Giang, and Hung Yen – where the recommended reduction in rice area aligns with the CS-MAP options. Second, we analyzed changes in crop patterns, including recommendations to avoid rice cultivation during specific seasons, across agricultural plans from 11 MRD provinces. We found that one province, Soc Trang, aligned with the CS-MAP recommendation in its Autumn-Winter agricultural plans in 2023, potentially corresponding to stronger El Niño conditions. This recommendation was also consistently included in all Winter-Spring seasons in Soc Trang.

A third adaptation option, changes in planting dates in MRD, was quantitatively examined using data from a sample of 3,264 households from VHLSS 2022 and 2023. Although the association between CS-MAP-recommended planting dates and household planting dates was significant, the coefficients were close to zero in both the Winter–Spring (WS) and Autumn–Winter (AW) seasons. However, we notice that the association varies depending on whether it is a normal or extreme year, and whether it is the WS or SA season. In the WS season, farmers' planting dates correlate with the CS-MAP recommended dates only in extreme years, whereas in the SA season, they correlate with the CS-MAP recommended dates only in normal years. More analysis is required to better understand how CS-MAPs influence farmers' planting dates. Controlling for time- and weather-related changes did not alter these results, suggesting a limited actual impact of CS-MAPs on household planting dates.

Finally, to assess the extent to which the reach of the CS-MAPs may have been associated with the households' planting dates level for this third adaptation option, we calculated the number of households in MRD whose planting dates, (recorded in fortnights), matched the CS-MAP recommended dates for 2022 and 2023. Since CS-MAPs are designed to guide adaptation in extreme years, we would expect that CS-MAPs had a greater influence on farmers' planting dates in 2023-2024.

Our findings suggest that in 2023, an extreme year, an estimated 27.4% of rice-growing households in MRD –equivalent to 171,600 households – planted rice in the fortnight that the CS-MAPs recommended in the event of an extreme year. These households were in the 13 MRD provinces, with the highest concentrations in Dong Thap, Kien Giang, Vinh Long, and Can Tho.

These figures likely underestimate the reach of CS-MAPs at the national level for two reasons. First, due to limited georeferenced data on CS-MAP recommendations, we could only calculate the reach within MRD provinces. A wider investigation encompassing provinces in the SCC-CH and NC regions would have been ideal, although we found little evidence of climate resilience planning in agricultural plans from these provinces. Second, in the VHLSS surveys, household planting dates were recorded for the previous 12 months, and so only a limited sample of households were likely reporting planting dates for the Winter-Spring or Summer-Autumn seasons in 2022 and 2023, which were when the extreme year scenario would have been operational.

Further efforts are needed to fully assess the validity of the theory of change behind the CS-MAPs innovation. In 2022 and 2023, we found limited evidence of the use of CS-MAPs in climate planning. However, it is important to note that these maps are designed for extreme climate years, meaning that their reach and impact may vary significantly based on the anticipated severity of climate events.

8. Environmental Conservation

8.1 Payments for Forest Environmental Services

In 2008, Viet Nam became the first Asian country to officially launch a programme to incentivize communities to protect forests through the Payments for Forest Environmental Services (PFES) Policy (Decree 380/2008[74], Decree 05/2008/NĐ-CP[75] and Decree 99/2010[76]). The leading agency coordinating PFES is the Viet Nam Forest Protection and Development Fund (VNFF).

At the provincial level, Forest Protection and Development Funds (FPDFs) act as intermediate agencies. The suppliers of forest environmental services are forest owners or forest authorized managers, naming individual/household forest owners, forest owners as communities/groups of households, forest management boards, forestry companies, commune people's committees, and other socio-political organizations.

The forest service users are hydropower plants, utility and industry water companies, and ecotourism companies. The PFES payment is determined on an output basis. Regarding Decree 156/2018, PFES money accounts for VND 36 (USD 0.00158)[77] in every kilowatt-hour of electricity sold to customers, VND 52 (USD 0.00229) in every cubic-meter of utility water, VND 50 (USD 0.00220) in every cubic-meter of industrial-use water, and 1% of revenue from ecotourism and aquaculture. However, forest service providers and users are not directly setting up contracts or making payments. Instead, FPDFs are responsible for signing entrusted contracts[78] with provincial forest service users on behalf of forest owners, collecting PFES payments, and making them to forest service providers in accordance with the forest area.

For inter-provincial forest service users, such as national hydropower plants that rely on water inputs flowing through multiple provinces, the central fund is responsible for collecting PFES payments from these service users and distributing the money to provincial agencies so that provincial FPDFs will distribute PFES payments to forest service providers. These payments encourage forest service providers to maintain sustainable land-use practices and adopt new practices that have environmental benefits, such as forest regeneration.

The PFES was implemented nationwide in 2010[76]. A legal framework of 20 instruments, including Circulars 80/2011, 60/2012, 85/2012, and 20/2012, strengthened the PFES by increasing payment levels, improving monitoring, covering forest owners' labor costs, and addressing payment delays. In 2017, the National Assembly Meeting passed the new Forestry Laws, into which PFES was embedded. This resulted in the adoption of Decree 156/2018/NĐ-CP

[74] Decree 380/2008 established the PFES in Son La and Lam Dong provinces: https://datafiles.chinhphu.vn/cpp/files/vbpq/2008/10/81256_qd380ttg.pdf

[75] Decree 05/2008/ND-CP established the Forest Protection and Development Fund: https://vanban.chinhphu.vn/default.aspx?pageid=27160&docid=56557

[76] Decree 99/2010 about the Policy of Forest Environmental Service: https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Nghi-dinh-99-2010-ND-CP-chinh-sach-chi-tra-dich-vu-moi-truong-rung-112264.aspx

[77] Using the 2018 average exchange rate of 1 VND = USD 0.00004396

[78] Entrusted contracts are signed by FPDF/VNFF with forest service users on behalf of the forest owners.

that elucidated some articles of the 2017 Forestry Laws, especially the payments and the role that FPDFs are expected to fulfill.

After PFES funds are collected from users, a portion is retained for management and reserves. The Central Fund retains up to 0.5% for management purposes, while provincial funds can retain up to 10% for management and 5% for reserves. The remaining funds are distributed to PFES providers based on the size of their forest area and a modified payment rate, which considers the forest's location and its contribution to forest services. Payments are made through bank transfers, mobile banking, or cash, depending on local conditions.

Several CGIAR projects have helped advance the PFES in Viet Nam. The Rewarding the Upland Poor in Asia for Environmental Services They Provide project (2002-05), coordinated by ICRAF, was a pioneering initiative. It developed mechanisms to incentivize upland farmers, encouraging them to maintain sustainable land-use practices and adopt new ones, thereby enhancing environmental benefits and alleviating poverty in upland areas. This project underscored the importance of direct buyer-supplier connections, moving away from public subsidies.

Further research was conducted through the CGIAR Research Program on Forests, Trees, and Agroforestry (2011-21). In 2013, CIFOR collaborated with MARD and the Viet Nam Forest Protection and Development Fund (VNFF) to assess PFES implementation from 2008 to 2012. Their Payments for Forest Environmental Services in Viet Nam: From Policy to Practice Report (Pham et al., 2013), was the first independent assessment of PFES, highlighting a critical gap in Monitoring and Evaluation (M&E). To address this, CIFOR and Winrock International co-developed an M&E framework in 2016. It was initially piloted in Son La Province and later expanded to several others. Many of CIFOR's proposed indicators are now integral to the VNFF's M&E guiding handbook for provincial Forest Protection and Development Fund offices.

Other notable projects include the Greater Mekong Subregion Core Environment Program (2015), the Viet Nam Forests and Delta Program (2012-21), the Evaluation of the Impact of the Policy on the Payment of Forest Environmental Services (2019), and the Sustainable Wetlands Adaptation and Mitigation Program (2019). These initiatives have worked on strengthening the PFES framework, ensuring more effective and sustainable environmental stewardship in Viet Nam.

The implementation and reach of PFES are evidenced through both administrative reports and empirical findings, although most studies rely on case studies. Pham et al. (2013) provide the first comprehensive overview of PFES implementation, two years after its launch. By 2012, steering committees had been established in 35 of the 63 Vietnamese provinces to oversee the program. Additionally, 27 provinces successfully created and maintained their own FPDFs. In 2012, PFES revenue amounted to approximately VND 1,172.44 billion (USD 55 million), with nearly 98% of the payments coming from hydropower plants. Lai Chau province received the highest PFES payments (approximately USD 11 million), followed by Kon Tum (USD 9.5 million) and Dien Bien (USD 7.4 million). Only 46% of PFES funds had been disbursed, primarily because of delays in determining the forest areas of individual owners and the absence of clear payment management guidelines.

More recently, Phan (2019) examined data from 180 stakeholders, including VNFF staff, forest ecosystem service users, provincial funds, state agencies, and NGOs. By the end of 2018, the VNFF had signed 95 agreements: 75 with hydropower companies and 17 with clean water providers.

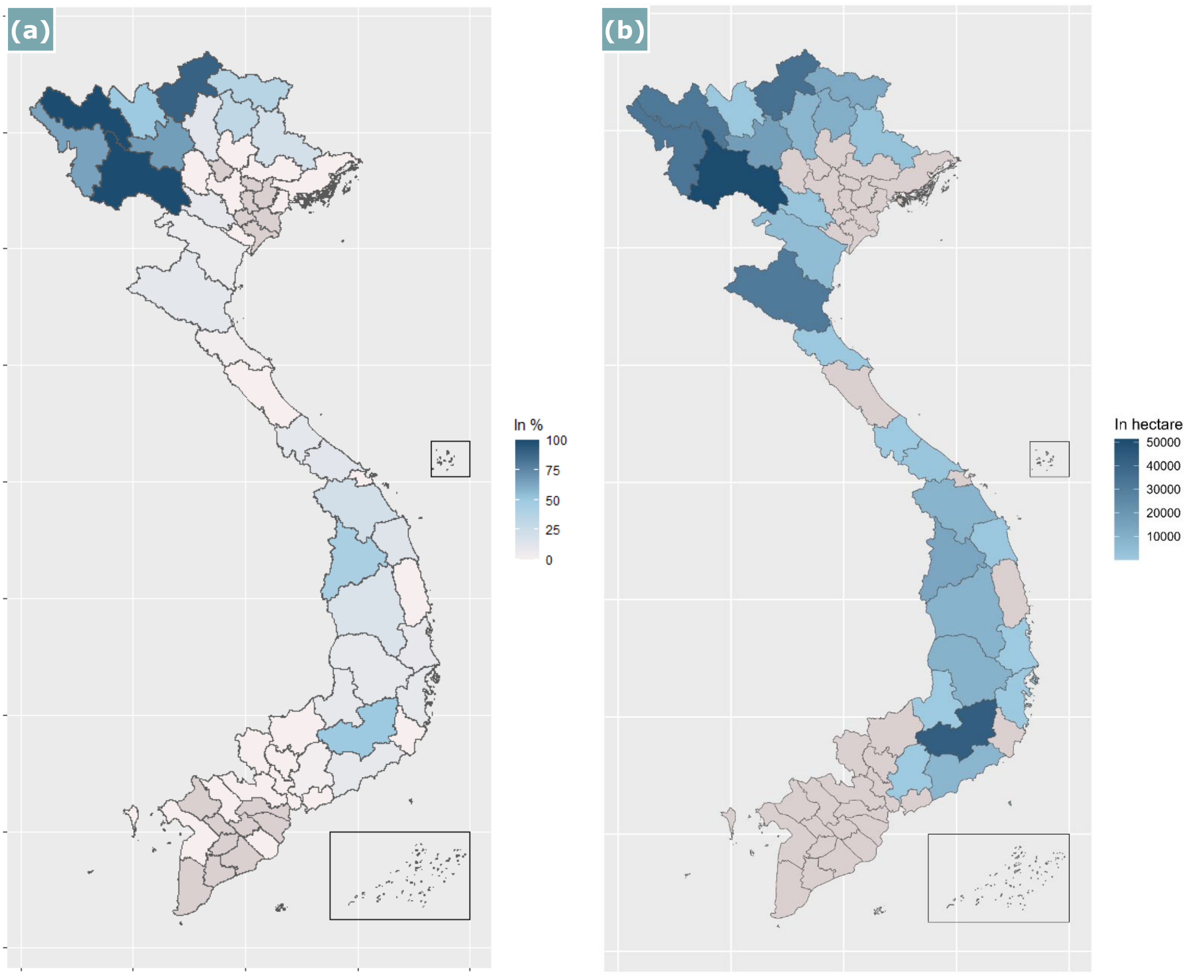
Empirical studies across several provinces in Viet Nam have also provided insights into the reach of PFES. The potential impacts of PFES have also been empirically assessed. Do & Naranong (2019) conducted a study across 25 villages in Quang Nam and Thua Thien Hue provinces, surveying 795 households. Of these, 25% (n=198) participated in the PFES. Payment rates were higher for poor households (USD 53 on average) than for non-poor households (USD 45 on average).

A case study focusing on Hong Trung Commune in A Luoi District, Thua Thien Hue Province, found that after nine years of PFES implementation, revenues were allocated to 620 forest owners, including state organizations, commune people's committees, communities, and households (Ngoc et al., 2021).

In northern mountainous regions, Thuy et al. (2020) surveyed 240 households in Son La Province. The annual payments per household ranged from VND 402,156 (USD 17) to VND 2,276,661 (USD 98). However, 77% of households experienced interrupted payments between 2009 and 2018. Le et al. (2016) examined four districts in Dien Bien province and found that by 2014, 88% of the USD 5 million in PFES payments had been received by forest owners, including individual households and communities. The study surveyed 179 households and 52 village heads, with all PFES payments managed under community contracts. Pham et al. (2021) examined the implementation and impact of the PFES program in the Dak Lak and Kon Tum provinces of the Central Highlands. The survey was conducted in 31 villages and 404 households. It was found that 51% of the households were PFES participants.

In our work, we attempted to measure the reach of PFES through a new question we added to the community-level questionnaire in the VHLSS 2024 survey. Our preliminary results, based on surveys conducted in the first three quarters of the year show that at the national level, 11.6% of communes surveyed were participating in PFES at the end of 2023. These communes were located in the NM, Central Highlands, and NCCCA (Figure 24). The share of communes with PFES mechanisms in place was the highest in the Northern provinces: Lai Chau and Son La (100%), Ha Giang (90%), and Yen Bai (67%). Across the country, 227,300 households benefit from PFES.

Figure 24: Percentage of communes per province with (a) operational Payments for Forest Environmental Services areas and (b) total forest area under PFES in 2023



Note: These preliminary data were collected from the 44 provinces legally participating in PFES. Data pertaining to provinces that do not participate in the PFES scheme were not collected and are depicted in grey.

Data source: VHLSS 2024, preliminary data.

9. Mechanization

The recent growth in mechanization in Viet Nam has mirrored trends seen in other developing countries in Asia. However, in the long term, Viet Nam's historical growth in agricultural mechanization is unique due to significant changes in its political and economic systems, which few other countries in Southeast Asia or South Asia have experienced. As the economy shifted towards the industrial and service sectors, the labor force distribution drastically changed labor scarcity has been a potential drive of mechanization in Viet Nam (Takeshima et al., 2020).

Policy measures have been an enabling factor in the diffusion of agricultural machinery in Viet Nam. Among the influential policies is the Prime Minister's Decision No. 68 (Decision 68/2013/QD-TTg)[79], along with Decision No. 738/QĐ-BNN-KHCN[80]. Moreover, Decision No. 813/QD-NHNN[81], aims to subsidize interest rates to promote high-tech agriculture, helping farmers purchase agricultural machines using bank loans. This decision stipulates that when a farmer purchases new agricultural machines that meet state quality standards, 100% of the bank loan interest is covered in the first two years, and 50% in the third year (Varangis et al., 2019).

These policies are designed to shape the future of Viet Nam's agriculture, with several key goals in mind, as the Minister of Agriculture and Rural Development claimed in Can Tho in 2022:

"Viet Nam aims to achieve a minimum of 70% mechanization in crop production by 2030, and the income of a farmer is expected to reach approximately VND 120 million (USD 5,140) per year by that time." (IRRI, 2022)

Over the past decades, Viet Nam's agricultural sector has undergone a profound transformation, marked by a shift towards modernization and mechanization. Central to this transformation are six key innovations to which CGIAR centers have devoted research efforts. These innovations, namely Laser Land Leveling (LLL), Drum Seeder, Combine Harvester (CBH), Mini-combine Harvester (MCBH), Rice Straw Baler (RSB), and Off-field Straw Management Practices, can enhance productivity and streamline labor-intensive processes, contributing to the sustainability and competitiveness of Viet Nam's rice agriculture.

Each of these innovations offers distinct advantages to the agricultural value chain. Throughout this chapter, innovations will be analyzed according to three phases of the agricultural production chain: pre-planting and planting, harvesting, and post-harvesting. This phased approach allows for a clearer understanding of how each innovation fits within and impacts different stages of the production cycle, highlighting their specific roles and benefits in the broader agricultural process. LLL facilitates precise land leveling, optimizing water use efficiency, and enhancing crop yields. Drum seeders automate rice seed sowing, reducing seed wastage and labor costs while ensuring

[79] Decision No. 68/2013/QĐ-TTg on supportive policies on reduction of losses in agriculture. https://vanbanphapluat.co/decision-no-68-2013-qd-ttg-on-supportive-policies-on-reduction-of-losses-in-agriculture

[80] Decision 738/QĐ-BNN-KHCN applying high technology and clean agriculture. https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-738-QD-BNN-KHCN-du-an-nong-nghiep-ung-dung-cong-nghe-cao-nong-nghiep-sach-2017-344305.aspx

[81] Decision 813/QD-NHNN loan provision program serving high-tech and clean agriculture development in Vietnam. https://thuvienphapluat.vn/van-ban/EN/Linh-vuc-khac/Decision-813-QD-NHNN-loan-provision-program-serving-high-tech-and-clean-agriculture-developmemt/366144/tieng-anh.aspx

uniform plant spacing for optimal growth. The CBH and its mini counterpart, MCBH, have the potential to significantly increase yields by reducing harvesting time and labor requirements, thereby addressing one of the most labor-intensive tasks in rice cultivation. The RSB manages post-harvest waste efficiently by bundling rice straw, enabling its use as animal fodder and composting material. Additionally, off-field rice straw management practices incentivize sustainable straw use through composting, mushroom cultivation, or cattle feeding, addressing environmental concerns and creating additional revenue streams for farmers.

This section, structured similarly to other chapters, delves into multiple aspects of each innovation. It begins by outlining the functionality and benefits of the innovations, followed by efforts by CGIAR Research Centers to promote them, and an analysis of adoption rates, including changes from 2022 to 2023 when possible. Insights from interviews in the MRD enrich the adoption analysis, highlighting farmer experiences and regional disparities, supported by VHLSS data and geographic mapping. The section then examines how these innovations align with CGIAR impact areas, exploring adoption trends by socioeconomic factors such as farm size, income, internet access, and demographics. Lastly, Appendix H evaluates methodological challenges in measuring adoption rates, comparing household surveys with community-level data to uncover discrepancies and their potential causes.

9.1 Laser Land Leveling Technology

In rice fields, significant sloping can lead to uneven water distribution, resulting in slower crop establishment and increased input costs for seeds, water, fertilizer, and pesticides. Traditionally, many farmers across Asia use draft animals and two-wheel tractors equipped with harrows and leveling boards to level flooded fields, a labor-intensive practice. Laser land leveling (LLL) technology offers a solution to these challenges.

LLL involves flattening and grading the land to achieve a uniform surface level. This process focuses on smoothing out minor irregularities rather than altering the overall topography of the land. Land leveling is essential for preparing agricultural fields, creating a suitable seedbed, or consolidating land, especially in regions with frequent heavy rains and seasonal water shortages like the humid tropics. In Viet Nam, farm size ranges from 0.2 to 0.5 hectares in northern Viet Nam and from 1 to 2 hectares in the southern part of the country (Belfort, 2016; Hien, 2021). These small and irregularly shaped plots hinder mechanization efforts, leading to lower energy efficiency and productivity in mechanized operations.

Using LLL, a field can be precisely leveled to a desired slope across its area. The technology employs a laser beam emitted from a transmitter and received by sensors attached to a leveling bucket on a tractor. The control system interprets the signal to adjust the height of the leveling bucket automatically. This process detects variations in field elevation and redistributes soil from higher to lower areas, achieving a highly accurate level surface.

Studies have shown that LLL can enhance fertilizer use efficiency by 10–13%, increase rice production by 5–15%, and improve irrigation water efficiency by 12–40% (Hien, 2014). It also reduces postharvest losses by 2–5% through more uniform crop stands, minimizing crop lodging after harvest (Nguyen-Van-Hung, 2022; Hien, 2014). When small fields are consolidated into larger plots, land-use efficiency can rise by 3–6%, and overall rice yield can increase by 5–8% (Hien, 2021). Additionally, precise leveling that reduces standing water in rice fields can cut methane emissions by at least 20%. Altogether, LLL can boost farmers' profitability by an average of USD 260 per hectare per season (Hien, 2014). The cost of laser leveling may reach up to USD 50 per hectare per season, translating to a USD 500 investment over ten seasons. This means that farmers who invest in LLL can potentially recover their costs within a single year, in an area where there are at least two cropping seasons.

The International Rice Research Institute (IRRI) demonstrated LLL in Viet Nam in 2004, mainly utilized in advanced agriculture. Viet Nam has increasingly adopted this technology, with 1,500 hectares leveled by 2017 (Hien, 2021). An early adopter, Viet Nam tailored the bucket´s scale-appropriate design to suit local conditions and conducted studies to optimize laser leveling's application. This was facilitated through a partnership between IRRI and Nong Lam University. Bilateral projects further promoted technology adoption nationwide under Viet Nam's Good Agricultural Practices policy (IRRI, 2021).

Since then, IRRI has actively supported various initiatives to expand LLL in Viet Nam, including stakeholder training, field demonstrations, and bolstered regional equipment supply chains. With the interventions of IRRI through the Closing Rice Yield Gaps with Reduced Environmental Footprint (CORIGAP; 2014-2020) and the Viet Nam Sustainable Agricultural Transformation bilateral projects, LLL has been adopted in about 4,000 ha in Viet Nam.

A household is considered to have adopted this technology if it has used an LLL machine to level at least one plot. Data from the 2023 VHLSS indicates nearly 409,300 households (5.4%) in Viet Nam reported using an LLL machine to level their largest plot[82] (Table 7).

The adoption of LLL technology is highly dependent on the specific topographic conditions of the terrain. It is expected to be more in demand in areas with moderate irregularities, where its application is feasible. In contrast, regions with very deep irregularities are less suitable. This pattern is evident in Viet Nam, where the North Mountainous Areas, characterized by more rugged terrain, have the lowest adoption rate (2% of households). Conversely, the Southeast and Central Highlands Regions, which feature a mix of mountainous areas, have the highest adoption rates; 11.5% and 12.1% respectively.

Adoption rates at the Enumeration Area (EA) level are examined to assess how widely the innovations have reached (Table 7). An EA is classified as an adopter if at least one household within it has adopted the technology. Thus, adoption rates at the EA level capture the geographical spread of the innovation rather than its intensity. The regional distribution of adoption rates at the EA level mirrors that at the household level, with the highest proportion of adopting EAs found in the Central Highlands (20.4%) and the lowest in the North Mountainous Areas (8.9%). This alignment suggests a correlation between the intensity of adoption and its geographical spread.

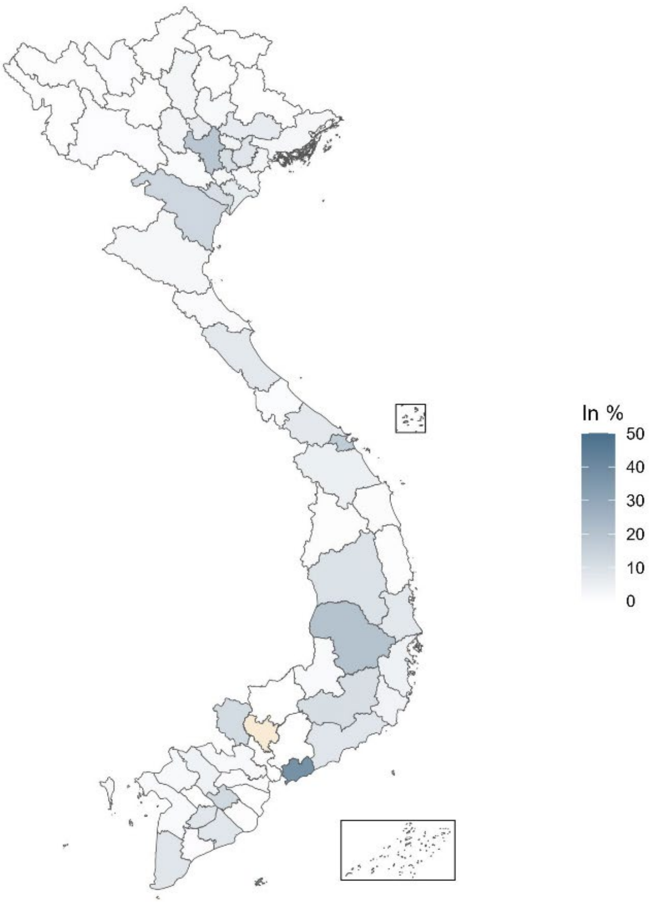
To better understand the farmers' context, a series of interviews was conducted in MRD, specifically in Dong Thap province, Hong Ngu district. In several of these interviews, farmers were asked whether they level their fields, how they do so, and what benefits and obstacles they have encountered. Although no farmer claimed to have implemented laser land leveling technology on their fields, some mentioned leveling their fields as part of the plowing process. The main benefit

[82] Since households were only surveyed about their largest plot, the adoption rates could be biased toward zero if farmers use LLL to level and potentially merge smaller plots.

highlighted by farmers was fertilizer efficiency. Interviewed farmers were aware that leveled plots require less fertilizer due to fewer variations in elevation, which leads to more consistent water retention and fertilizer distribution. However, even farmers who have invested heavily in land leveling expressed doubts about its efficacy. They noted that despite leveling the land using a machine, some areas remain irregular, forming subsided spots where water collects during the rainy season. Farmers pointed out that it is necessary to replant seeds in these lower areas.

LLL adoption rates by province are depicted in Figure 25. The technology presents higher adoption rates in the northern, central, and southern provinces of the country. Notably, in the northern region, more specifically in the RRD, the Ninh Binh and Hung Yen provinces reached the highest adoption rates, with 10.9% and 10.4%, respectively. In central Viet Nam, the provinces of Da Nang (17%) and Dak Lak (20.2 %) had the most adopters. Notably, in the southeast, Ba Ria Vung Tau province reached the highest adoption rate in the country (37.5%). Neighboring this province is the Binh Thuan province with an adoption rate of 8.3%. As discussed before, the adoption of this technology appears to be associated with provinces that possess a relatively flat area, where this technology is possible to implement.

Figure 25: Laser land leveling adoption rates by province

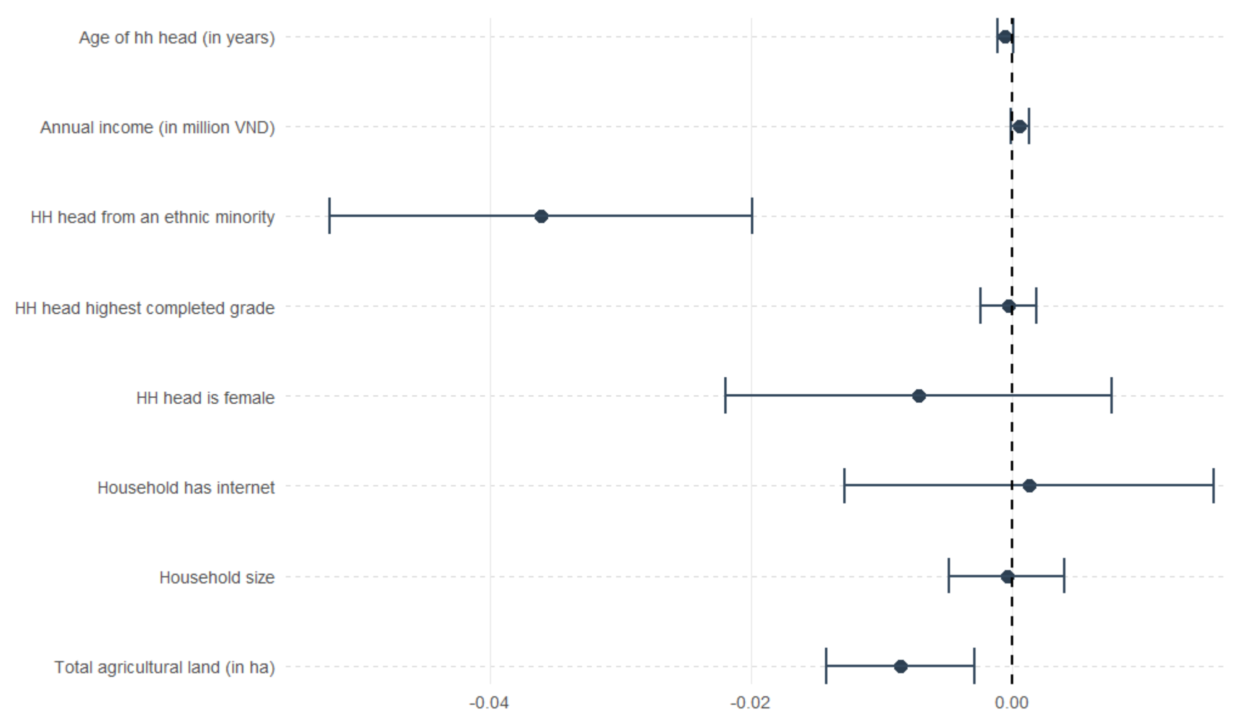


Note: Provinces shown in beige do not have available data.
Data source: VHLSS 2023

Understanding the characteristics of adopters is crucial to identifying the correlates of adoption. A multivariate regression analysis was conducted to explore the relationship between adoption and key socioeconomic factors, including the age, sex, education level, and ethnicity of the household head, as well as household size, internet access, income, and total agricultural land. This analysis helps reveal whether these socioeconomic characteristics increase the likelihood of adopting LLL technology.

Figure 26 presents the point estimates from the LLL regression analysis, along with their 95% confidence intervals. Age of the household head, ethnic minority status, and total agricultural land are negatively associated with the likelihood of adopting LLL technology, while annual household income positively influences adoption. Specifically, if the household head belongs to an ethnic group other than Kinh, the probability of adoption decreases by four percentage points, holding all other variables constant. Additionally, older household heads are less likely to adopt this technology; an increase of ten years in age is associated with a 0.054 percentage point decrease in adoption likelihood. Similarly, each additional hectare of agricultural land corresponds to a one-percentage-point reduction in the probability of adopting LLL. Conversely, a VND 1,000,000 (USD 44) increase in annual household income is associated with a 0.057 percentage point increase in the likelihood of using this technology. The remaining variables were not statistically significant at any conventional confidence level.

Figure 26: Estimated associations between household characteristics and adoption of laser land leveling



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

HH = household

Source: VHLSS 2023

9.2 Combine Harvester

A combine harvester (CBH) is an adaptable agricultural machine designed to harvest crops more efficiently by integrating multiple operations into one. It typically features a cutting platform at the front to cut crop stalks, a reel or auger for feeding the cut crop into the machine, a threshing mechanism to separate grain from stalks and husks, and a cleaning system to remove impurities from harvested grain. As the CBH moves through the field, the cutting platform cuts the standing crop while the threshing mechanism separates the grain from the straw. Cleaned grain is then stored in an onboard tank for transport or further processing.

The use of CBHs has been shown to decrease crop losses significantly. Research indicates that the implementation of these machines can reduce crop loss by approximately 2-4% during the harvesting process, which is crucial for maintaining yield levels and improving overall profitability (Husaini et al., 2021). In addition to reducing labor costs and crop losses, CBHs also contribute to enhanced agricultural productivity. Their efficiency allows farmers to harvest larger areas in a shorter time frame. This is essential during peak harvest seasons when timely harvesting is critical to prevent spoilage and ensure quality (Chandra et al., 2024). Moreover, the introduction of advanced technologies in CBHs, such as automated monitoring systems, enhances their operational efficiency and reliability. These innovations allow for better management of harvesting parameters, ensuring that the machines operate at optimal levels, which further minimizes losses and maximizes output (Jiang et al., 2022).

The efficiency of CBHs is significantly influenced by field topography. Productivity decreases notably on slopes exceeding 2º due to uneven loading of the cleaning system, leading to grain losses of up to 3.5% on a 5º slope, with the cleaning system accounting for approximately 60% of all losses (Belinsky et al., 2019). Environmentally, they support sustainable agriculture through their fuel-efficient designs, which reduce ecological footprints. Although they require substantial initial investment and ongoing maintenance, their durability and reliable performance make them a worthwhile long-term investment for agricultural enterprises.

The interviews conducted in Dong Thap province, Hong Ngu district, allow us to better understand the farmers' context and gain more detailed insights into the adoption of CBHs. These interviews suggest that farmers have widely adopted CBHs due to their efficiency and cost-effectiveness compared to manual harvesting. All farmers that were interviewed, have been using CBHs for ten years or more, appreciating that they effectively cut and separate grains, reducing the risk of missed panicles and unseparated grains, which is more common with manual methods. The cost of renting one, typically around VND 150,000 (USD 6.6) per 1,000 square meters, is also more economical than manual harvesting, which ranges between 200,000 (USD 8.8) and VND 300,000 (USD 13.2). While CBH benefits are clear, some farmers claimed that grain losses are larger than those resulting from manual methods. According to the farmers, this might be addressed by more careful operation of these machines. Nevertheless, the consensus among farmers in the area is that CBHs are the preferred method, especially given the challenges in securing sufficient labor for manual harvesting.

The history of CBHs in Viet Nam reflects a process marked by challenges and significant advancements. In 1977, Viet Nam imported five Russian CBHs. They each weighed 11 tonnes, so struggled with the country's soft soil conditions. Subsequent efforts between 1980 and 1999 by research institutes and provincial factories to develop local models faced similar issues, including frequent breakdowns and extended repair times. However, with Viet Nam's economic growth from 2000 onwards and increasing rural labor shortages, interest revived. Despite initial setbacks, around fifteen small-scale local manufacturers attempted to produce CBHs, yet widespread adoption was hindered by persistent challenges with soft soils, lodged crops, and machine reliability.

From 2006 onwards, the number of CBHs in Viet Nam experienced rapid growth, driven by five annual contests organized by MARD from 2006 to 2011. These contests assessed CBHs on criteria such as field capacity, losses, paddy cleanliness, reliability, harvesting cost, and stability. They spurred significant improvements in design and performance, leading to an influx of imported Chinese models until 2009. As a result of these contests, most began adopting rubber tracks for improved mobility on soft soils. Despite advancements, concerns over machine reliability persisted, opening the market for the Japanese Kubota combine, which emerged as a dominant player by 2014, constituting approximately 85% of the combined market in Viet Nam (Gummert et al., 2013; Hien, 2021; Hien & Nghi, 2016; Sakata, 2020).

In July 2023, MARD partnered with the IRRI to host a field demonstration in Vi Thuy district, Hau Giang province, focusing on mechanizing rice straw collection and processing. This event attracted over 500 participants, including rice farmers from the MRD. An array of technologies including CBHs were showcased by various agricultural machinery companies and research institutes. These included the Center for Research and Transfer of Science and Technology of Nong Lam University (IRRI, 2023).

The adoption rate, defined by CGIAR, includes households whose fields were harvested using a CBH rented through a cooperative or service provider. Adoption increased significantly at the national level, rising from approximately 5,091,000 households (65.4%) in 2022 to 5,621,000 households (74%) in 2023. This marks an 8.7 percentage-point increase.

Adoption rates varied widely across regions, ranging from 35.6% in the North Mountainous Areas to 97.4% in the Southeast Region in 2023. Moreover, adoption rates increased across all regions between 2022 and 2023. Three regions saw larger increases: the Red River Delta, Central Coast, and North Mountainous Areas regions experienced increases of 13.6, 11, and 6.2 percentage points, respectively.

It is worth noting that despite these three regions experiencing similar increases, they started from very different adoption rates in 2022. This contrasts with the theory that adoption rates typically follow an S-shaped function[83], where after an initial rapid growth phase, the rate of adoption slows during the later phase. This decline can be attributed to factors such as market saturation, diminishing returns from technology, and various adoption barriers. Farmers in the latter stages of adoption may encounter more constraints, including limited financial resources, inadequate infrastructure, and resistance to change.

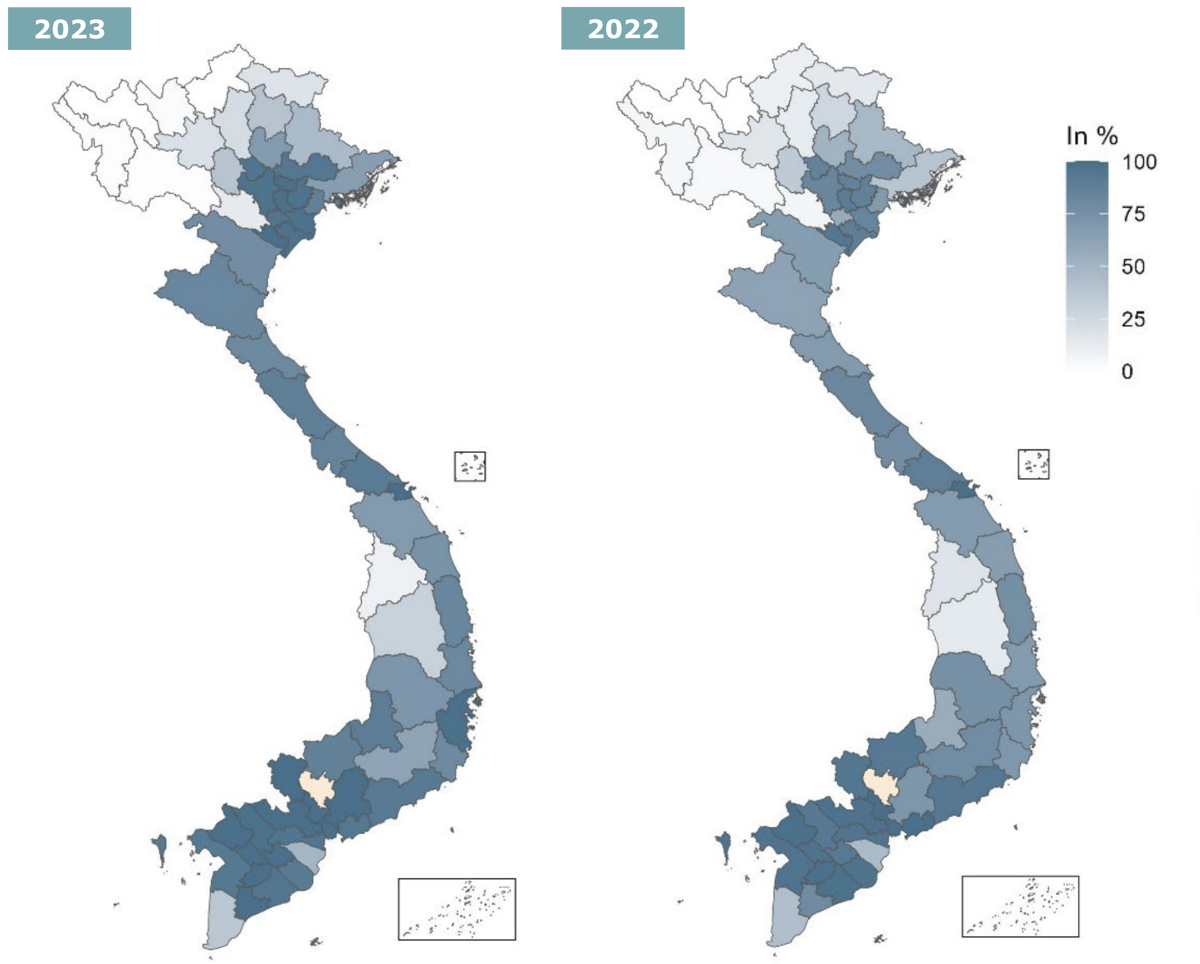
On the other hand, at the EA level (Table 7), statistically significant increases in adoption rates were observed in the Red River Delta, Central Coast, and Central Highlands regions. Particularly

[83] The S-curve theory of technological adoption describes the typical pattern of how new technologies spread through a population over time. Initially, adoption is slow as innovators and early adopters begin using the technology. This is followed by a rapid increase during the growth phase as more individuals adopt, and finally, it levels off as the market reaches saturation.

noteworthy was the Central Highlands region, which experienced an increase of 22 percentage points, indicating a geographical expansion in these areas from 2022 to 2023. Conversely, examining MRD reveals a different scenario. In this region, neither the intensity nor the geographical adoption rates increased (statistically significant) between 2022 and 2023, suggesting potential market saturation or existing barriers preventing further adoption among remaining farmers.

In terms of geographical adoption (Figure 27), high and moderate adoption rates (above 50%) can be observed across the country, with some exceptions in the Northwest, parts of the Northeast regions, and the Central Highlands, which are the three most mountainous regions. A cluster of provinces with full adoption rates in 2023 is found in the MRD and Southeast provinces. In central Viet Nam, the most notable case is Thanh Pho Da Nang, with a full adoption rate in both 2022 and 2023. Following this province, two neighbors stand out: Thua Thien Hue, with adoption rates of 91.2% in 2023 and 88.6% in 2022, and Quang Tri, reaching 84.6% and 77.4% in the two years.

Figure 27: Combine harvester adoption rates by province

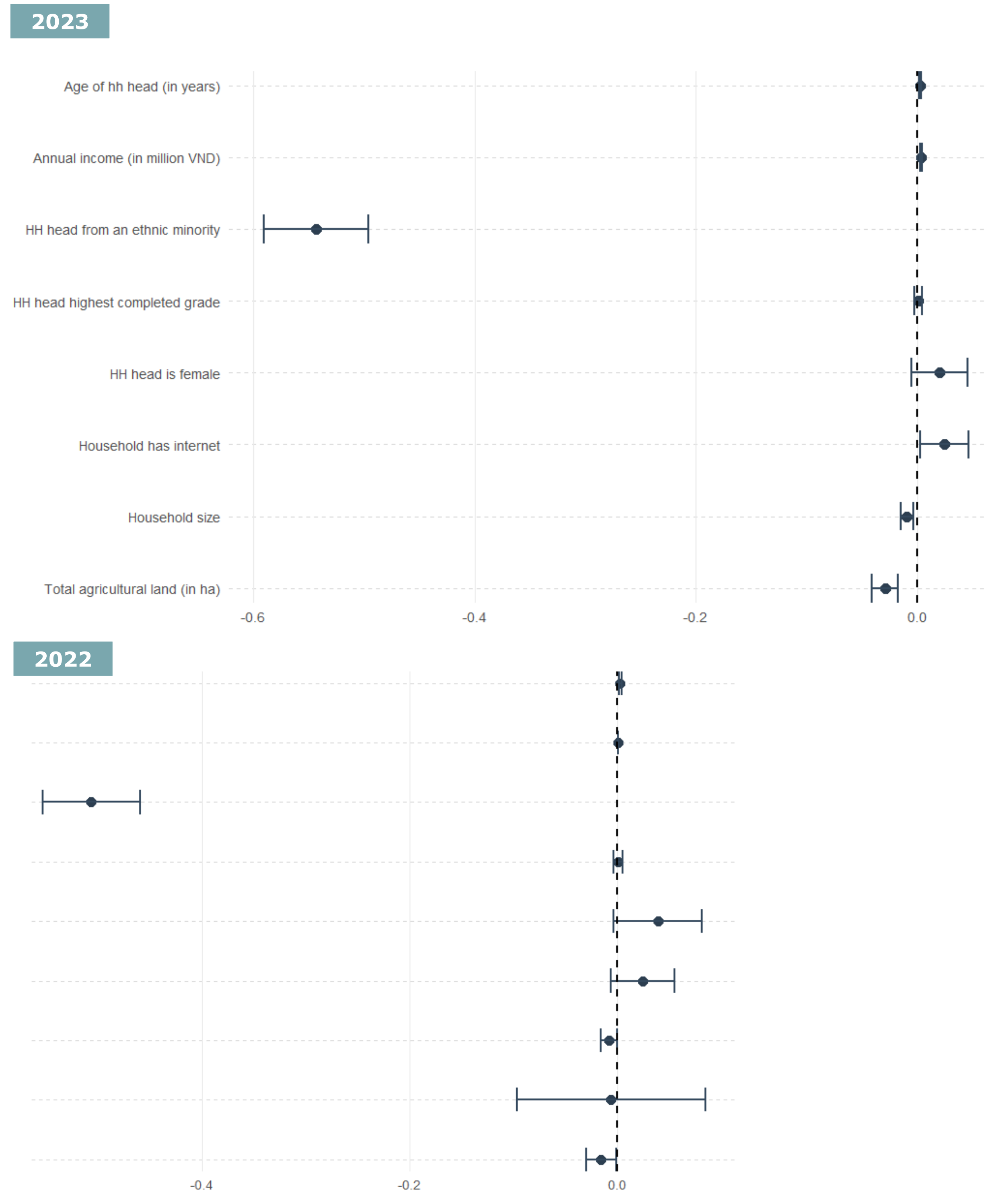


Note: Provinces shown in beige do not have available data.
Data source: VHLSS 2023 & VHLSS 2022

Figure 28 presents the estimated coefficients for CBH adoption, offering insights into how specific characteristics influence the likelihood of adoption. The analysis shows that all studied characteristics, except education level, are statistically significant in relation to adoption. If the household head is female, the household is 2% more likely to adopt a CBH. Conversely, belonging to an ethnic minority decreases the probability of adoption by 54%. Older household heads are more likely to adopt, and internet access increases the likelihood of adoption by 2.5%. Adding one additional household member reduces the probability by 0.9%. If farmers extend their fields by a hectare, they are 29% less likely to adopt a CBH.

The 2022 point estimates indicate that ethnicity, age of the household head, household size, annual income, and agricultural land are associated with CBH adoption. All variables maintain similar magnitudes to the 2023 results, except for agricultural land, where each additional hectare corresponds to a three percentage point decrease in the likelihood of adoption. Notably, compared to other innovations where annual household income plays a significant role, its impact here is considerable, suggesting that financial constraints may be one of the primary barriers to adopting this machinery.

Figure 28: Estimated associations between household characteristics and adoption of combine harvesters



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

Source: VHLSS 2023

9.3 Mini-Combine Harvester

The mini-combine harvester (MCBH) is a compact version of the standard model, tailored to meet the needs of smallholder farmers and fields with limited space. Despite their smaller size, they efficiently collect crops. In Viet Nam, their introduction addressed various challenges encountered by traditional models in adapting to the country's diverse topographies and soil conditions. Standard CBHs often face issues such as sinking into soft soils due to their weight, difficulties in harvesting lodged rice, and reliability concerns. In contrast, the lightweight design of the MCBH, typically weighing around 600 kg, powered by 12-hp diesel engines, and equipped with a 1.3 m cutter bar, enables them to navigate Viet Nam's irregular terrains effectively (Hien, 2021; Justice et al., 2021)

The MCBH offers several distinct advantages over a standard model for smallholder farmers. First, due to their smaller size, they are more versatile and adept at accessing confined areas and uneven terrain. Second, they are more cost-effective for farmers with constrained budgets, both in terms of initial purchase and ongoing expenses. Third, their adjustable wheel types enable them to operate effectively across diverse soil conditions in Viet Nam's agricultural landscape, ensuring reliable and efficient crop collection (Justice et al., 2021). Additionally, they require less maintenance and consume less fuel, further reducing operational costs. Because of their smaller size, they efficiently handle smaller-scale harvesting tasks, empowering small-scale farmers to successfully gather their crops without reliance on larger-scale technology.

Adoption of this innovation includes households that utilized an MCBH that meets specific criteria: 600 kg with a 1.3-m cutter bar and a 16-HP engine, available for ownership or rental through a cooperative or service provider. In 2022, approximately 800,300 households in Viet Nam adopted this machine, representing an adoption rate of 10.3% (Table 9).

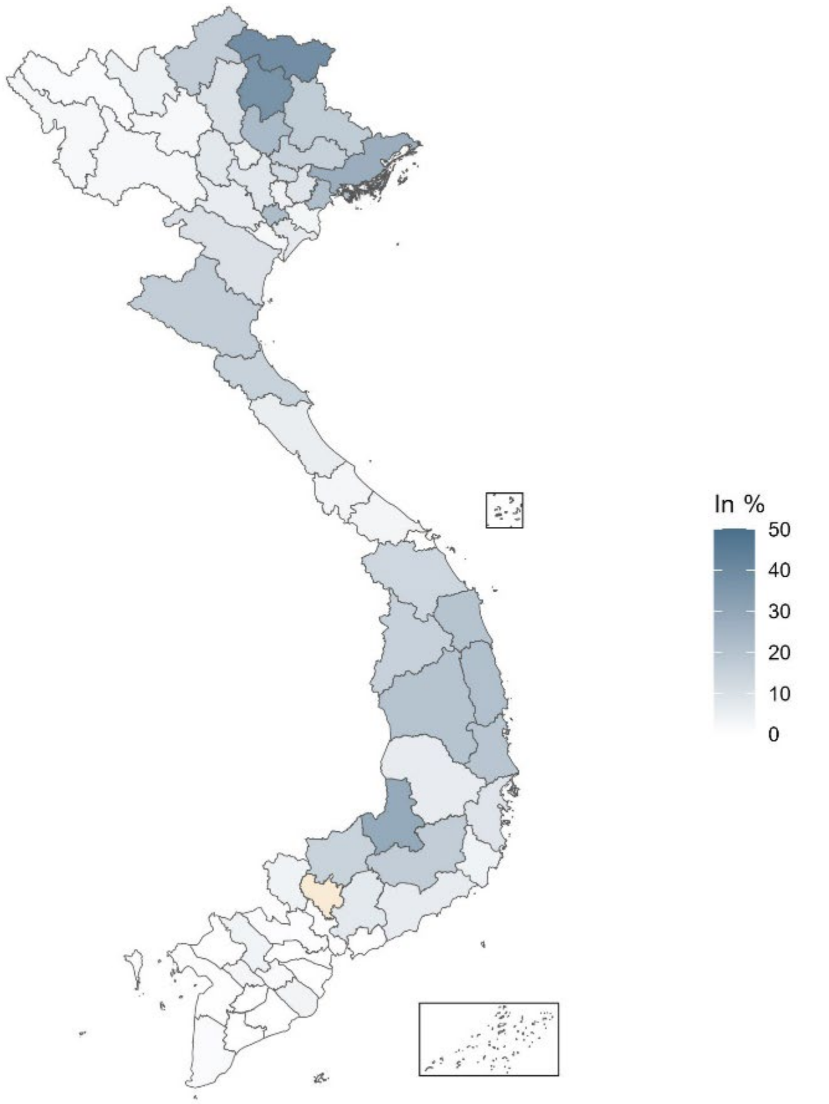
Examining regional adoption rates at the household level reveals considerable variation, with rates ranging from 1.2% in MRD to around 13% in the Central Highlands, Central Coast, and North Mountainous Areas. The topographic conditions in these latter regions make the MCBH particularly suitable, likely explaining its higher adoption rate. In contrast, the lower adoption rate in MRD can be attributed to the widespread use of regular CBHs in this region.

At the EA level, the regions with the widest geographical adoption of the MCBH are the Central Highlands and North Mountainous Areas, with rates of 45.4% and 40.5%, respectively. Although the Central Coast has one of the highest adoption rates at the household level, its adoption rate at the EA level is lower (27%). This suggests that while the intensity of adoption in the Central Coast is comparable to that in the Central Highlands and North Mountainous Areas, its geographical spread is more limited. The relatively lower adoption rate of this machine can be attributed to various factors beyond the substitution effect between the MCBH and its larger model. These factors include limited access to providers and cost-effectiveness, which are viable only in specific regions of Viet Nam.

Figure 29 illustrates the adoption rates of the MCBH, with distinct clusters emerging in the Central Highlands, South Central Coast, and Northeast regions. Cao Bang province, in the North Mountainous Areas, stands out with the highest adoption rate, where 38.7% of farmers used an MCBH in 2022. In the same region, Bac Kan, Quang Ninh, and Thai Nguyen provinces ranked among the highest adoption rates in the country with 37%, 27.2%, and 22.9%, respectively.

In the Red River Delta region, provinces Ha Nam and Hai Phong city notably reached adoption rates of 22.1% and 21.3%, respectively.

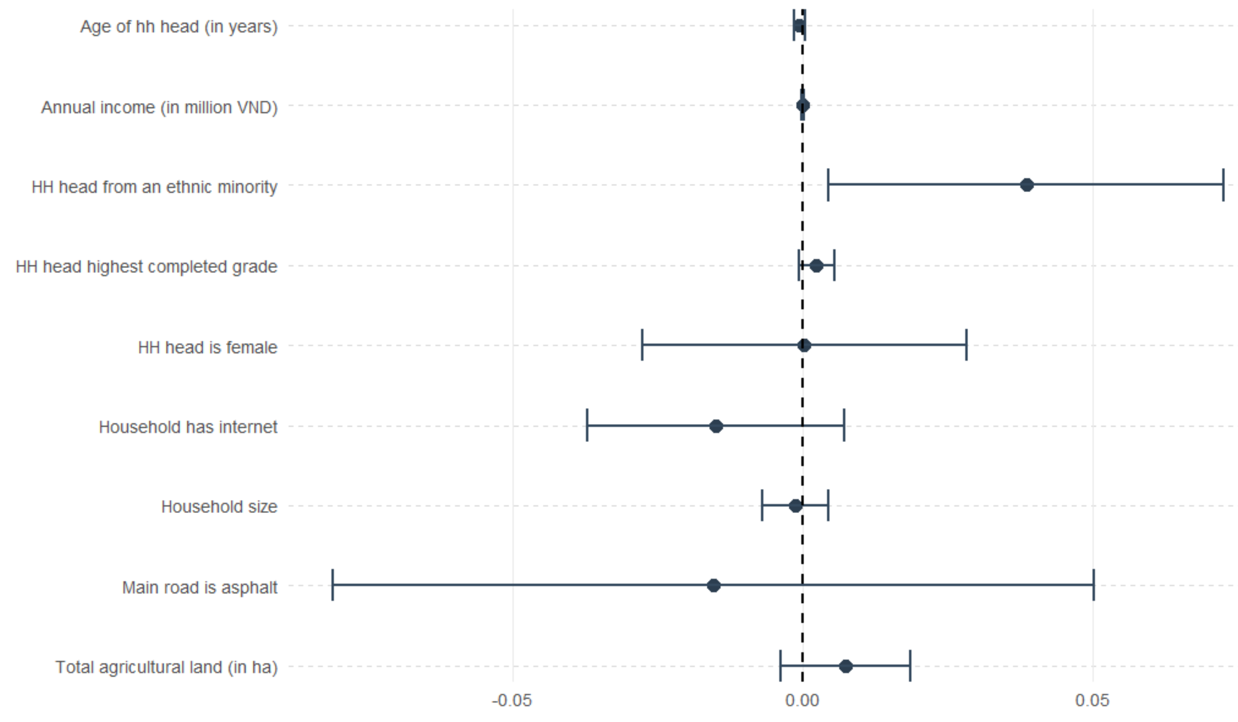
Figure 29: Mini-combine harvester adoption rates by province



Note: Provinces shown in beige do not have available data.
Data source: VHLSS 2022

The point estimates for the MBCH multivariate regression, along with their confidence intervals, are presented in Figure 30. When the effects of all characteristics are considered simultaneously, only the ethnicity of the household head has a statistically significant effect on the adoption of this machinery. In households where the head belongs to an ethnicity other than Kinh, the probability of adoption decreases by 3.84 percentage points.

Figure 30: Estimated associations between household characteristics and adoption of mini-combine harvesters



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

HH = household

Source: VHLSS 2022

9.4 Rice Straw Baler

In Asia, the annual growth in rice and straw production to meet demand presents ongoing challenges in straw management. Across South and Southeast Asia, the burning of rice straw contributes significantly to hazardous air pollution levels, posing health risks. To tackle this issue, stakeholders including scientists, engineers, and the private sector are actively developing various applications for rice straw, aiming to establish sustainable value chains that benefit farmers in the long term. Following harvest, rice straw bundles must be compressed into bales for efficient transportation. The widespread adoption of combine harvesters (CBHs), which often leave straw in the fields, has compounded the difficulty and cost of straw collection (Gummert et al., 2020).

The increased use of CBHs has driven up straw collection costs. High labor expenses and labor shortages make manual collection impractical for many farmers, leading them to resort to burning straw. This practice, while economically rational for farmers, exacerbates pollution and greenhouse gas emissions. Some authors also point to missed value-added opportunities (Nghi et al., 2015).

A rice straw baler (RSB) is specifically designed to gather and compress straw into dense bales suitable for storage, transport, and various uses such as livestock feed or bedding. Straw is gathered from the field either by a baler attachment or in tandem with a CBH during harvest. Then a pickup mechanism collects the straw and feeds it into the baling chamber, where a plunger or piston compresses it until tightly packed. The baling chamber is equipped with knotters or twine mechanisms that secure the bale with twine or wire once fully compressed. The finished bale is then ejected onto the ground or a trailer for transport and storage. Farmers can adjust the size and density of the bales to meet specific needs, providing a convenient and effective solution for managing straw harvests.

The introduction of RSBs in 2014 greatly facilitated the collection of straw following combine harvesting. In 2016, a seminar and technology demonstration on gathering and treating rice straw was held in Can Tho City, organized jointly by the Vietnamese National Extension Center, Nong Lam University, and IRRI. The event attracted participation from local manufacturers and imported baler dealers, who conducted field measurements using four different balers on a typical field yielding 4.6 tonnes of straw per hectare (Hien, 2021).

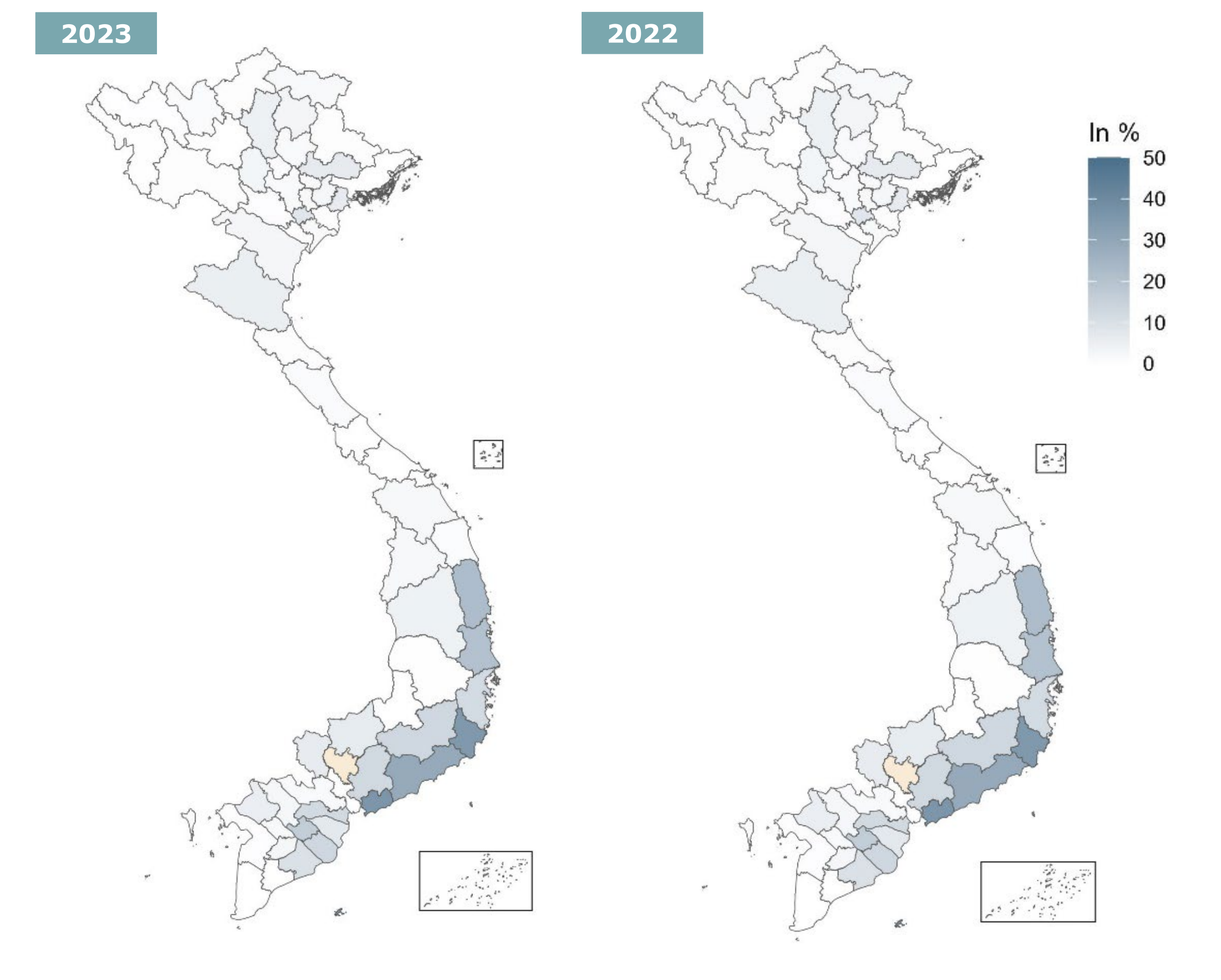
In July 2023, to advance the mechanization of rice straw collection and processing technologies, MARD collaborated with IRRI to organize a field demonstration on rice straw management. This event, held in Vi Thuy district, Hau Giang province, promoted circular and low-emission agriculture. Various agricultural machinery companies and institutes, such as the Center for Research and Transfer of Science and Technology of Nong Lam University, presented a variety of technologies. These included RSBs suitable for both wet and dry fields, CBHs, and sustainable farming practices such as rice straw composting, mushroom production, organic farming using rice straw compost, bio-bedding for livestock, and the production of rice straw pots as a bioplastic alternative (IRRI, 2023).

In 2022, the adoption rate of RSBs in Viet Nam was 2.7%, meaning that around 207,600 households used this machine. This rate increased by 1.4 percentage points in 2023, reaching 4% - approximately 303,600 households (Table 9). At the regional level, household adoption rates in 2022 showed little variation, ranging from 0.7% in the North Mountainous Area to 5.3% in the Southeast Region. In 2023, there was a notable increase in adoption rates in the Southeast Region (7.8 percentage points) and the Central Coast (2.9 percentage points), both of which were statistically significant. Conversely, the Central Highlands experienced a statistically significant decrease in its adoption rates (1.9 percentage points), while the Red River Delta saw no significant change. At the EA level, adoption rates in 2022 varied from 3.7% in the North Mountainous Areas region to 15.2% in the Southeast Region. Although several regions experienced increases in adoption rates in 2023, none of these changes were statistically significant, indicating no substantial geographical expansion during this period.

Beyond lack of knowledge, another potential barrier to adopting this innovation could be the rising costs of renting these machines. With the increased use of CBHs, the cost of gathering straw has been on the rise (Nghi et al., 2015). Moreover, additional costs for selling RSBs can arise due to transportation. For instance, they are transported 100 km from Vinh Hung district to Tan An city using a 10-tonne vehicle capable of carrying 400 bales. The estimated transportation cost is approximately USD 24.0 per tonne (Nghi et al., 2015).

The distribution of RSB adoption rates by province is shown in Figure 31.

Figure 31: Rice straw baler adoption rates by province

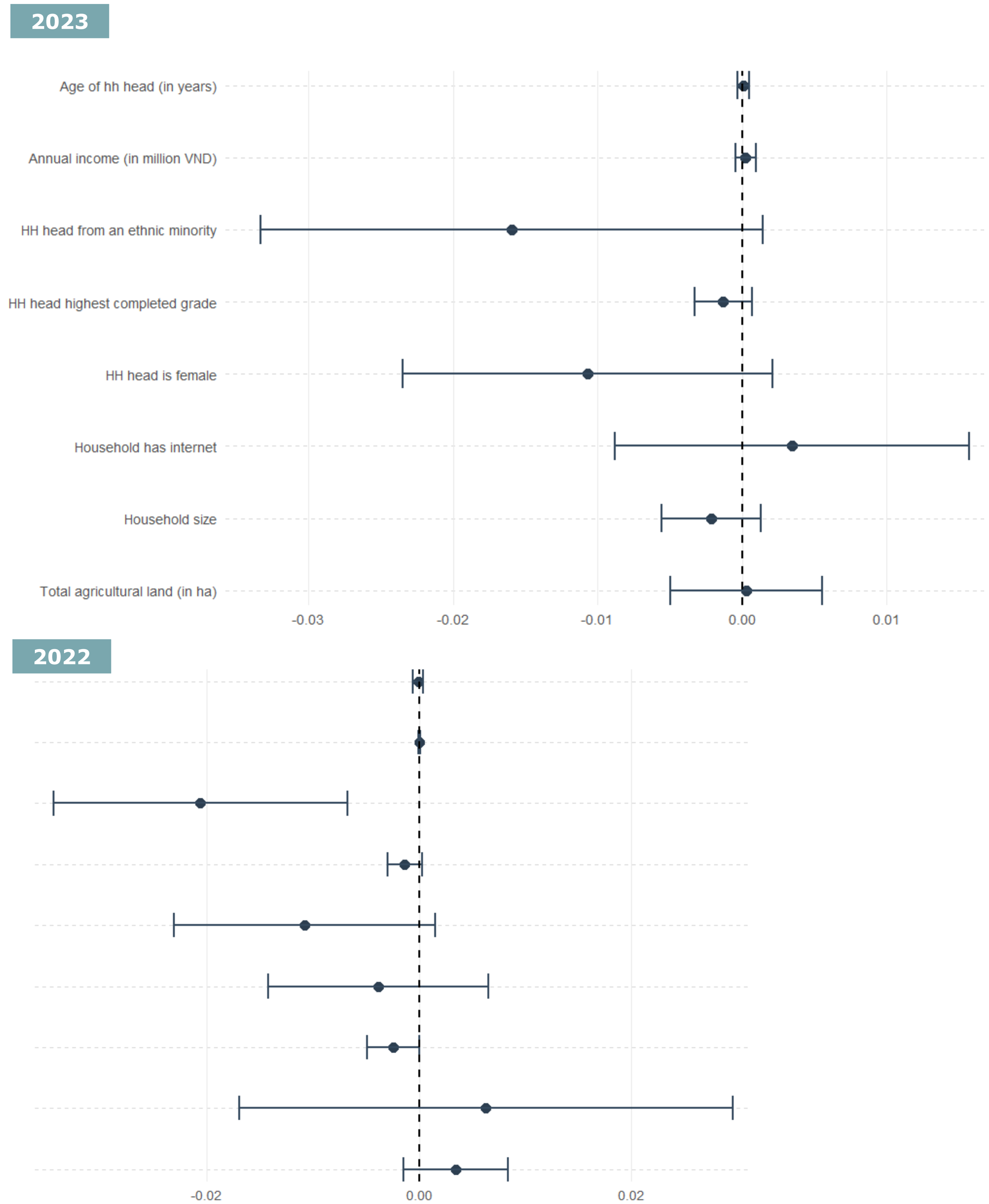


Note: Provinces shown in beige do not have available data.
Data source: VHLSS 2023 & VHLSS 2022

The maps reveal that most provinces in northern Viet Nam have adoption rates below 10%, while a cluster of provinces in the South Central Coast and Southeast Regions show significantly higher rates. Specifically, Ba Ria - Vung Tau in the south east has the highest adoption rate in 2023, with 35.8% of households adopting this innovation, despite having a zero-adoption rate in 2022 – an interesting shift in RSB adoption for the province. Following Ba Ria - Vung Tau, Ninh Thuan and Binh Thuan provinces to the north have adoption rates of 34.9% and 28.5%, respectively. Further north in the South Central Coast region, Binh Dinh and Phu Yen also exhibit relatively high adoption rates, with 22% and 20.3% of households, respectively, having adopted this innovation.

The multivariate analysis exploring the characteristics associated with RSB adoption in 2022 reveals two statistically significant factors. The likelihood of adoption decreases by 1.1% if the household head is female. Additionally, if the household head belongs to a non-Kinh ethnicity, the probability of adopting an RSB is 2.1% lower. The same analysis for 2023 indicates that only the ethnicity of the household head is significantly associated with RSB adoption; households with a head from a non-Kinh ethnicity were 1.6% less likely to adopt this technology (Figure 32).

Figure 32: Estimated associations between household characteristics and adoption of rice straw baler



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

HH = household

Source: VHLSS 2023

10. Sustainable Intensification Practices

The stocktake identified 22 innovations related to Sustainable Intensification (SI) practices. These innovations enhance or maintain agricultural productivity while minimizing negative environmental impacts.

This section documents the reach of five innovations: ‘Three Reductions, Three Gains’ (3R3G) and ‘One Must Do, Five Reductions’ (1M5R); Alternate Wetting and Drying (AWD); Drum Seeder, Off-field Straw Management; and Sustainable Water Use for Coffee Production. Nationally representative data on these innovations were collected in the VHLSS 2022 and 2023. Consult the stocktake for more information regarding innovations not included in this section[84].

10.1 ‘Three Reductions, Three Gains’ and ‘One Must Do, Five Reductions’

The roots of ‘Three Reductions, Three Gains’ (3R3G) can be traced back to the mid-1990s, when initiatives were launched to persuade farmers to refrain from using pesticides during the initial 40-day period following seed planting. IRRI developed the Integrated Pest Management (IPM) framework, which gained popularity through the 'No Early Spraying' (NES) mass media initiative in the late 1990s (Huan et al., 1999).

In 2001-2003, IRRI conducted on-farm research in Can Tho, Tien Giang, and Vinh Long provinces to assess the extent to which seed and fertilizer use could be reduced. Subsequently, research sites established in 11 provinces of MRD showed that reducing the use of seeds, fertilizers, and insecticides, had little effect on yield and allowed farmers to earn about USD 35 per hectare more in the Summer-Autumn season and USD 58 per hectare more in the Winter-Spring season. This increase in profit margin from rice production was mainly attributed to the reduced costs of insecticides and fungicides while the contribution from fertilizer costs was small (Huan et al., 2005). The information that reducing inputs can enable farmers to earn higher profits was certainly in conflict with their beliefs; therefore, it was considered important to spread awareness. The dissemination of 3R3G began in Can Tho Province in March 2003. Improved crop management under this approach was communicated as leading to three gains: healthier plants; higher production levels; and higher economic efficiency for farmers (due to reduced input costs and increased yield.)

In accordance with the 2005 MARD technical document, the dissemination of 3R3G was expanded, with funding allocated to all provinces. The dissemination occurred through various means, including extension activities, campaigns, and diverse mass media formats, such as television and radio dramas, visual aids, public demonstrations, farmer-focused events, and loudspeaker announcements.

[84] These include: Site-Specific Nutrient Management (SSNM), drum seeders, mechanical transplanters, Women's Village Savings and Loan Associations (VSLA) in coffee-based agroforestry systems, ecosystem-based adaptation (EbA) practices, sustainable coffee and black pepper value chains, sustainable cassava management practices, silage technology and vine-cutting machines, groundnut management practices, community-based soil erosion management, innovative agricultural value chain financing (AVCF), Managed Aquifer Recharge (MAR) techniques, Companion Modeling (ComMod) for resilient water management, water storage infrastructures (WSIs), seasonal calendars for nutrition, innovations in fruit and vegetable intake, and integrated vegetable seed systems.

The ‘One Must Do, Five Reductions’ (1M5R) approach represents an update to the 3R3G approach. It was formulated during Irrigated Rice Research Consortium (IRRC)'s Phase IV (2008-2012) and has been enhanced by several International Rice Research Institute (IRRI) research initiatives, including the Closing Rice Yield Gaps in Asia program (2013-16 and 2017-20). To adhere to 1M5R guidelines, farmers must utilize certified seeds (One Must Do) and decrease seed quantities, nitrogen fertilizer usage, pesticide application, water consumption, and post-harvest waste (Five Reductions). This innovation aims to maximize rice productivity while minimizing the environmental impact of its cultivation.

The 1M5R program, first implemented in An Giang province, was acknowledged by MARD as a technical advancement through the Decision 532-QD-TT-CLT[85] in 2012. This recognition ensured that subsequent national policies for lowland rice cultivation included the promotion of the 1M5R package as an objective. While MARD oversaw the policy direction at the national level, provincial DARDs were tasked with implementing 1M5R extension and governance locally.

Tracing the history of 3R3G and 1M5R, we have attempted to understand why these innovations were formulated as a package. This is possibly due to two common reasons. First, technological packages were developed as a result of interdisciplinary researcher collaboration – ranging from agronomists to economists - and policymakers. It is not economical to disseminate these innovations as single recommendations, especially in remote rural villages (Leathers & Smale, 1991). Second, to achieve a specific expected outcome, there must be interactions between components of a bundled package – a single innovation alone cannot bring about an expected yield rate (Ryan & Subrahmanyam, 1975). This reasoning follows from our tracing of the evolution of agricultural packages: IPM was first introduced in the 1990s; initial research on 3R3G, Sustainable Rice Intensification (SRI), and AWD was carried out in Viet Nam in the early 2000s; the promotion of 1M5R started in 2008, and Vietnamese Good Agricultural Practices (VietGAP) was introduced in 2010. Indeed, 3R3G aimed to lower inputs without compromising yields, and then 1M5R aimed to achieve the country’s ambitions for reducing GHG emissions (World Bank, 2023). 1M5R also complements the government’s transformative model of ‘Small Farmers, Large Fields’ (‘Large Field Model’) in the MRD, signaling a transition from a focus on the quantity of rice produced, to its quality and added value, for high-quality export markets (Thang et al., 2017, as cited in Stuart et al., 2018). Of all these innovations, 3R3G/1M5R and AWD were developed through the research efforts of CGIAR whereas SRI and VietGAP were not.

At the end of each year, provincial DARDs issue an agricultural plan that establishes production targets for the forthcoming year. The plan provides advice and recommendations for farmers regarding which rice varieties to plant, which potential pests and diseases to look out for, schedule guidance on water management, and recommended planting dates. These plans then filter down to inform the work carried out by commune-level agriculture extension workers. We analyzed these documents to identify recommendations related to 3R3G/1M5R requirements. This helps us understand the extent to which they may have been disseminated by extension services.

In the maps in Figure 33, we color a province blue if its agricultural plan mentions either of the two packages. The maps on the left indicate whether the packages were mentioned at least

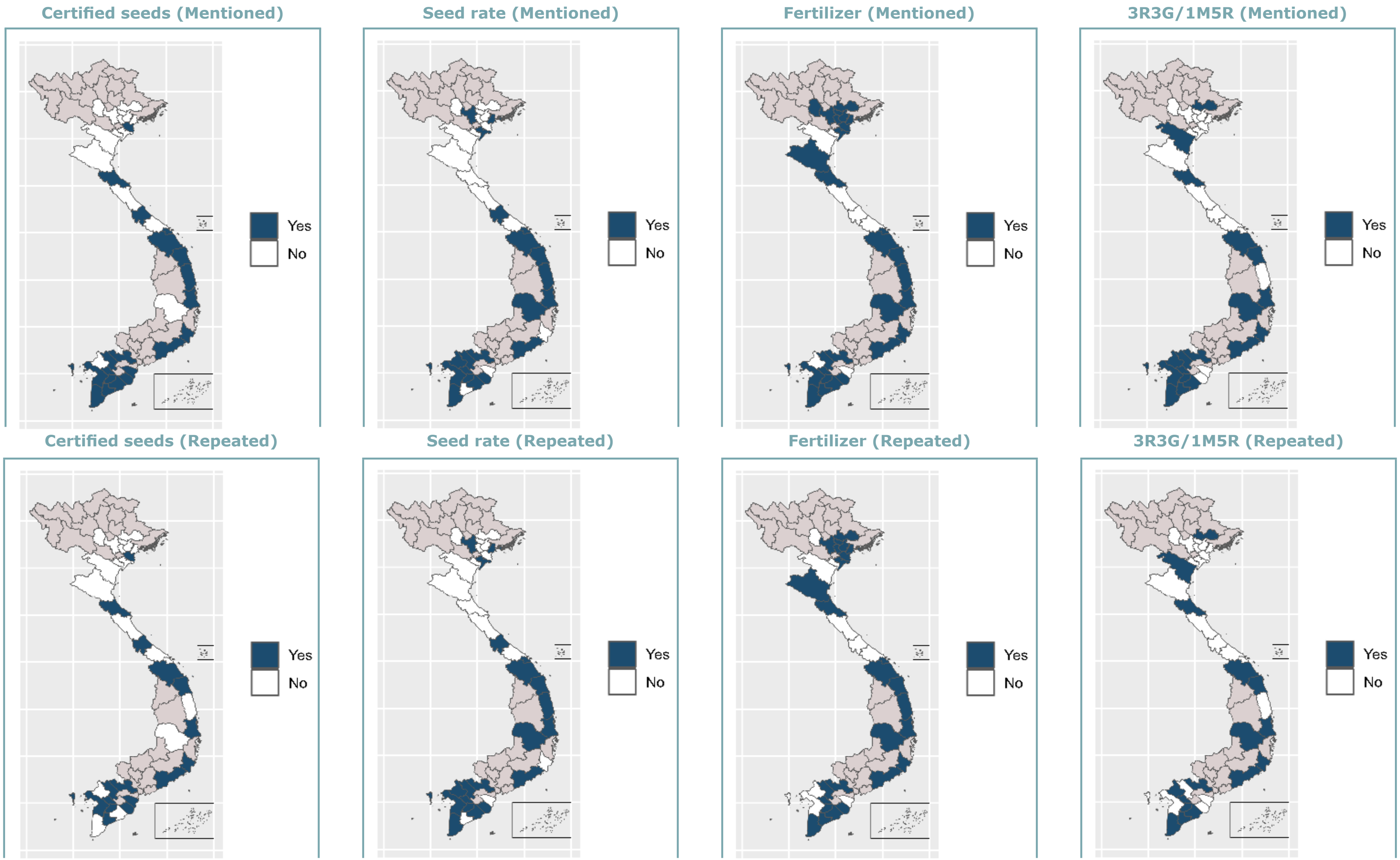
[85] Decision No. 532/QD-TT-CLT dated November 7, 2012 recognizes "1 Must 5 Reductions" as a technical advance.

once during 2020 to 2024, while the maps on the right show whether the mention is repeated across years.

First, it is clear that the majority of provincial plans consistently reiterate these requirements, indicating a persistent and pronounced emphasis on these practices. Second, there are regional differences. In general, we are more likely to see frequent references to 3R3G/1M5R requirements in MRD and SCC regions. In contrast, the agricultural plans of most provinces in the NCC region do not mention input use at all. Third, certain reduction practices have received relatively less attention in agricultural plans. This is particularly evident in provinces within RRD, where certified seeds and seed rate reductions are rarely mentioned in agricultural plans.

Overall, these maps demonstrate that the 3R3G/1M5R package recommendations have been institutionalized and are still part of agricultural planning ten years after the launch of 1M5R. These packages have likely benefited from extensive dissemination efforts throughout the country.

Figure 33: Vietnamese provinces referencing 1M5R/3R3G components in agricultural plans



Data source: Agriculture plans in 37 provinces in Viet Nam (2020-2023).

The literature on the adoption of 1M5R and 3R3G in Viet Nam mostly focuses on specific districts of MRD.

Huelgas et al. (2008) conducted focus group discussions and key informant interviews with close to 200 farmers, officials, and seed growers in An Giang and Can Tho in 2006. They claim that 80% of farmers across the two provinces were aware of 3R3G through media campaigns and traditional extension work. They estimate that consequently, farmers reduced seed rates by 45% in An Giang and 34% in Can Tho. They also estimate that 35% of farmers in An Giang and 25% in Can Tho reduced fertilizer use, and 39% of farmers in An Giang and 24% in Can Tho reduced pesticide use. Overall, they claim that 53% of farmers in An Giang and 35% in Can Tho implemented at least one 3R3G practice.

In 2011, Thi et al. (2013) interviewed 471 households from six districts in An Giang. They found that trained farmers were more likely to use certified seeds (53%), and to use fewer agricultural inputs, including reduced seed rates, fertilizer, and pesticides, although they do not provide specific estimates of adoption rates. Le et al. (2018)'s study in a cooperative in Hau Giang found that 80% of farmers had progressively reduced their seed rates from 150 to 130 kg/hectare.

Connor et al. (2021)'s surveys in An Giang and Can Tho provinces (n = 465 households) conducted in July 2019 found that 90% of farmers used certified seeds, 86% had reduced seed rates, and 74% had reduced fertilizer and pesticides. Lovell et al. (2021)'s survey of 160 households in Tien Giang conducted in 2015 found that 60% of households adopted practices compliant with IPM recommendations.

Finally, Flor et al. (2021)'s review of the adoption of 1M5R in national policies shows that 1M5R training has been delivered to 104,448 farmers, who in turn have implemented the practice on 113,870 hectares across the eight provinces included in the VnSAT project[86]. A total of 155,780 farmers participated in 3R3G training sessions and adopted this package on 175,442 hectares.

Our attempt to measure the adoption of these innovations among rice farming households in Viet Nam involves new questions we added to the VHLSS questionnaire in 2022 and 2023. We asked farmers about the use of certified seeds, seed rate reduction, and fertilizer reduction. In addition, we also asked farmers if they were following the package by naming it directly (that is, using the Vietnamese words for the terms 'One Must Do, Five Reductions' or 'Three Reductions, Three Gains').

In the following analysis, we provide estimates of the adoption and reach of the 3R3G requirements, followed by an exploration of the geographical distribution of adoption and the characteristics of adopters. We then delve into each of the three reduction components: seed rate, fertilizer, and pesticide use[87].

Figure 34 presents an overview of the percentage of households whose farming practices align with the 1M5R/3R3G recommendations. Certified seeds are the most widely adopted, with 90% of farmers, representing approximately 6.8 million households nationwide, reporting that they planted some certified seeds (lenient criterion) and 70% reporting they planted only certified seeds (strict criterion).

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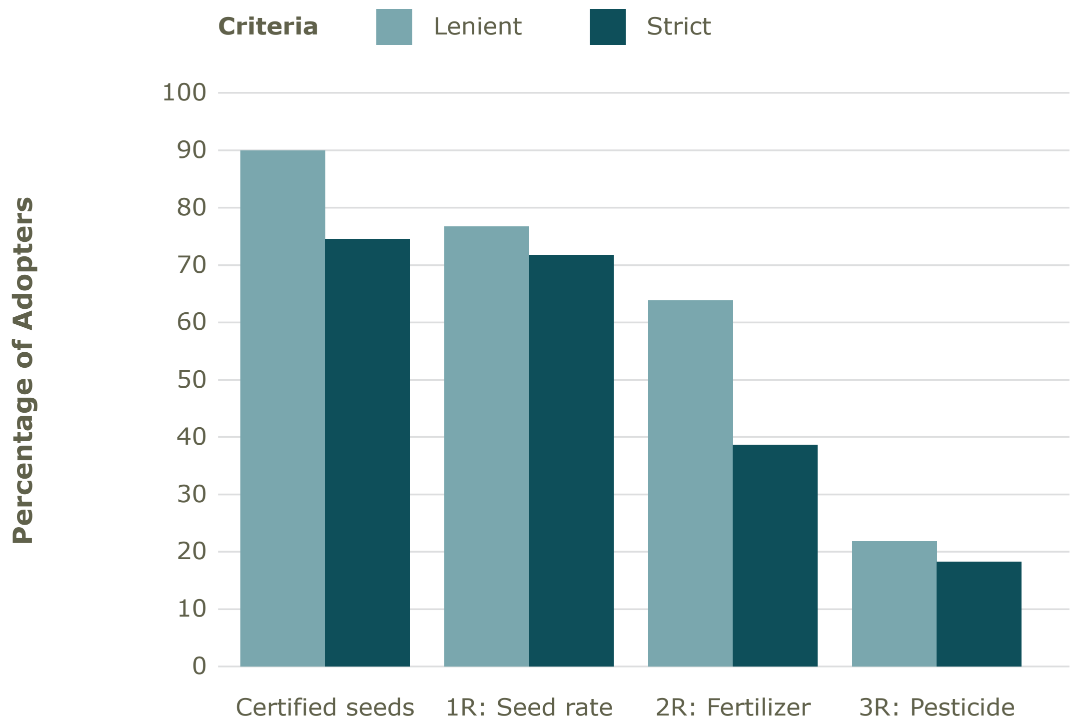
86 These provinces are An Giang, Can Tho, Dong Thap, Hau Giang, Kien Giang, Long An, Soc Trang, Tien Giang.

87 Adoption data on the two additional reductions requirements in 1M5R – AWD and use of a combine harvested – are documented in their respective subsections.

Figure 34: Adoption rates of 1M5R/3R3G practices by lenient and strict criteria in Viet Nam in 2023



Note: Certified seeds (strict): all seeds planted should be certified. Certified seeds (lenient): A combination of certified and farmers' seeds are planted. Fertilizer (strict): Maximum 100 kg of nitrogen is applied per ha, and it is split across at least three applications. Fertilizer (lenient): Maximum 110 kg of nitrogen is applied per ha, and it is split across at least two applications. Pesticide (strict): Maximum of three applications; no applications before panicle imitation or after flowering stages. Pesticide (lenient): Maximum of six applications, no applications before panicle initiation or after dough stages.

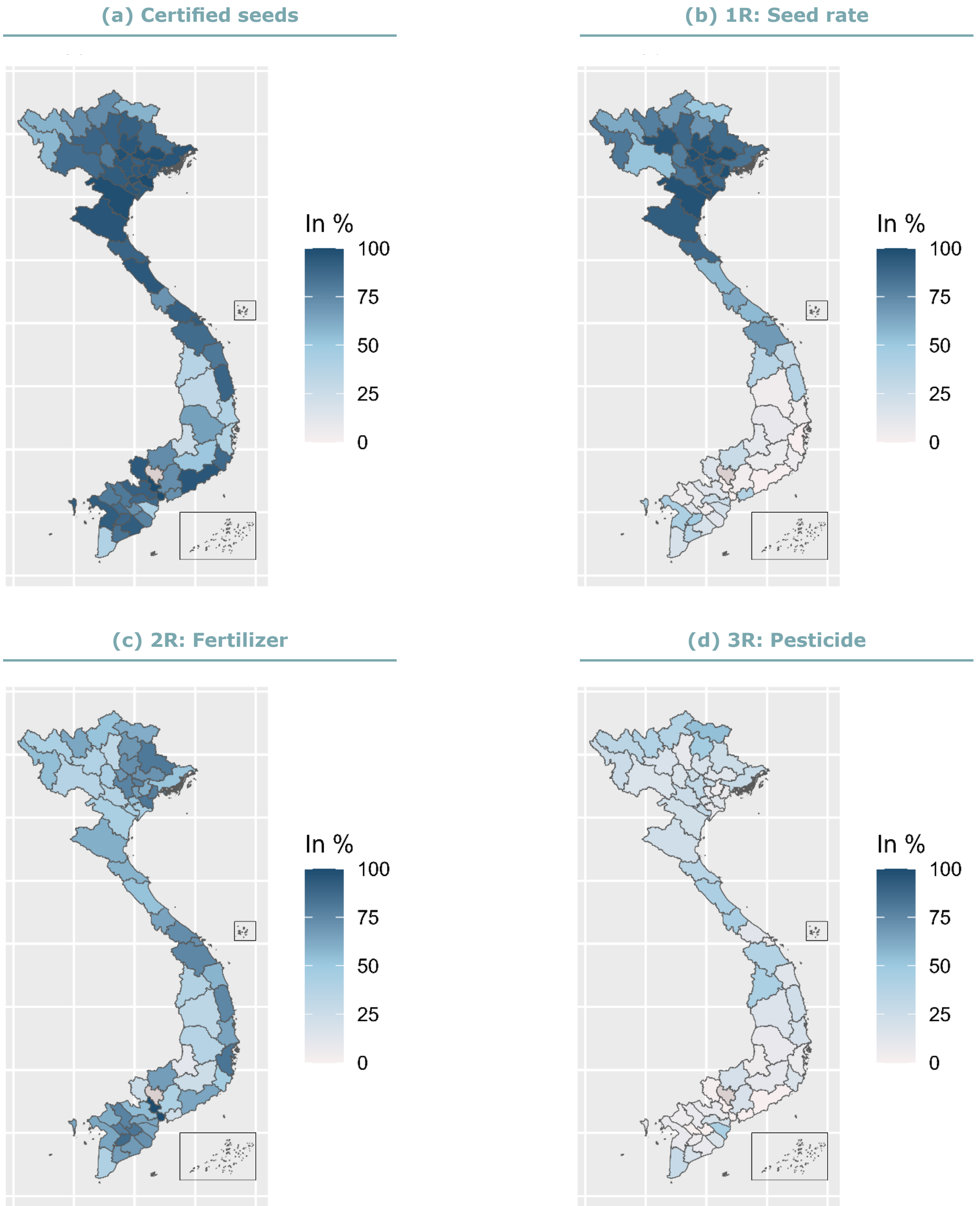
Data source: VHLSS 2023.

Next, around 5.4 million households (63% of rice-growing households) reported following the recommendation to keep the seed rate below 120 kg/ha (lenient criterion). A relatively smaller number (38% under strict standards) of farmers reported they met the fertilizer application guideline. Finally, 21% of households – equivalent to 1.6 million –reported they met the pesticide application guideline. In total, approximately 10.5% of households were implementing all three reduction guidelines, translating to around 787,800 households practicing sustainable rice intensification.

In Figure 35, we map household-level adoption rates by province utilizing the lenient criteria. Certified seed adoption rates are relatively high across the country. RRD and NCC exhibit adoption rates exceeding 75%, followed by MRD and Southeastern regions. Several northern and central provinces demonstrated lower rates. Seed rate patterns displayed the most striking variation across the country, with a notable decline in the adoption rate of the 3R3G/1M5R seed rates guideline as we move from north to south. As we can see, this also means that a lot fewer farmers in the SCC region and parts of MRD follow the seed rate recommendation. This may be related to seeding methods as unlike in the north where transplanting is more common, in the south farmers tend to hand seed, which may make it difficult to monitor seed rates.

The adherence to fertilizer use guidelines is more uniform across the country, although adoption appears to be slightly higher in MRD, RRD, and some central areas. Finally, pesticide requirements are followed in only a few provinces. These are in the Northern Midlands and Mountain Areas (NM) (along the Chinese borders), North Central and Central Coastal Areas (NCCA), and Central Highlands (CH).

Figure 35: Household adoption rates at the province-level for (a) Certified seeds, (b) 1R: seed rate, (c) 2R: fertilizer, (d) 3R: pesticide

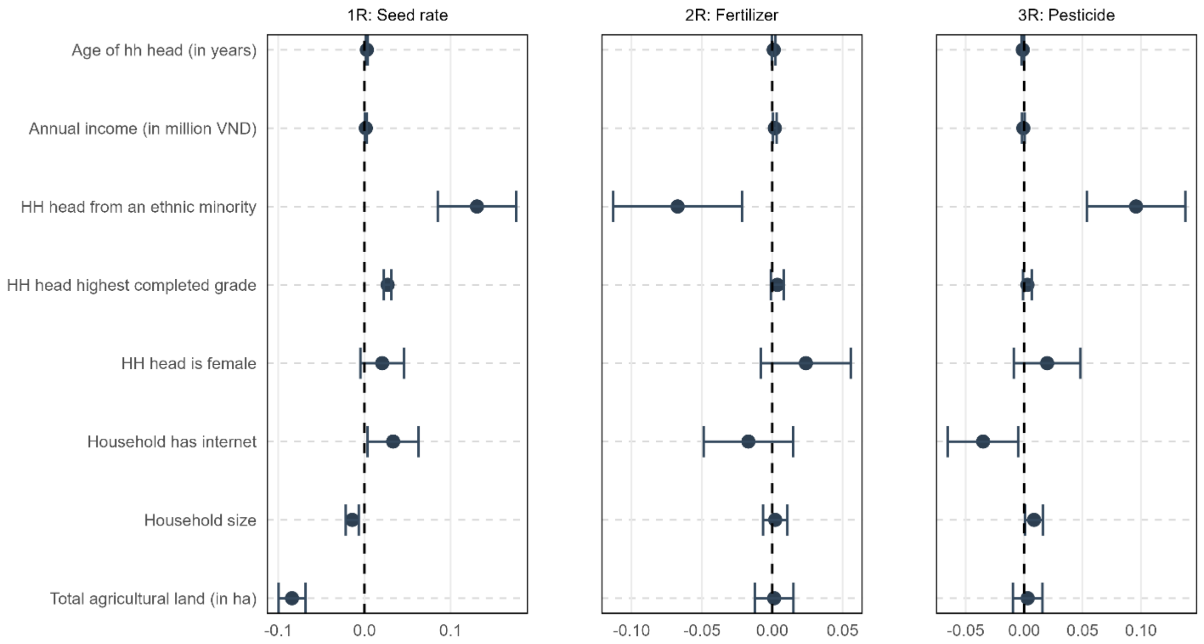


Note: Lenient criteria are used to code adoption of each component.
Data source: VHLSS 2023

Next, we examine adopters' characteristics using ordinary least squares (OLS) regression analysis. Figure 36 presents the estimates derived from these models and their corresponding 95% confidence intervals. The three variables exhibiting the largest effect sizes across all three reductions are household head ethnicity, gender, and access to the Internet.

The results indicate that a household head from the non-dominant Kinh ethnicity is statistically significant in all three models, although the association is positive for seed rate and pesticide use but negative for fertilizer requirements. Household internet access consistently exhibits a positive association with seed rates and a negative association with pesticide reduction.

Figure 36: Estimated associations between household characteristics and adoption of 3R3G components



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines. Lenient criteria are used to code adoption of each component. Coefficients and 95% confidence intervals are estimated from a multivariate regression.

Data source: VHLSS 2023.

10.1.1 Use of Certified Seeds

In Viet Nam, certified seeds are seeds that meet official quality standards and are approved by the Department of Crop Production under MARD. The government has encouraged the use of certified seeds, with the objective that by 2030, 90% of the seeds planted will be either certified or Filial 1-hybrid seeds (Prime Minister, 2020).

In the VHLSS 2023 surveys, nearly 90% of farmers declared using certified seeds as the only input for their crop, and another 18% report they use a combination of (purchased) certified seeds and their own recycled seeds[88]. These numbers are equivalent to approximately 6.78 million households that use certified seeds (and 5.6 million households that use a combination of both certified seeds and recycled seeds).

The RRD and Southeast areas have the highest adoption rates, with 96% of the households declaring they used certified seeds. MRD, NCCA, and NM, all have approximately 80% farmers adopting. The lowest adoption rate of certified seeds occurs in CH, with about 72%.

In qualitative interviews conducted in the Dong Thap province, we explored the mechanisms through which farmers' perceptions of acquiring and planting certified seeds are shaped. Interviews indicated at least two ways in which farmers assessed that they were indeed using certified seeds. First, farmers rely on trusted shops, and some even travel long distances to purchase certified seeds:

"I usually do not buy seeds at the shops around here. Instead, I travel extra miles to a shop near the market, where the seller is an agricultural engineer. I think it is okay to believe in his recommendations. So, I buy seeds at his shop." (Household 24, Dong Thap Province).

Farmers also inferred whether the seeds were certified based on price. They were willing to accept higher prices, expecting higher seed quality:

"I buy seeds from a reputable place. I have been buying seeds there for 13 years. I trust this place. In general, the seeds they sell are good. When I soak, I know the seed is good [because the germination rate] is approximately 99%. [Other farmers claimed to use certified seeds, but only see a germination rate of 90%] because it depends on the place of sale. They bought them at a cheap price, and there must be a problem. The seeds I buy are more expensive. For example, people bought [at] VND 13,000 VND (USD 0.6) [per unit], I bought VND 14,000-15,000 (USD 0.61-0.66) [per unit]." (Household 09, Dong Thap Province).

Second, farmers use germination rates as an indicator of authentic and truly certified seeds. Some farmers even deferred their payment to seed suppliers until the germination rate was apparent:

"The seed that I bought and used are certified seeds, so the rate is high, reaching 95% […] Because the suppliers [companies] sponsor seeds or offer deferred payments for farmers, they must give us quality seeds. Otherwise, they can't get any money" (Household 04, Dong Thap province).

It is apparent that farmers have developed multiple strategies to evaluate the authenticity of their seeds. However, a few farmers admitted that they still could not be sure if the seeds they bought were certified or not:

"When I buy seeds, they put them in that bag of certified seeds. I do not know because they put the seeds there. Last season, I bought certified seeds at up to 16,800/kg. I do not know [if they are trustworthy]. When I see that people buy from that agent, I follow them. I don't know." (Household 02, Dong Thap Province).

We now document each of the three reduction practices in more detail.

[88] This estimate is based on farmers' self-reports. It diverges from our finding using rice DNA fingerprinting data, which suggests that 48% of farmers used CGIAR-related Rice varieties in 2022 (Section 6.3)

10.1.2 Reduction One: Seed Rates

In 2023, 76% of households (equivalent to 5.4 million households) reported that they had applied less than 120 kg of seed per ha (lenient criterion) in the previous Winter-Spring season. Under the strict criterion, 71% of households applied less than 100 kg of seed per ha.

Qualitative interviews revealed that farmers' adoption of the seed reduction guideline generally occurred gradually. Farmers mentioned that they first tried to lower their seed rate after the idea was introduced to them through community events or by word of mouth from neighboring farmers. In the beginning, farmers tended to allocate a small area in their plot (e.g. tens of square meters) for experimentation; then, if satisfied with the results, they applied the new rate to the whole field. Some farmers who received direct training on 1M5R/3R3G adopted seed reduction throughout their farm with full confidence, possibly because of the trust they placed in scientists.

Some farmers continued to reduce seed rates over a few years if they saw that the newly adopted rate was efficient, and they stopped when they reached what they considered to be an "optimal" number. For instance, from a farmer in Dong Thap:

"It took me three years to gradually reduce the seed sowing rate [from 20 kg/1000 m2 to 10 kg/1000 m2]".

However, some farmers considered the 3R3G/1M5R recommendations on seed rate to be too low. One farmer explained that reducing the seed rate to 13 kg per 1,000 m2 was feasible because it did not reduce his yield. However, he was not willing to reduce the rate further:

"When I sow 13 kg per 1000 m2, the plants grow sparsely, the yield remains the same, and pests and diseases also decrease. And now the fertilizer price is high, if the seed rate is low, it will help reduce the fertilizer amount, so I think a low seed rate is effective. I am pleased [with the current seed rate [100 kg/ha]. Further reduction [of seed rate] is not possible. The current seed rate is fine." (Household 08, Dong Thap province).

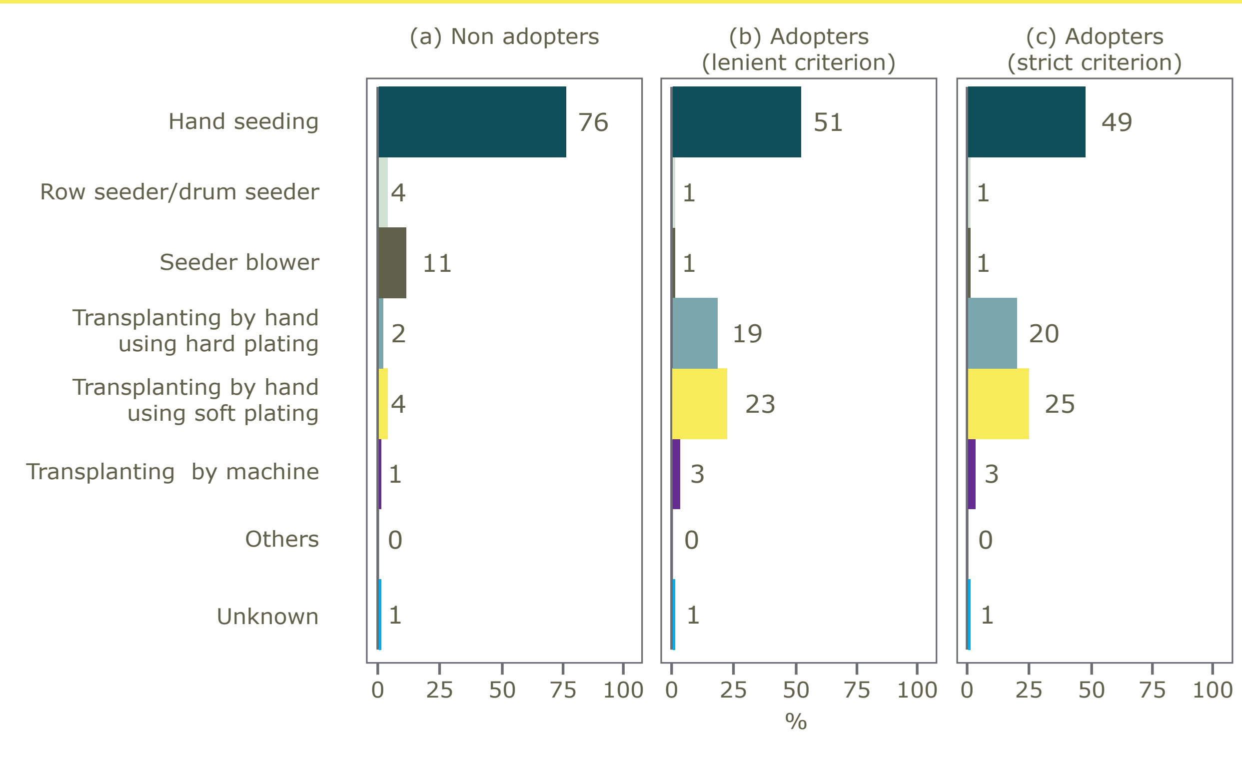
Despite understanding the benefit of a low seed rate, farmers often hesitated because of fears of golden apple snails, poor soil quality, specific rice varieties, climatic disasters, or societal judgment. These concerns are likely driven by high direct and indirect farming costs (Anand, 2014). Farmers prioritize the total harvested yield over marginal profits from reduced seed rates. They take pride in harvesting more rice bags than others, even if they incur higher input costs (seed rates, fertilizers, and plant protection drugs) and are less profitable. In addition, higher seed rates provide a sense of security from the higher expected yields. Farmers also fear being judged as "lazy" for using a low seed rate and feel anxious if their rice crop appears less green or thinner than in neighboring plots. This point is exemplified by a household from Dong Thap province:

"When I visit the field, seeing sparse crops makes me really nervous. Especially my wife when she visits and sees the sparse crop, she nags me very hard." (Household 34, Dong Thap province)

The survey module also included questions regarding the seed rate that farmers applied in their plot previously, and the year they decided to reduce their seed rate. Based on the average report, adoption of the lower seed rate remained low until approximately 2013, after which there was a marked upward trend. This acceleration aligns with the introduction of the 1M5R initiative, a national policy implemented in 2013 aimed at reducing seed rates. The year 2018 also appears to be a significant milestone, potentially reflecting additional policies or support that may have further encouraged adoption. However, we note that memory bias, or households' tendency to favor round numbers, might also explain these findings. The survey year was 2023, so 2018 is five years prior, and 2013 is ten years prior.

Our findings also indicate that adopters of the seed reduction requirement are more likely to grow transplanted rice (Figure 37). Specifically, farmers who adhere to (the lenient) 3R3G seed rate guidelines were more likely to engage in manual transplanting, utilizing both soft (23%) and hard plating (19%) techniques, in addition to hand seeding. Under the strict criterion, these percentages are slightly higher, at 20% and 25%, respectively.

Figure 37: Incidence of different rice seeding and transplanting methods among (a) non-adopters (b) adopters of 120kg of seed per ha (lenient criterion) and (c) adopters of 100kg of seed per ha (strict criterion)



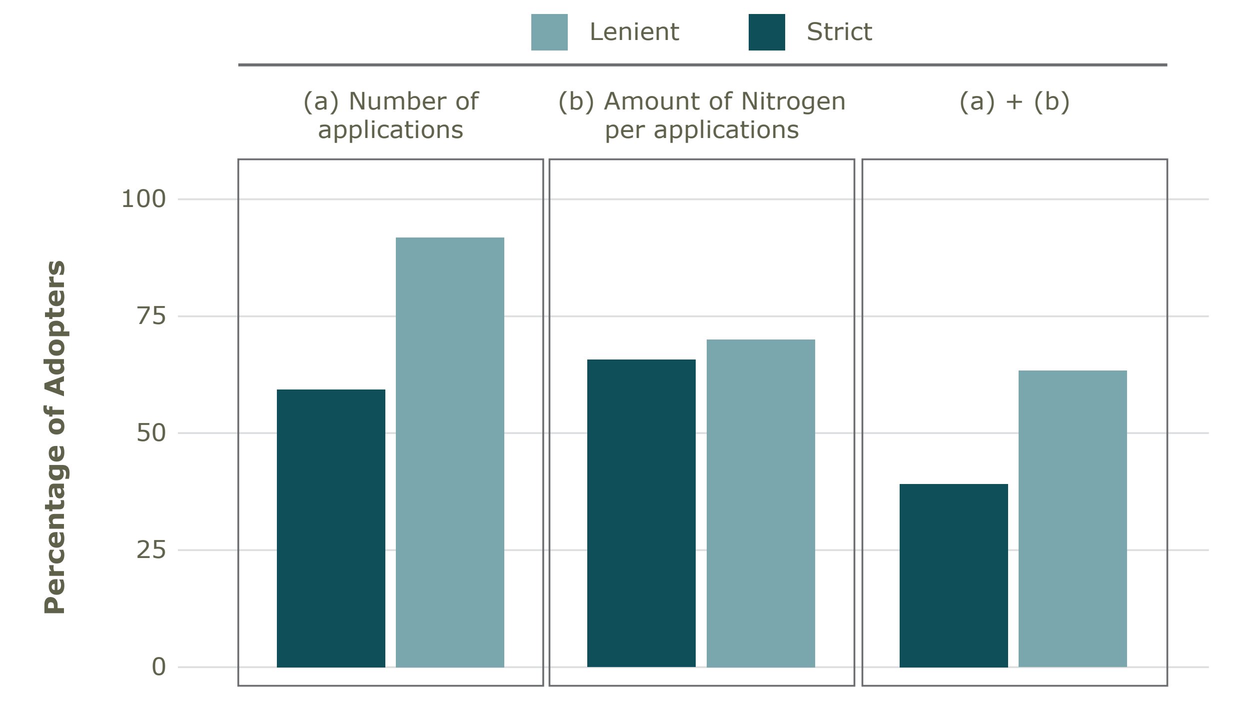
Data source: VHLSS 2023.

10.1.3 Reduction Two: Fertilizer Use

In 2023, 63% of rice-growing households complied with the 3R3G/1M5R lenient fertilizer use recommendations and 38.5% complied with the strict criterion. This is the equivalent of 4.7 and 2.9 million households, respectively.

Fertilizer-related guidelines state the total number of applications and the total amount of nitrogen in all applications. As illustrated in Figure 38, approximately 90% of households comply with the lenient recommendation to apply no more than three applications of nitrogen fertilizer, and 60% follow both the lenient recommendation on the number of applications and the recommended amount of nitrogen. In addition, it shows that 75% of farmers meet strict (and therefore also the lenient) recommendation to apply less than 100 kg/ha of nitrogen (less than 110 kg/ha). However, as Panel (a) shows, there was less compliance with the strict recommendation to administer fertilizer through two or fewer applications.

Figure 38: Adoption of fertilizer use recommendations under strict and lenient criteria: (a) number of fertilizer applications, (b) amount of nitrogen per application, and (c) both



Note: Strict: Maximum 100 kg of nitrogen per ha and minimum three split applications. Lenient: Maximum 110 kg of nitrogen per ha and minimum two split applications.
Data source: VHLSS 2023.

Qualitative data highlighted the context-specificity of fertilizer applications. Even in similar environments, or the same farm, farmers reported markedly different approaches to fertilizer use, depending on soil quality and plot elevation. Notably, farmers tended to report applying more fertilizer than recommended on their highland plots, as they perceive this soil to have insufficient nutrients. One farmer said:

"I understand [that in 3R3G, it is recommended to apply a maximum 100 kg/hectare], but my plots are not like other people's plots, there are lowered patches and elevated patches in the field. I do not need to apply fertilizer in the lowered patches, but just apply it in the elevated patches. Therefore, the amount of nitrogen fertilizer is similar to that [200 kg of urea per hectare in four applications]. In the past, I only used about two bags of fertilizer for this 2ha of rice. However, since the day the dike was built, the amount of fertilizer has been higher. Now, there are dikes, and the water cannot flow over. Before the flood season, floods would go over the bank and provide alluvium to the soil. Now I spread six bags of fertilizer per hectare, but sometimes it's not enough." (Household 8, Dong Thap Province).

10.1.4 Reduction Three: Pesticides

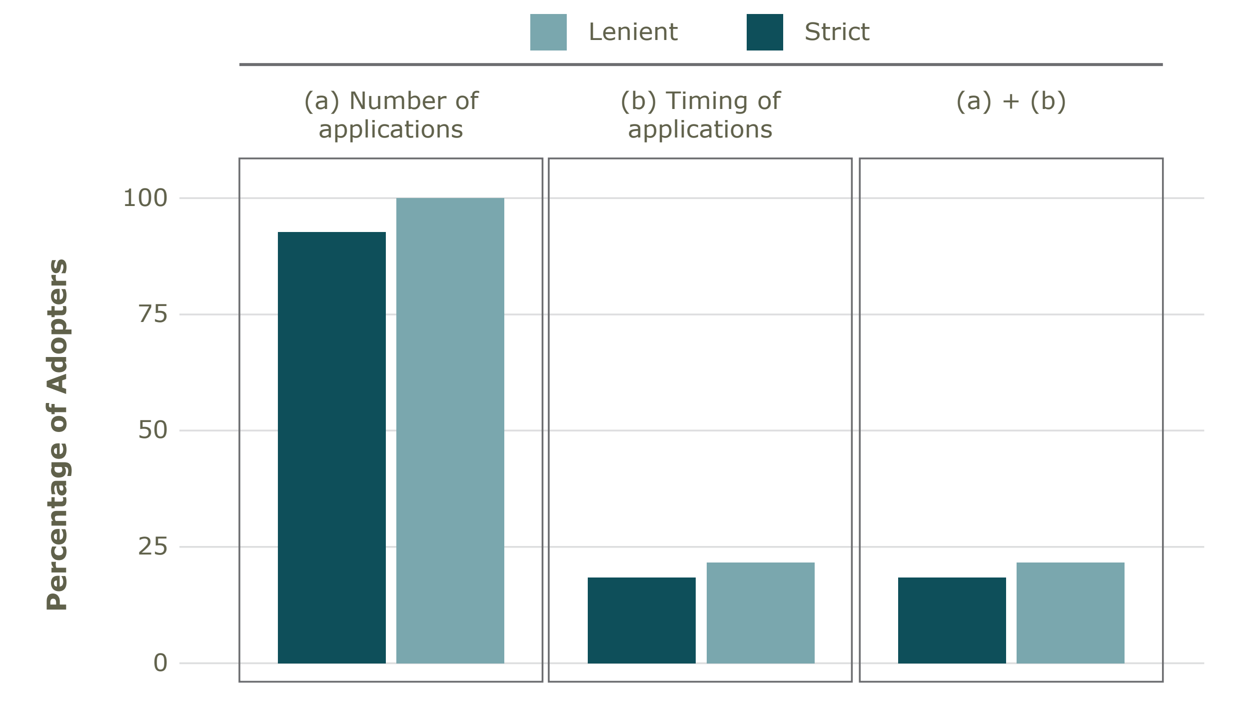
The 3R3G/1M5R recommendations for pesticides are for farmers to administer a maximum of three insecticides and three fungicide applications. In VHLSS survey data we find that on average a rice-growing household put in 1.88 applications across insecticides and fungicides together. However, qualitative interviews indicated a substantial amount of pesticide mixing:

"From then until now. My fellows usually buy and mix together 4-5 things to spray, and when they know I only mix 1-2 things, they also question. I buy the strong pesticides, costing a bit more, but it is fine if effective. I am afraid of fake pesticides. No drug is as effective as Tin: I sprayed at milky and dough stages, and the drug helped to make the grains good – the traders stayed and competed to buy my rice. The grains are fully filled and good." (Household 13, Dong Thap province).

When we apply the computation method suggested by the 3R3G/1M5R guidebook (Nguyen-Thi-My-Phung et al. 2020), we find that on average farmers administered 3.65 applications. Disaggregating the VHLSS data by the total number of pesticides used in these different applications, the average number of farmer applications was 3.65[89].

The pesticide recommendation also states that farmers should avoid applying pesticide for 40 days after sowing. We find that only about 21% of farmers follow this (lenient) recommendation (Figure 39, Panel b).

Figure 39: Comparison of 1M5R pesticide application requirements under strict and lenient criteria



Note: Strict: Maximum three applications; no applications before panicle imitation and after flowering stages. Lenient: Maximum of six applications, no applications before panicle initiation and after dough stages.
Data source: VHLSS 2023.

[89] According to the guidebook, a spraying that combines different plant protection drugs should be counted as multiple applications.

Thus, we find that most households comply with the guideline to administer fewer applications of pesticides, but only one-fifth of them avoid applying insecticides and fungicides in a 40-day window after sowing, as recommended. Therefore, putting together these two requirements, we find that in 2023, 21% of rice-growing households, equivalent to 1,611,585 households, followed the pesticide-use recommendation.

Qualitative data complement this finding. Farmers fear that if they detect pests and diseases, they must not hesitate to apply pesticides, or they will lose their crop. They also frequently opt for a preventive approach during the 40-day window due to concerns that pests from neighboring fields may migrate to their rice crops if adjacent farmers utilize pesticides while they do not:

"While there was a brown planthopper, other farmers sprayed it but I did not spray it. However, when my harvest was damaged, the other man was not. So, other family members could blame me for not knowing how to calculate carefully. So, when you do farming, you have to go to the field to see, find out if the crops require something, and then ask other farmers for advice. Ask them what pesticides you need to spray, learn what is good, and remove the bad ones." (Household 34, Dong Thap province).

Finally, the survey module also included questions to determine if the farmer was applying the pesticide for preventive or curative purposes. Although the IPM approach states that chemical controls should only be used as a last resort, indicating that they should be used for curative rather than preventive reasons (Deguine et al., 2021), 1M5R/3R3G guidelines do not make such a distinction. While a higher proportion (55%) of rice-growing households claimed using insecticides and fungicides for treatment, 45% were still applying pesticides for preventive purposes.

10.2 Alternate Wetting and Drying

It is estimated that rice cultivation under continuous flooding is responsible for approximately 41% of agricultural GHGs in Viet Nam (Reavis et al., 2021). This is because waterlogged conditions foster the growth of methanogenic bacteria, which produce methane, a significantly more potent greenhouse gas than carbon dioxide. The water management strategy known as Alternate Wetting and Drying (AWD) involves a cyclical pattern of irrigation and soil drying that allows the soil to reoxygenate between watering periods, thereby reducing the proliferation of anaerobic bacteria in the soil. AWD enables farmers to conserve water and decrease methane emissions while maintaining rice productivity.

The inception of AWD research in Viet Nam can be traced to initial studies conducted by the IRRI, with AWD principles first implemented in a pilot study across three provinces in 2002-03. Subsequently, an assessment conducted in the An Giang Province over three consecutive rice-growing seasons (Lampayan et al., 2015), revealed that farmers adopting AWD experienced a 17% increase in returns, primarily because of reduced input costs. The decrease in irrigation frequency – up to four times fewer irrigation events per crop than traditional methods – resulted in water and labor savings, translating into higher profits for farmers. Loan (2020) reported comparable outcomes in their research.

The AWD guidelines state that: a) the field must be irrigated when the water level drops 15 cm below the soil surface; b) the field must be flooded during the flowering stage; and c) after flowering, the water level must be allowed to fall 15 cm below the soil surface before the field is re-irrigated. In early trials, a field water tube (or 'pani pipe') was embedded into the soil on farmers' plots to help them ascertain the water level depth.

The Vietnamese government endorsed the adoption of AWD in 2011 through MARD Decision 3119. Since 2016, AWD has been recognized as a crucial element in Viet Nam's strategy to mitigate climate change, contributing to the country's Nationally Determined Contributions (NDC) under the Paris agreement (Decision 819/QD-BNN-KHCN)[90]. Over the past decade, eight governmental decrees have emphasized the importance of AWD implementation. The administration aims for between 0.2 and 0.5 million hectares of rice-growing areas to be under AWD by 2030.

In line with this, IRRI research since 2016 has focused on AWD scaling. This includes contributions to the development of suitability maps that identify areas with high mitigation potential, and the development of AWD training materials and technical instructions. Notable projects include the CGIAR Research Program on Climate Change, Agriculture and Food Security (2016-2021) and the Climate and Clean Air Coalition (CCAC) Phase 2: Methane Mitigation from Rice (2016-2020). Agricultural extension training programs organized training events in 30 provinces across Viet Nam. IRRI provided technical assistance to scale up AWD practices in eight provinces in MRD via the 'Viet Nam – Sustainable Agricultural Transformation' (VnSAT, WB, 2015-2022) project. It is estimated that more than 800,000 farmers have received AWD training (IRRI, 2020a).

AWD is also a requirement of the 1 million Ha project on high quality and low emission rice farming, initiated in 2024 (Decision No.: 145 /QD-TT-CLT)[91].

Several studies have documented the adoption of AWD in Viet Nam. These studies have concentrated on MRD and usually relied on data collected at the district or commune levels. Yamaguchi et al. (2016)'s qualitative study in An Giang Province involved structured interviews with 21 households in 2003 to explore how farmers adapted to AWD in rice paddies. They found that farmers discontinued the use of pani-pipes and relied on visual observation to assess water levels and to guide irrigation practices.

Yamaguchi et al. (2019) used a geographic information system (GIS) and statistical methods to identify the effects of irrigation conditions on provincial-scale AWD dissemination and implementation in the An Giang province. The sample size consisted of 156 communes, and AWD adoption was measured through field observations by extension agents. The research revealed a significant increase in AWD adoption, from 18% of paddy areas in 2009-2010 to 52% by 2014-2015. The study attributed the differences in adoption rates across different communes to environmental factors, such as paddy elevation and the density of irrigation channels.

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[90] Decision No. 819/QD-BNN-KHCN dated March 14 , 2016 approving the Action Plan for Responding to Change climate of agriculture and rural development in the period of 2016 - 2020, with a vision to 2050. https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Quyet-dinh-819-QD-BNN-KHCN-hanh-dong-ung-pho-bien-doi-khi-hau-nganh-nong-nghiep-2016-2020-2050-310923.aspx

[91] Decision No.: 145 /QD-TT-CLT dated March 27, 2024 On the Promulgation of the Process and Guidelines for "Technical Process for Producing High-Quality and Low-Emission Rice in the Mekong Delta: https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-145-QD-TT-CLT-2024-huong-dan-Quy-trinh-ky-thuat-san-xuat-lua-chat-luong-cao-613332.aspx

Table 21 highlights the adoption rates of water management practices measured through different questionnaire protocols in VHLSS 2022 and 2023.

Table 21: Overview of AWD adoption rates by measurement method

	VHLSS 2022		VHLSS 2023	
	EAs	Households	EAs	Households
	Measurement A			
Self-reported data by name	13.7	5.4	24.7	10.7
	Measurement B			
Self-reported data – 1 drydown of 5 days minimum	32.1	12.9	NA	NA
Self-reported data – At least 2 drydowns of 5 days minimum	57.2	30.7	NA	NA
	Measurement C			
Self-reported data – 1 drydown of 5 days minimum	NA	NA	14.7	5.4
Self-reported data – At least 2 drydowns of 5 days minimum	NA	NA	10.5	3.3

Note: Measurements B and C relate to the rice growth period between transplanting and flowering.

NA = Not Available.

Data source: VHLSS 2022 and 2023.

In 2022, we asked about the timing of drydowns through the question: "Between transplanting and flowering, how many times was the plot left dry?". The duration of the drydown period was collected as an average: "How many days on average was the plot left dry before irrigation was applied?". In VHLSS 2023 we improved our measurement method. The timing of the drydown was collected through a visual aid that depicted the rice crop cycle. Farmers could precisely pinpoint the rice growing stage at which the field had been dried down. In addition, they also reported the duration of each drydown event.

A comparison between the 2022 and 2023 adoption rates, obtained through two different measurement protocols, reveals a large gap in adoption estimates. We posit that in VHLSS 2022, the relevant AWD timing was not well understood by enumerators/interviewees, and so they included in the count of drydowns the period before the harvest when fields are commonly dry, thus inflating the adoption rate.

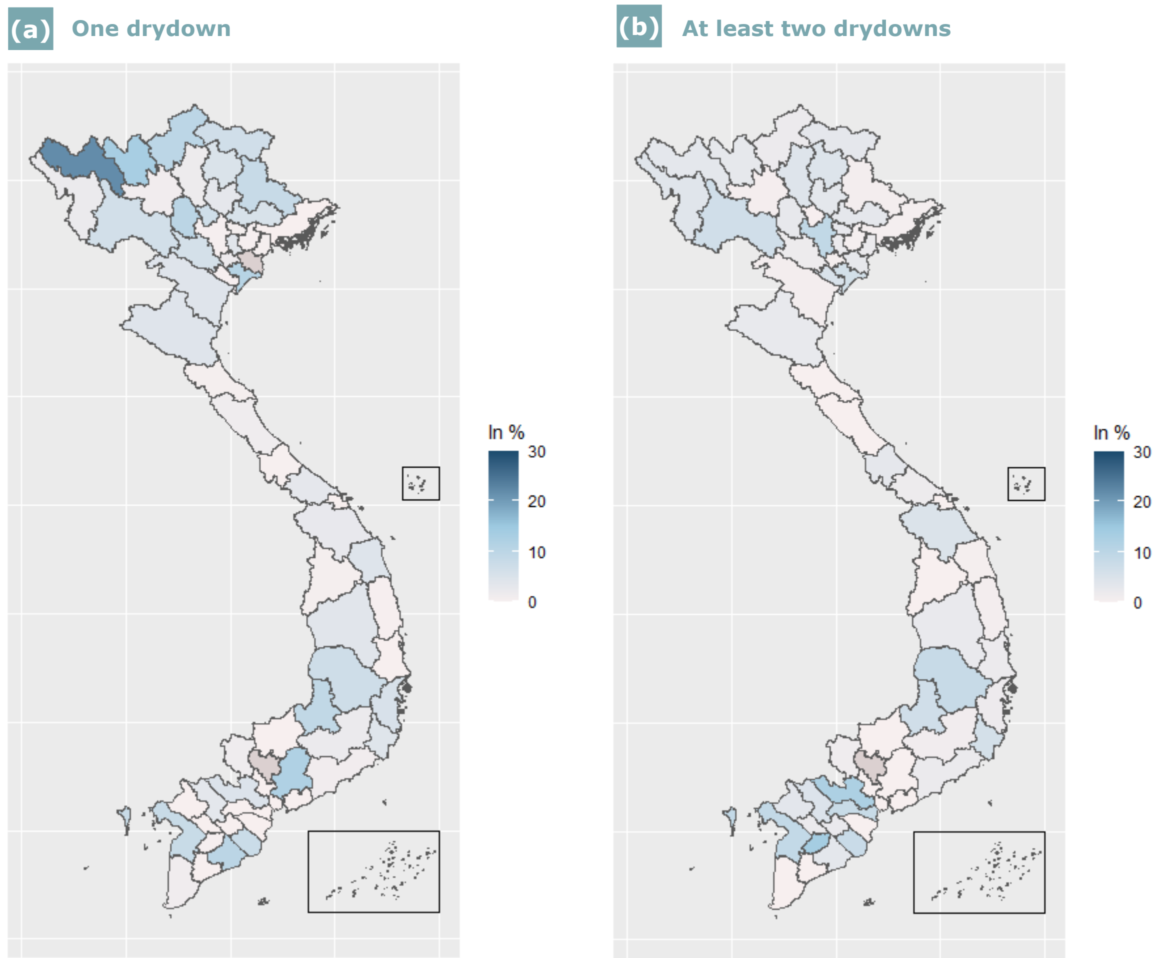
In 2023, 12.6% of EAs and 5.4% of households reported having experienced at least one drydown lasting a minimum of five days. The adoption rates decreased further when multiple drydown events were considered. Only 10.5% of EAs and 3.3% of households reported implementing at least two drydowns for five days or more. The AWD reach corresponds to 408,700 households (one drydown) and 249,300 households (two drydowns).

It is important to note that our survey protocols did not allow us to establish whether farmers had intentionally dried their fields, or if they had independent control over when the drydown occurred.

Figure 40 shows where AWD adopters are located. Eight percent of households in RRD, 6% in NM, 5% in CH, and 4% in MRD reported one drydown between transplanting and flowering. Thai Binh had the highest adoption rate, with one-third of households reporting one drydown. Six other provinces had more than 10% of households reporting one drydown: Phu Tho, Ha Giang, Nam Dinh, Dong Nai, Lao Cai, and Lai Chau.

On the other hand, the highest proportion of households reporting two or more drydowns was found in MRD (6%), followed by RRD and CH. The provinces with the highest rates in MRD were Hau Giang, Long An, and Kien Giang, with 15%, 12%, and 10%, respectively.

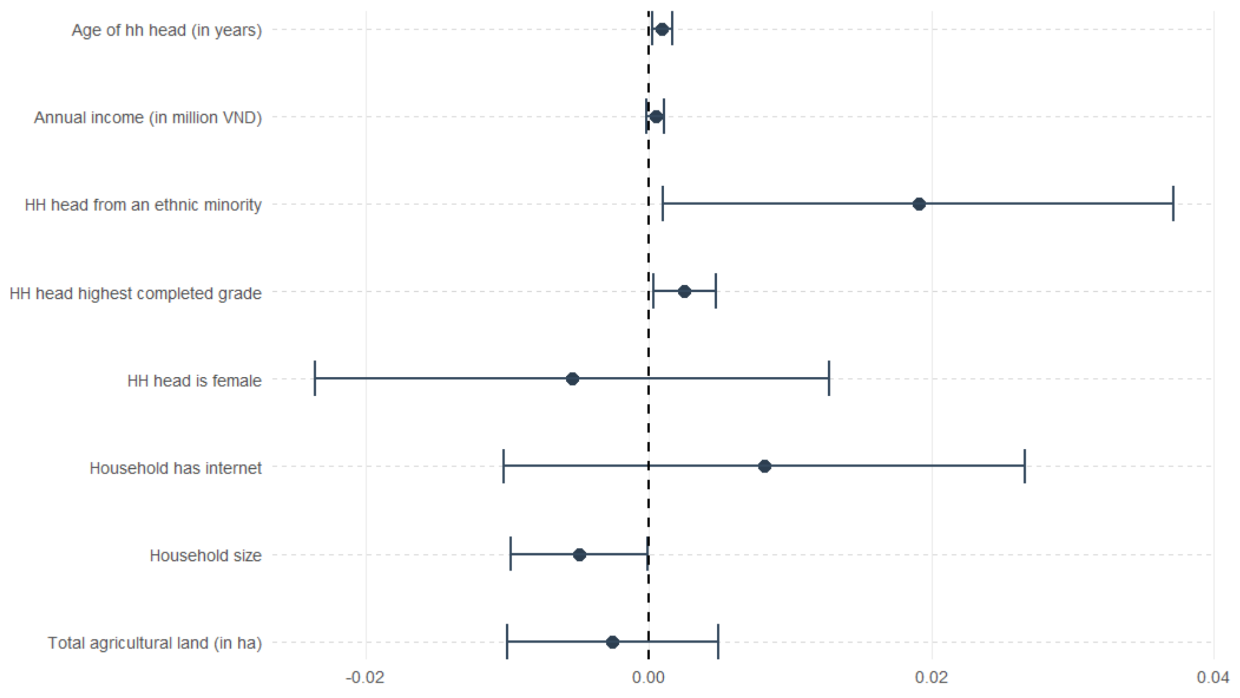
Figure 40: Percentage of households reporting drydowns at the province-level, a) one drydown, and b) at least two drydowns



Data source: VHLSS 2023.

The multivariate analysis revealed little association between household characteristics and drydowns (Figure 41). Only one factor was significantly correlated: households with a head from an ethnic minority were more likely to report one drydown.

Figure 41: Estimated associations between household characteristics and adoption of AWD (one drydown)



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

Data source: VHLSS 2023.

10.3 Drum Seeder

The two most common methods for seeding rice are direct seeding and indirect seeding, or transplanting. Drum seeders represent a mechanized approach to direct seeding that enhances efficiency and ease of sowing across large areas. Typically, a drum seeder consists of a cylindrical drum equipped with evenly spaced slots or holes on its surface. As the seeder is pulled or pushed across the field, seeds are deposited into the rotating drum. The seeds are uniformly distributed onto the soil surface below as the drum rotates and releases them through the perforations or slots. The rotation speed of the drum can be adjusted precisely to control the rate of seed distribution, allowing for accurate seeding rates tailored to specific crop and soil conditions.

It is essential to differentiate between mechanized and non-mechanized drum seeders. Mechanized drum seeders utilize machinery for swift and efficient seed sowing, reducing labor requirements and improving precision. In contrast, non-mechanized drum seeders require manual effort, making them more labor-intensive but cost-effective for smaller fields. The VHLSS specifically examines the use of non-mechanized drum seeders, guiding subsequent analyses based on these specifications.

Drum seeders significantly enhance the precision and efficiency of seed planting processes, ensuring seeds are planted at optimal depths and spacings to mitigate risks of overcrowding and increase crop yields. These devices also expedite the sowing process by covering large areas quickly, allowing farmers to maximize productivity. Compared to labor-intensive manual seeding methods, drum seeders reduce dependency on extensive workforces during planting seasons. Their precision conserves seeds and resources while ensuring uniform seed distribution, promoting consistent crop growth, and simplifying maintenance (Mohanta et al., 2019).

Rice transplanting involves the manual or mechanical relocation of immature rice seedlings. The traditional method of manual transplanting takes approximately 100–200 labor hours per hectare (Nguyen-Van-Hung et al., 2019; Quilty et al., 2014). However, mechanical transplantation emerges as the most promising option due to its labor-saving benefits, ensuring timely transplanting and achieving optimal plant density, thereby boosting output (Mohanta et al., 2019). In regions like MRD, mechanized transplanting has supplanted manual methods, offering advantages such as higher yields, reduced risks of pests and diseases, minimized postharvest losses, and improved conditions for seed production practices (IRRI, 2020b). Recent findings from the VnSAT-IRRI team (Nguyen-Van-Hung et al., 2020) indicate that mechanized transplanting can slash seed rates by 40%, leading to substantial reductions in agronomic inputs, pest and disease risks, and lodging of rice plants, thereby minimizing losses during harvesting.

The introduction of drum seeders to Viet Nam dates to 1988 when they were initially designed by IRRI engineers with the primary goal of reducing seed rates and production costs. On-farm trials have demonstrated that using drum seeders can decrease the seed rate from 200 kg to 80–120 kg per hectare (Agricultural Extension Office, 1999). Subsequently, the model underwent modifications by the Can Tho Plastic Joint Stock Company in Viet Nam, where plastic components replaced predominantly metal parts. These adaptations rendered the drum seeders lighter and less expensive, facilitating easier transport and maneuverability between fields (Huynh, 2009). By 2003, there were 23,859 drum seeders in use in the Mekong Delta, with 9,014 of them located in the Can Tho Province (Tuan, 2003).

In January 2004, a team from IRRI, Can Tho University and CLRRI conducted a census of rice farming households in the Thoi Lai commune, where drum seeder technology had been demonstrated. The study sampled 78 adopter and 41 non-adopter households, finding that contact with extension workers correlated with drum seeder adoption. Other factors, such as seed usage, wives' education levels, household income, and social class, positively affected adoption. In contrast, poorer households, where wives had lower education levels and worked as unpaid laborers, were less likely to adopt drum seeders (Paris & Chi, 2005).

A household is considered to have adopted this technology if it has used a drum seeder on at least one plot during the previous Winter-Spring season. Data on this innovation is available from the 2022 and 2023 waves of the VHLSS. It's important to note that the VHLSS specifically queries the use of non-mechanized drum seeders. Moreover, throughout this section, both row seeder and drum seeder will be treated as the same machine in line with IRRI's classification. In 2022, about 344,500 households (4.4%) in Viet Nam reported using drum seeders for crop seeding (Table 7). However, the number of households that adopted this innovation decreased to around 128,000 (1.7%) by 2023, marking a statistically significant decline of 2.8 percentage points.

Adoption rates for drum seeders showed significant regional variation. In 2022, the MRD led with a household adoption rate of 18.9%, which was well above the national average. However, by 2023, all regions experienced a decline in adoption rates, with MRD seeing the second-largest decrease of 8.9 percentage points. The most substantial change occurred in the Southeast Region, where adoption rates dropped from 10.9% in 2022 to 1% in 2023.

At the EA level, the adoption rates of drum seeders decreased across all regions, with a decline of 15.6 percental points observed in MRD. This notable reduction contributed to a national adoption decrease of 7.5 percentage points. This suggests that both the adoption intensity and the geographical extent of adoption across regions changed significantly between these two years.

To get a better understanding of the decrease in drum seeder adoption rates, it is necessary to analyze the flow of changes between different seeding methods in 2022 and 2023. For this purpose, a common rotating panel for these two years with a sample size of 5,735 households – representing around 3 million households – is used. Although this rotating panel is a subsample, it provides valuable insights into shifts in seeding methods. According to the panel, in 2022, farmers used the following methods: hand seeding (71%), transplanting (23.6%), drum seeder (3.3%), seed blower (1.6%), and others (0.5%). By 2023, this distribution shifted to hand seeding (56.8%), transplanting (36.6%), seed blower (2.9%), drum seeder (1.5%), and others (2.2%). Among drum seeder adopters in 2022, 19.4% continued with the same method in 2023, while 46.3% switched to hand seeding, 20.5% to seed blowers, 11.8% to transplanting, and 2.1% to other methods.

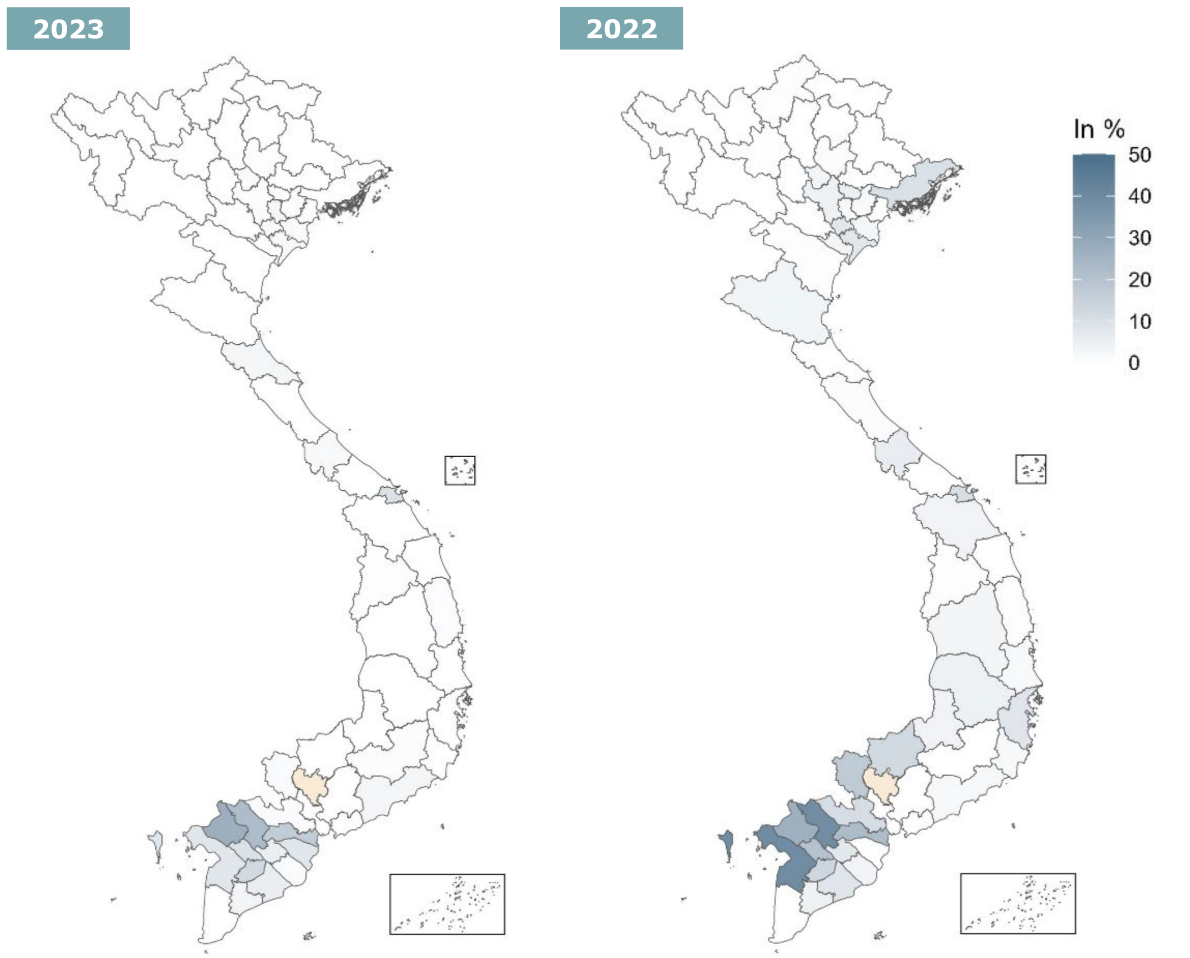
As noted, MRD which accounted for 62.3% of drum seeder adopters in 2022 according to the two-year panel, experienced a significant decrease in drum seeder adoption rates. Among 2022 adopters in this region, 29.7% continued using a drum seeder in 2023, while 33.6% switched to seed blowers and 30.8% to hand seeding. Therefore, seed blowers and hand seeding emerged as the primary methods for replacing drum seeders in the Mekong River Delta. Similarly, although the Southeast region represented only 1.6% of drum seeder adopters in the two-year panel (1.87% in the full 2022 sample), it also saw a marked decline in adoption. According to the panel, 31.3% of farmers continued using a drum seeder in 2023, while 55.8% switched to seed blowers and 12.9% to hand seeding. Thus, in the Southeast region, drum seeders were largely replaced by seed blowers.

Farmers interviewed in Dong Thap province, Hong Ngu district, shared mixed experiences with drum seeding. While some adopters recognized the benefits, such as reduced seed rates (e.g., from 20 kg to 12 kg per 1,000 m²) and improved disease management, they also highlighted significant challenges. The drum seeder's weight and the manual effort required to use it make it difficult, leading many farmers to revert to manual seeding or seed spreaders, especially in larger fields where labor costs and availability are issues.

The particular case of one farmer who lent his fields to organizations to conduct demonstrations can shed light on this phenomenon. According to the interviewee, mechanical transplanting may facilitate better hill development, stronger plants, and improved photosynthesis due to increased spacing between plants. However, it also requires significant investment and precise soil preparation, which can be limiting factors. Thus, the decline in drum seeder adoption rates may be attributed to the introduction of the mechanical transplanting innovation that offers greater benefits, as well as farmers finding the drum seeder cumbersome to use due to its heaviness.

Figure 42 illustrates the adoption rates of the drum seeder by province for the two waves of the VHLSS in 2022 and 2023. The majority of provinces in the northern and central regions exhibit adoption rates below 25%. In contrast, the northern provinces of MRD show higher adoption rates, with Kien Giang and An Giang leading in 2022, reporting adoption rates of 39.2% and 26.3%, respectively. By 2023, An Giang was positioned as the province with the highest adoption rate at 26.6%, while Kien Giang experienced a significant drop to 7.8%. This decline exemplifies the national reduction of drum seeder usage, as discussed earlier.

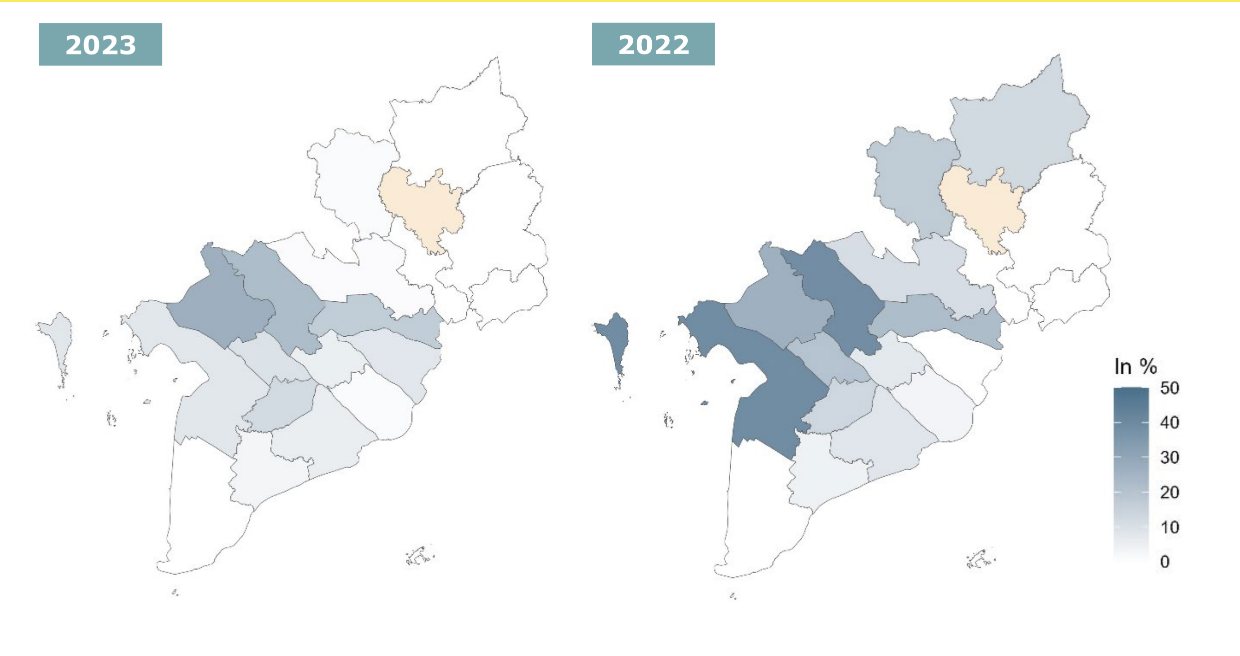
Figure 42: Drum seeder adoption rates by province



Note: Provinces shown in beige do not have available data.
Data source: VHLSS 2023 & VHLSS 2022

As discussed above, the MRD and Southeast regions experienced the most significant decreases in drum seeder adoption rates. Figure 43 provides a closer look at these regions, illustrating adoption rates by province. In MRD, Kien Giang Province saw the largest decline, dropping from 39.2% in 2022 to 7.8% in 2023. Dong Thap Province also declined, with adoption rates falling from 38.8% to 22.1% over the same period. In the Southeast region, Tay Ninh Province recorded the steepest drop, from 17.4% to 1.38%, followed by Binh Phuoc, where adoption decreased from 12.6% to zero.

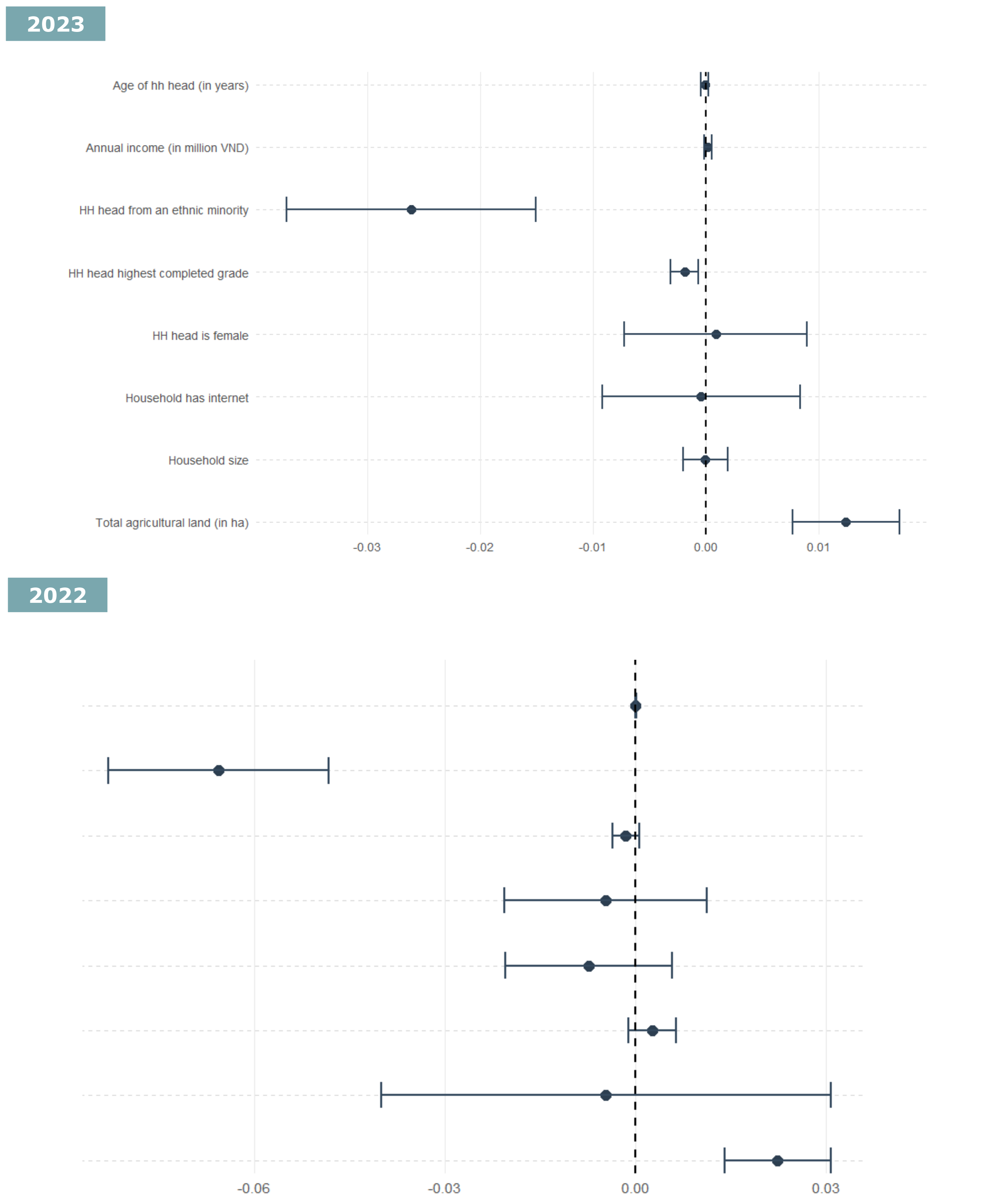
Figure 43: Drum seeder adoption rates in provinces from the MRD and Southeast regions



Note: Provinces shown in beige do not have available data.
Source: VHLSS 2023 & VHLSS 2022

To understand the characteristics associated with adoption of the drum seeder, the point estimates are depicted in Figure 44. In 2023, the ethnicity of the household head, education level, and agricultural land size are statistically significantly associated with drum seeder adoption. If the household head is from a non-Kinh ethnicity, the likelihood of adopting this machine decreases by three percentage points. Each additional hectare of land reduces the probability of adoption by one percentage point, and each additional year of education is associated with a 0.19 percentage point decrease in adoption likelihood. In the 2022 data, the same three characteristics are associated with drum seeder adoption, but the effect of ethnicity is larger as having a household head from a non-Kinh ethnicity reduces the probability of adoption by 6.6 percentage points.

Figure 44: Estimated associations between household characteristics and adoption of drum seeder



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

Data source: VHLSS 2023

10.4 Off-field Straw Management

After collecting the straw, farmers have various options to manage it effectively and increase their agricultural value-added while promoting environmentally friendly practices. Three off-field straw management technologies on which CGIAR has focused research efforts are rice straw-based composting, rice-straw mushroom (RSM) cultivation, and rice straw silage production for cattle feed.

As the name suggests, rice straw-based composting converts the rice straw biomass into compost. The inclusion of rice straw optimizes nutrient factors and the decomposition process, significantly enhancing the quality of the compost product. The compost can be used to improve the soil or can be directly utilized as a planting substrate. Compost application leads to crop yield increments and improvement of soil fertility (Goyal et al., 2009). This use of the rice straw promotes agricultural sustainability, contributes to healthier plant growth, reduces dependence on synthetic fertilizers, and mitigates greenhouse gas emissions associated with agricultural waste disposal (Nguyen-Van-Hung et al., 2020).

At the same time, researchers, engineers, and entrepreneurs are developing a range of alternative uses for rice straw to be an input in a commodity around which sustainable value chains can be built. Mushroom cultivation using rice (or wheat) straw is an agricultural endeavor that produces food from rice and wheat straw in addition to making it easier to dispose of this waste in an environmentally responsible manner. Straw mushrooms are relatively easy to cultivate and only require a 14-day incubation period. A production yield of roughly 5–10% mushroom products (or 50–100 kg of mushrooms per tonne of dried straw) can be obtained by using rice straw for mushroom cultivation (Thuc et al., 2020).

However, since rice straw-based composting and silage production for cattle feed exceeds what a household can typically manage, only RSM cultivation will be considered when estimating adoption rates at the household and EA levels.

In July 2023, MARD and IRRI organized a field demonstration in the Vi Thuy district of Hau Giang province to advance mechanized rice straw collection and processing technology, promoting low-emission circular agriculture. The introduction of various solutions to rice straw management issues was presented, emphasizing the value addition to the rice value chain through the collection and processing of agricultural residues like rice straw, which can generate income and improve livelihoods. To scale up the use of rice straw machinery, MARD encouraged stakeholders to engage farmers' cooperatives for more effective investments and workforce distribution.

On December 12, 2023, in Hau Giang, Viet Nam, MARD and IRRI launched the Sustainable Development of One Million Hectares of High Quality and Low-Emission Rice Associated with Green Growth in the MRD by 2030 program during the International Rice Festival. This initiative aims to restructure the rice production system, promote sustainable farming practices to boost productivity and economic efficiency and enhance the income and livelihoods of farmers. The launch was complemented by field demonstrations showcasing mechanized direct-seeded rice, mechanized rice straw composting, remote control lawn mowers, and drone applications. These demonstrations featured equipment from various organizations and companies, including IRRI, CLRRI, Tu Sang Company, and Sai Gon Kim Hong Company (IRRI, 2024).

A household is considered an adopter of off-field rice straw management practices if it uses rice straw for cultivating paddy straw mushrooms (oyster mushroom Pleurotus). In 2022, 6.8% of households reported partially removing straw from the field, while 22.6% opted for complete removal. Among these households 0.2% engaged in mushroom cultivation. This represents 4,900 households at the national level (Table 7). The adoption rates of these off-field straw management practices vary significantly across regions. More specifically, only three regions engage in this practice: Adoption rates are MRD (0.9%), SCC (0.2%), and North Mountainous Areas (0.1%).

10.5 Sustainable Water Use for Coffee production

Nearly 90% of Viet Nam's coffee-growing areas, equivalent to approximately 640,000 hectares, are in the Central Highlands (CH). Scientists have estimated that current cultivation practices overuse water in the dry season (January-April) and could be cut by 50-60%. They have warned that as temperatures increase with climate change, farmers will likely face water shortages. In collaboration with partners, CGIAR centers have tested water-saving techniques for coffee production in five provinces of the region. In the early 2000s, IWMI worked with Hanns Neumann Stiftung and Nestle on coffee water footprint calculations. The results indicated that under normal climate conditions, farmers could use 70% of the locally recommended water level by MARD (400 L/plant/irrigation) and continue to sustain yields of up to 4 t/ha (D'Haeze et al., 2015).

This benchmark was subsequently regarded as a viable target, as demonstrated by the backing of policies on both regional and national echelons. In 2017, the Dak Lak Provincial People's Committee approved the 'Plan for Sustainable Coffee Production' (Decision No. 3540/QD-UBND)[92]. The plan acknowledged the likely impacts of climate change on coffee production and proposed recommendations (such as training, raising awareness for farmers on sustainable water use, and applying water-saving irrigation techniques). Several programs to promote water-saving irrigation (with technology from Netafirm) have been conducted by the Agriculture Extension Office, some with support from the VnSAT project. In the NDC 2020, the stated efforts to reduce GHG emissions in Viet Nam included mention of " water-saving irrigation techniques on hundreds of hectares of coffee‟ (The Socialist Republic of Viet Nam, 2020)

A handful of studies have highlighted coffee farmers' water management practices in CH (Byrareddy et al., 2020; Quoc Ho et al., 2022; Tran et al., 2021) These empirical studies conducted in the 2020 -2022 period all report that households in the Central Highlands consumed well above the 400L/plant/irrigation recommended threshold.

Tran et al. (2021) analyzed water use efficiency in irrigation for Robusta coffee crops in Lam Dong Province, Viet Nam, based on a survey of 194 coffee growers. Utilizing a Cobb-Douglas production function and regression modeling, the study revealed that farmers used significantly more water than necessary – 1,200–1,500 m^3/ha per irrigation round compared to the recommended 650–800 m^3/ha. They emphasized the importance of extension services

[92] The Decision to develop the implementation plan of the sustainable coffee development project (2020-2030) is available at https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-3540-QD-UBND-2017-Ke-hoach-thuc-hien-De-an-phat-trien-ca-phe-ben-vung-Dak-Lak-392866.aspx

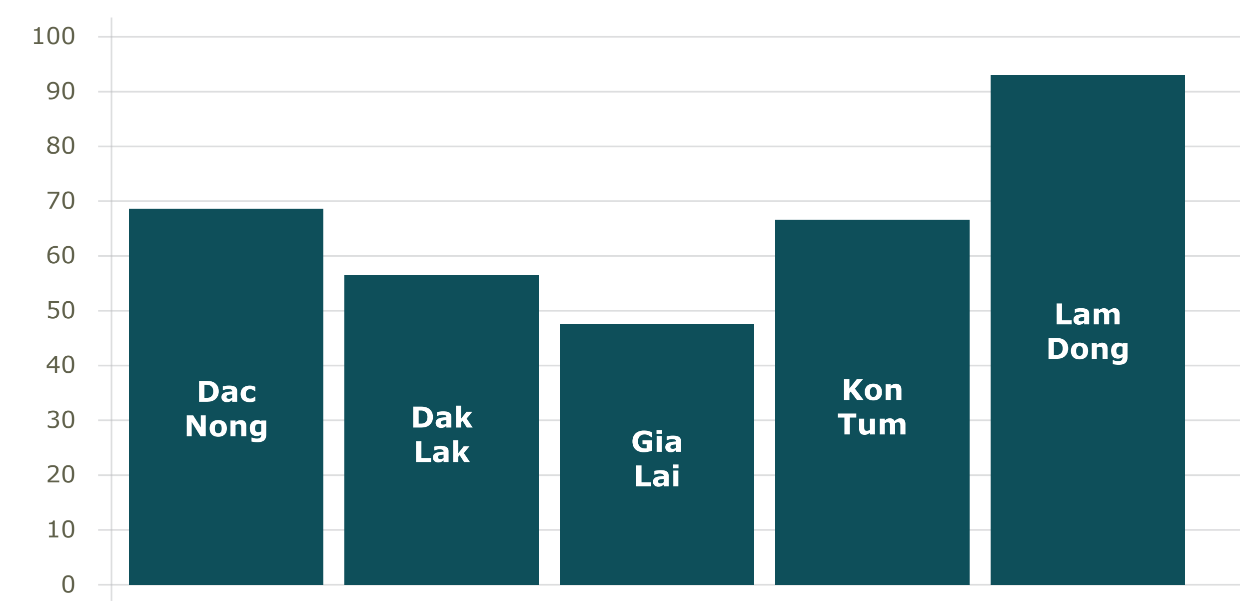
and highlighted that farms located near water sources demonstrated more efficient water management practices.

Quoc Ho et al. (2022) explored the impact of irrigation technologies and sustainability certification on water usage in coffee farming. Analyzing data from 829 Vietnamese coffee farmers over three crop years (2012/13 to 2014/15), they found that farmers using sprinklers consume less water than those drawing water from micro-basins (1,117 m^3 per tree per year compared to 1,246 m^3 per tree per year). Recommendations were made to reduce water quantities by half without compromising yields.

Finally, Byrareddy et al. (2020) examined irrigation practices on Robusta coffee farms in Viet Nam, focusing on water utilization and strategies to enhance efficiency without compromising yield. Utilizing CROPWAT – software to calculate the right amount of water needed for the irrigation of crop fields – and hierarchical Bayesian modeling, the authors analyze data from 558 farms over ten cropping years (2008/2009–2017/2018) across four major coffee-producing provinces in CH (Dak Nong, Lam Dong, Dak Lak, and Gia Lai). The study highlights significant variations in water use, with the highest volumes used in Dak Lak and Gia Lai (1,364–1,818 liters per tree annually) during dry seasons, and lower volumes in Dak Nong and Lam Dong (909–1,364 liters). They also indicate that irrigation water can be reduced by 273–536 liters per tree annually in average rainfall years while maintaining yields above 3,000 kg/ha.

Results from the VHLSS indicate that in 2023, 63% of coffee-growing households in CH, representing approximately 491,400 households, reported using less than 400 liters of water per coffee plant per irrigation round during the rainy season. This practice was most widely adopted in Lam Dong province, where 93% of households reported they applied less irrigated water than the threshold, as shown in Figure 45.

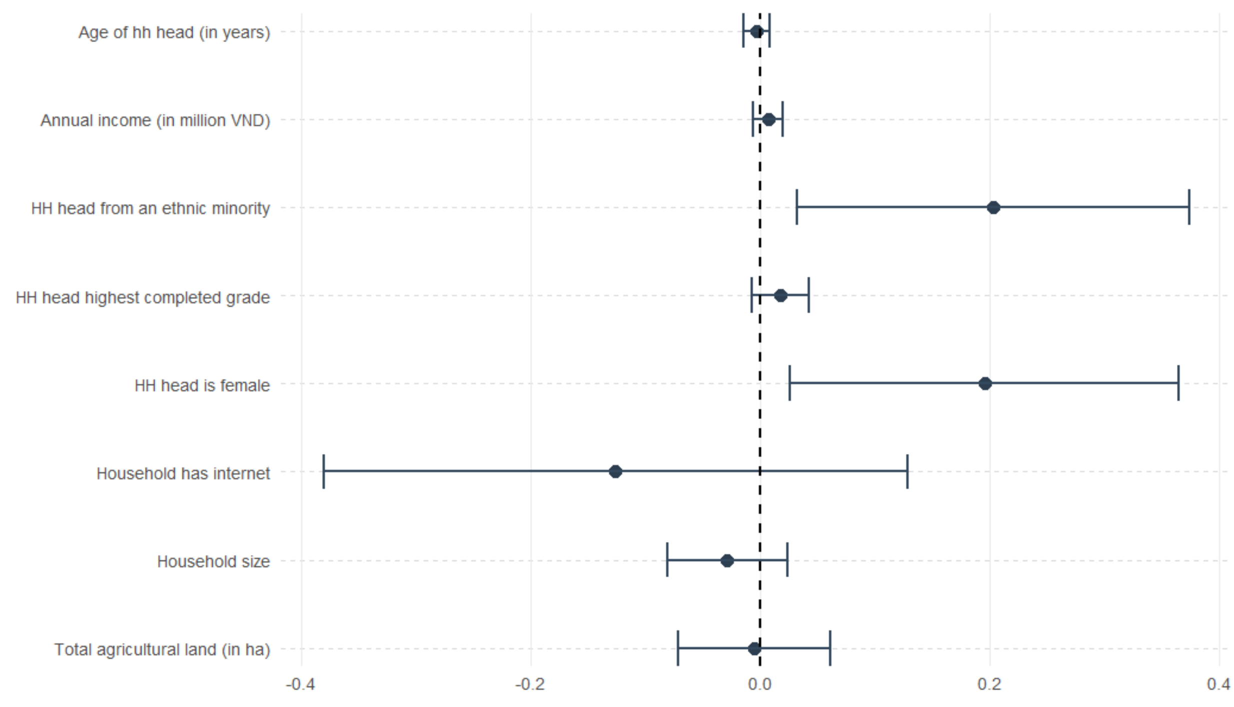
Figure 45: Adoption of water-saving practices for coffee production in the Central Highlands provinces



Data source: VHLSS 2023.

In Figure 46, OLS regression analysis on SWCP adoption reveals that household heads who are from an ethnic group and females are more likely to adopt (both cases: 0.2, p<0.05).

Figure 46: Estimated associations between household characteristics and adoption of Sustainable Water for Coffee Production



Note: The point estimates (dots) correspond to a multivariate regression analysis, where the dependent variable is a dummy equal to one if the household is an adopter. Standard errors are clustered at the commune level. The 95% confidence intervals are displayed as lines.

HH = household

Data source: VHLSS 2023.

11. Conclusion

Viet Nam benefits from a unique geographical situation and employs a multilateral approach to trade (Do, 2022). At the start of this country study, we posited that Viet Nam’s access to technology and diffusion have been significantly influenced by its trade partners, notably China, Japan, Korea, and the USA, potentially diminishing the influence of CGIAR compared to other country-level studies. Instead, this report demonstrates that even in a middle-income, export-oriented economy such as Viet Nam, the adoption of CGIAR-related innovations is now in evidence.

CGIAR has dedicated decades to research in Viet Nam, spanning diverse portfolio domains and the work of eight CGIAR Research Centers and partners. This has generated numerous agricultural innovations, many of which may have been adopted by Vietnamese farming households in ways that have not been documented. This report has systematically taken stock of these innovations, providing an overview of CGIAR's Research Initiatives in Viet Nam, their evolution into tangible solutions, and evidence of their adoption.

During this period, CGIAR activities in Viet Nam spanned six primary domains: aquaculture and capture fisheries, breeding innovations, digital tools, environmental conservation, livestock and human health, mechanization, and sustainable intensification practices. Through a combination of desk research and interviews with CGIAR researchers and national collaborators, we gathered information and opinions on adoption pathways and the scale at which adoption had taken place to narrow down the list of innovations to 19 that had likely diffused to a significant scale.

This study provided adoption estimates for each of these 19 innovations and insights into the geographic distribution of adoption and the socioeconomic characteristics of adopters. Assessing the reach of agricultural innovations, defined by adoption levels and beneficiary numbers, is key to understanding their impact.

In 2023, improved rice varieties had reached close to two million households. Sustainable intensification practices, including ‘Three Reductions, Three Gains’ and ‘One Must Do, Five Reductions’, Alternate Wetting and Drying, and Sustainable Water Use for Coffee Production, also show significant adoption. Meanwhile, some innovations, such as GIFT-derived tilapia strains, were present in a few farming households but are likely to be more prevalent in the commercial sector, as evidenced by the high presence of GIFT-derived tilapia fingerlings in hatcheries. Compelling links to CGIAR research were identified for 10 of these innovations and it is estimated that between 3.7 and 3.9 million Vietnamese households have been reached.

This indicates a significant potential impact on rural communities and underscores the enduring influence of CGIAR’s work in Viet Nam. It also highlights the crucial roles of National Agricultural Research Systems (NARS), public sector dissemination efforts, and private sector markets in facilitating the diffusion and adoption of these innovations.

One limitation of this study is that it provides only a snapshot of the innovations' adoption lifecycle. A similar exercise conducted ten years ago would have probably yielded very different results on adoption. In addition, the fact that data were only collected over a three-year horizon means that we cannot reliably measure innovations such as climate services that can only be seen in action during extreme events. Finally, some major research activities from CGIAR centers, such as food systems, may not have intended farming households to be the primary beneficiaries. These innovations are referenced in the stocktake and policy contribution documents (Annex G), but we were unable to shed light on their reach. Consequently, we recognize that the impact of CGIAR work may go beyond the beneficiaries documented in this report.

The results may offer valuable lessons for other countries seeking to replicate Viet Nam's agricultural development, although Viet Nam's centralized approach to agricultural planning is relatively uncommon in comparison to other countries.

This country study has also introduced several methodological advances that can be adopted and improved upon in future impact-assessment studies. We conducted the first DNA fingerprinting strain identification survey for fish at the household level. To improve the accuracy of the measurement of complex bundles of agronomic practices, such as 3R3G/1M5R, we implemented a mixed-methods approach. Efforts have also been made to code and analyze the text of supplementary data sources, such as annual and seasonal agricultural plans, which form the basis of the content delivered through agriculture extension services. All survey protocols and datasets are open access, and we hope will prove useful to academics and CGIAR researchers.

This report represents a large effort to document and analyze the adoption of CGIAR-related innovations in Viet Nam. For CGIAR donors and development aid agencies, this report highlights how research outputs have translated into household adoption, and more broadly benefited the agricultural sector. The Vietnamese government has long recognized agricultural innovation as a critical driver of economic growth, and this report provides novel, empirical insights to inform policymaking and development strategies. For the research community, the documented innovations, methodological advancements, and open-access datasets offer a robust foundation for future impact assessments. Continuous tracking of agricultural innovations through nationally representative panel surveys is essential to identify what works and what does not. Ultimately, this report is a testament to the potential of science to be embraced and effectively scaled, offering hope for advancing sustainable development in Viet Nam.

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Harvesting improved cassava varieties.
Dong Nai province, Vietnam.
Credit: CIAT/GeorginaSmith

Appendix A. List of Policy Outcomes Plausibly Attributable to CGIAR Research in Vietnam

The policy outcomes are ordered by theme. A detailed description of each policy outcome, including the information gathered on CGIAR's contribution is available in Annex G.

Climate and GHG Mitigation Policies

- Tools and methodologies help identify Vietnam's Nationally Determined Contributions (NDC) to the Paris Agreement (2017 - present).
- Lam Dong Provincial Government Decision No. 68/QĐ-UBND (01/2021): Approves the green-growth action plan (GGAP) of Lam Dong province (2021–2030).

Forestry and Agroforestry

- Decrees 05/NĐ-CP and 99/NĐ-CP implementing the Payments for Forest Ecosystem Services (PFES) in Vietnam (2008-today)
- Decision 523/QĐ-TTg: Vietnam Forestry Development Strategy for the period 2021–2030 and a vision to 2050.
- ASEAN Guidelines for Agroforestry Development (2018): Adoption of regional agroforestry guidelines.
- Identification of Agroforestry contribution in the Vietnam NDC (2018-2020): Highlights agroforestry's role in national climate goals.
- Spatial Characterized Agroforestry (SCAF) online database (2013 - 2014): Spatial database for agroforestry initiatives.
- Decisions 2477/QD-BNN-HTQT (2016) and 3753/QD-BNN-HTQT (2021): Structure the national Agroforestry Working Group (2016 - present).

Water and Environmental Management

- Change in sluice gate operations for managing salinity in the Delta (2003-today).
- The Mekong Dams Observatory and database (2011-2018): Provides data on dam impacts in the Mekong.
- The Greater Mekong Forum on Water, Food, and Energy (2015-18): Addresses inter-sectoral challenges in the Mekong region.
- Decision No. 1383/QD-TTg (2020): Implementation of national water accounting.
- Decision No. 64/2014/QD-TTg (2014): Organization of resettlements for hydropower dam projects influenced by the World Commission on Dams (WCD, 1997–2001).
- Companion Modeling Approach (ComMod): Identifies resource-sharing scenarios between actors.

Nutrition and Health

- Agriculture, Nutrition, and Health (ANH) Academy: Supports research and capacity building.
- Zero Hunger National Action Program (NAP, 2018–2025): Contributions to the framework and monitoring.

Livestock and Human Health

- Decision No. 50/2014/QD-TTg (2014): Policies on subsidies for farmer household animal husbandry improvements (2015–2020).
- Decision No. 5273/QD-BNN-HTQT (2016): National Vietnam One Health Strategic Plan (OHSP) for Zoonotic Diseases (2016–2025).
- Vietnam Taskforce for Food Safety Risk Assessment (2012-today): Focus on food safety improvements.
- Risk-based approach to Food Safety management (2017): Adopted by the Vietnam government.
- Vietnam One Health Research Centre (2017-today): Promotes interdisciplinary research on health.

Rice Sector

- Rice Natural Resource Management practices (2011-today): Mitigation mechanisms in Vietnam's GHG policies.
- Decision No. 1898/QĐ-BNN-TT (2014-2020): Restructures Vietnam's rice industry.
- Sustainable Rice Platform (2011-today): Mainstreams results of IRRI research.
- Circular No. 19/2019/TT-BNNPTNN (2019): Regulations on the collection, treatment, and use of crop by-products.
- The ASEAN Rice Net (2019-today): Regional rice research collaboration.
- Council for Partnership on Rice Research in Asia (CORRA, 1996-today): Supports rice research partnerships in Asia.

Cassava Sector

- Decree 1605/BVTV-TV (2017): Technical Process for the Prevention of Cassava Mosaic Disease (CMD).

Coffee Sector

- Decision 2085/QĐ-BNN-TT (2016): Replanting process for Robusta coffee.

Other

- Decision-35/2008/QD-BNN (1997-2008): Recognizes, encourages, and regulates quality conditions for informal seed systems.

Appendix B. Survey Weights

Population Weights

The weights are calculated by GSO at the EA level (variable *wt*45), meaning that all households within the same EA (usually at the same size as a village) receive the same weight[93]. These are frequency weights that indicate how many households in the EA are represented by a particular surveyed household. Throughout this report, several adoption rates, calculated as the percentage of adopters, are reported at various geographical levels. For instance, to calculate the weighted adoption rate for a given EA, the sum of weights for adopter households must be divided by the sum of weights for all households within the EA. The formula for calculating the adoption rate at the EA level is as follows:

$$EA\, weighted\, adoption\, rate_{pk} = \frac{\sum_{i=1}^{I}(AD_{pji} \times wt45_{pji})}{\sum_{i=1}^{I}(wt45_{pji})}$$

Where *i* corresponds to the household, *p* corresponds to the given province (*P* is the total number of provinces, which is 63), *j* to the given EA where household *i* locates (*j* ranges from 1 to *J* denoting the total EAs in province p). AD_{pji} is a dummy variable equal to one if the household is an adopter and $wt45_{pji}$ is the weight assigned to the EA *j* where household *i* locates. This formula can be generalized to other geographical levels, such as provinces or regions, by adjusting the sums in both the numerator and denominator for the specific level. Therefore, the formula for calculating the national weighted adoption rate is:

$$ational\, weighted\, adoption\, rate = \frac{\sum_{p=1}^{P}\sum_{j=1}^{J}\sum_{i=1}^{I}(AD_{pji} \times wt45_{pji})}{\sum_{p=1}^{P}\sum_{j=1}^{J}\sum_{i=1}^{I}(wt45_{pji})}$$

Rice-growing Households Weights

Adjustments to the weights for rice-growing households were necessary for two key reasons. Formerly, the VHLSS surveys were not specifically designed to target rice-growing households since they attempt to cover all aspects of a household’s living standards, and the GSO-designed weights were prioritized to calculate the Consumer Price Index (CPI). Since the number of households selected per EA is fixed regardless of the proportion of rice-growing households, this subsample may be underrepresented or overrepresented in certain EAs.

Latterly, Viet Nam's economy has undergone significant structural changes in recent years, with rapid growth in non-agricultural sectors like industry (Thu et al., 2016). This shift has driven

[93] Nevertheless, in equation notation, the subscripts *j* and *i* emphasize that the calculations are performed at the household level.

labor out of agricultural sectors, leaving a decrease in the number of rice-growing households. According to GSO, the number of rice-growing households decreased from 8,512,566 in 2016 to 7,976,267 in 2020, reflecting an annual growth decrease of about 1.61%. Thus, the projected number of rice-growing households was 7,720,924 in 2022 and 7,596,334 in 2023. Nevertheless, using the VHLSS weights, the total estimated number of rice-growing households for these years is 6,755,555 and 6,882,354, respectively. This discrepancy indicates an underrepresentation of rice-growing households in the VHLSS survey design.

To address both the underrepresentation in overall numbers and the misrepresentation of rice-growing households within each commune, two adjustments were implemented. First, it is assumed that the correct representation implies that the probability of finding a rice-growing household in a commune, is φ_k. This proportion is estimated using data from the 2019 Census to determine the total number of households in each commune, and from the 2016 Rural, Agricultural, and Fishery Census to identify the total number of rice-growing households within the communes[94]. Instead, in the VHLSS samples, it is observed that in each commune, an x_m fraction of households grow rice. Then, a constant α_m is determined for each commune to equalize this proportion. This can be expressed as:

$$\alpha_{Rice,m} = \frac{Rice{-}growing\ households\ census_m / Total\ households\ census_m}{Rice{-}growing\ households\ sample_m / Total\ households\ sample_m} = \varphi_m / x_m.$$

This constant is multiplied to the weights to correct for misrepresentation within communes ($\alpha_{Rice,m} \times wt45_m$). If the constant is greater than 1, it indicates that the commune is underrepresented before the adjustment. Conversely, if it is less than 1, the commune is overrepresented. Second, to address discrepancies due to structural changes in the overall numbers, a common factor k_{Rice} to all communes was defined to ensure that the total sum of the weights, after the adjustment introduced by $\alpha_{Rice,k}$, aligns with the projected numbers of rice-growing households for 2022 and 2023. The formula to calculate this constant is:

$$k_{Rice} = \frac{R_{Rice}}{\sum_{m=1}^{M} \alpha_{Rice,m} \times wt45_m}$$

In this formula, R_{Rice} corresponds to the projected number of households that grow rice in either 2022 or 2023, based on the GSO's 2016 Rural, Agricultural, and Fishery Census. By combining these two adjustments, the formula to calculate the adjusted weights for a rice-growing household i in the commune *m* is:

$$wt_{rice,m} = \frac{R_{Rice}}{\sum_{m=1}^{M} \alpha_{Rice,m} \times wt45_m} \times (\alpha_{Rice,m} \times wt45_m)$$

[94] Since total numbers of (rice-growing) households are not available at EA-level, all weights were calculated at the commune level.

Where, $wt_{rice,im}$ corresponds to the adjusted weights for the rice-growing households. Therefore, the national weighted adoption rate, for a specific innovation related to rice-growing activities, will be determined by:

$$National\ adoption\ rate\ = \frac{\sum_{p=1}^{P}\sum_{m=1}^{M}\sum_{i=1}^{I}(AD_{pmi}\ \times\ wt_{rice,pmi})}{\sum_{p=1}^{P}\sum_{m=1}^{M}\sum_{i=1}^{I}(\,wt_{rice,pmi})}$$

The variable weight_final_rice is available in both datasets present in the Repository.

Rice-growing Households Weights (DNA sample)

The sample size for rice DNA was assigned without regard to the population size of rice-growing households within each commune, leading to an unbalanced sample frame, introducing under- and over-sampling issues across EAs. To address the issue, adjusted weights for the rice DNA subsample were calculated following the same approach as the rice-growing households weights. First, a constant to address the misrepresentation within communities of these DNA rice households is calculated as:

$$\alpha_{DNA\ Rice,m} = \frac{Ricegrowing\ households\ census_m / Total\ households\ census_m}{DNA\ rice\ households_m\ / Total\ households\ sample_m}$$

Where *DNA rice households*$_m$ corresponds to the number of households where rice fingerprinting was conducted in the commune m. Second, the overall underrepresentation is addressed by calculating $k_{DNA\ rice}$, a common factor that assures the total sum of the weights will be equal to the total projected rice-growing households in 2022 and 2023.

$$k_{DNA\ rice} = \frac{R_{Rice}}{\sum_{m=1}^{M}\alpha_{DNA\ rice,m} \times wt45_m}$$

By combining the two adjustments the formula to compute the DNA rice weights is:

$$wt_{DNA\ rice,m} = \frac{R_{Rice}}{\sum_{m=1}^{M}\alpha_{DNA\ rice,m} \times wt45_m} \times (\alpha_{DNA\ rice,m} \times wt45_m)$$

The national and subnational adoption rates were calculated using the same approach as for the rice-growing households, although using the adjusted weights for the rice DNA subsample. The variable weight_rice_DNA can be found in the VH22_data.csv file present in the Repository.

Cassava-growing Households Weights (DNA sample)

Similar to rice, the sampling design led to the under- or overrepresentation of cassava-growing households within communes. Following a similar approach to address the under and overrepresentation within the commune, a constant is calculated[95]:

$$\alpha_{Cassava,m} = \frac{Cassava\ households\ census_m / Total\ households\ census_m}{DNA\ Cassava\ households\ sample_m / Total\ households\ sample_m}$$

Second, to correct discrepancies caused by structural changes in the overall household numbers, a common factor $k_{Cassava,m}$ was calculated. This factor ensures that the total sum of the weights corresponds with the projected number of households for 2022 and 2023. The formula for calculating this common factor is:

$$k_{Cassava} = \frac{R_{Cassava}}{\sum_{m=1}^{M} \alpha_{Cassava,m} \times wt45_m}$$

In this formula, $R_{Cassava}$ corresponds to the projected number of households that grow the crop in either 2022 or 2023. Therefore, the formula to calculate the adjusted weights for household *i* where DNA samples of cassava were taken in the commune m is:

$$wt_{\ cassava,m} = \frac{R_{Cassava}}{\sum_{m=1}^{M} \alpha_{Cassava,m} \times wt45_m} \times (\alpha_{Cassava,m} \times wt45_m)$$

The variable weight_cass can be found in the VH23_data dataset present in the Repository.

An overview of the weighting approach adopted for each of the 17 innovations is presented in Table 22.

[95] Data sources used to calculate the cassava constants are available in the Repository.

Table 22: Overview of the weighting approaches used for each innovation

Section	Innovation	Weights	Variable
5	Genetically Improved Farmed Tilapia (GIFT)-derived strains weight_gift	Population weights	
6	CGIAR-related Cassava varieties	Cassava-growing households weights (DNA sample)	weight_cass
6	CMD-resistant Cassava varieties	Cassava-growing households weights (DNA sample)	weight_cass
6	CGIAR-related Rice varieties	Rice-growing household weights (DNA sample)	weight_rice_DNA
6	Salt-tolerant Rice varieties	Rice-growing household weights (DNA sample)	weight_rice_DNA
7	Climate-Smart Mapping and Adaptation Planning	Rice-growing households weights	weight_final_rice
7	Agro-Climatic Bulletins	NA	NA
8	Payments for Forest Environmental Services	Census estimate	NA
9	Laser Land Leveling	Rice-growing households weights	weight_final_rice
10	Drum Seeder	Rice-growing households weights	weight_final_rice
9	Combine Harvester	Rice-growing households weights	weight_final_rice
9	Mini-Combine Harvester	Rice-growing households weights	weight_final_rice
9	Rice Straw Baler	Rice-growing households weights	weight_final_rice
10	Off-field Straw Management practices	Rice-growing households weights	weight_final_rice
10	'Three Reductions, Three Gains' (3R3G) and 'One Must Do, Five Reductions' (1M5R)	Rice-growing households weights	weight_final_rice
10	Alternate Wetting and Drying	Rice-growing households weights	weight_final_rice
10	Sustainable Water Use for Coffee Production	Population Weights	weight_coffee

Note: NA = non-available

Appendix C. Regression Models and Variable Definitions for CS-MAP Analysis

Our dataset comprises household-level observations indexed by i (household), d (district), and t (year). The dependent variable was hhplantdate, which represented each household's self-reported planting date. The key independent variables include the following:

- $extremeyear_{dt}$: a binary indicator of whether the year was classified as extreme (1 if extreme, 0 otherwise). The year was considered normal if that province's agricultural plan mentioned a weak El Niño or did not mention El Niño. It was considered extreme if the plan mentioned that a moderate or strong El Niño event was forecast for the year.
- $advicedate_{dt}$: the planting date that would have been recommended in province p in year t, if the CS-MAP recommended planting dates were followed, based on the forecast about the year.
- Year dummy variables for 2022 and 2023

In Section 7, we present three OLS models.

Our baseline model regresses hhplantdate on advicedate, the recommended planting date from CS-MAPs. This model evaluates whether the CS-MAP recommended date (normal or extreme) is associated with the household planting date. A significant positive estimate of β_1 would indicate that households' planting dates correlate with the dates recommended as per the CS-MAPs.

$$hhplantdate_{idt} = \beta_0 + \beta_1 \cdot advicedate_{dt} + \epsilon_{idt}$$

Model 2 extends the baseline by incorporating year indicators to account for potential time-related changes across the study period. This helps isolate the association between household planting dates and CS-MAP-recommended dates from broader trends or shocks in each year. Once again, a significant positive estimate of γ_1 would indicate that households' planting dates correlate with the dates recommended as per the CS-MAPs.

$$hhplantdate_{idt} = \gamma_0 + \gamma_1 \cdot advicedate_{dt} + \gamma_2 \cdot Year2022_t + \gamma_3 \cdot Year2023_t + \epsilon_{idt}$$

Model 3 adds an interaction term between advicedate and the *extreme year* dummy variable. This model examines whether the association with CS-MAP recommendations differs in extreme years against normal years. If farmers respond to recommendations more proactively when severe weather is forecast, we would find δ3>0.

$$hhplantdate_{idt} = \delta_0 + \delta_1\, advicedate_{dt} + \delta_2 \cdot extremeyear_{dt}$$
$$+ \delta_3 \cdot (advicedate_{dt} \times extremeyear_{pt}) + \delta_4 \cdot Year2022_t + \delta_5 \cdot Year2023_t + \epsilon_{idt}$$

Appendix D. Measurement and Categorization of 3R3G Components

1R: Seed Rates

In VHLSS 2023, we asked households separate questions about the area of their largest plot and the quantity of seeds they planted on this plot in the past Winter-Spring season. Plot areas were reported in contextually relevant units in the local language. However, area units are heterogeneous across regions: the same word may refer to different sizes in different regions. For example, a "sao" in the North refers to 360 square meters, but it is equivalent to 500 square meters in the Central region and 1,000 square meters in the South. Similarly in the South, a "cong" can be either 1,000 square meters (same as "sao", known as "Cong Dat Nho [Smaller "Cong"]) or 1,300 square meters (so-called "Cong Dat Lon" [Larger "Cong"]). We used the local context in each case to standardize units before the analysis.

For seed rate data, the main challenge is that area units are often missing. For approximately 4% of the households, the area units of the largest plot are missing. We therefore addressed this issue using the following strategy – first, we filled in the units for as many households as possible by using the area units from the fertilizer module where area units were also captured; those that still remained missing were filled in with the modal area unit in the EA of the household; and finally, we filled in with the modal area unit if the household's commune.

2R: Fertilizer

Farmers were first asked to list all their applications of fertilizer, and then asked about the quantity of fertilizer applied, and the timing of each application. To identify timing, we used a visual aid (Annex D) that showed different growth stages of the rice plant and asked farmers to indicate the growth stage when the application was carried out. This method helps reduce recall bias in the reporting of fertilizer or pesticide use (Stevenson et al., 2019).

A key indicator to evaluate the amount of greenhouse gas emission from fertilizer use is the amount of nitrogen applied. To calculate this, it is crucial to know the types of fertilizer used by farmers. In our survey, we ask households to provide the name and composition of each fertilizer used in the previous season. For Urea, Phosphate, and Potassium (known as Kali in Vietnamese) fertilizers, there was unanimous agreement on the amount of Nitrogen in each: Urea contains 46% Nitrogen, while Phosphate and Potassium do not contain Nitrogen.

However, farmers apply various other types of fertilizers, including mixed NPK (Nitrogen, Phosphate, Kali/Potassium), mixed NP (Nitrogen and Phosphate), or DAP (Diammonium phosphate), to name a few. Although we asked farmers to provide a specific formula for these fertilizers, the data show that they often misidentified the formula of the fertilizer they had used, for example reporting that they used mixed NPK but then providing the formula for urea.

These cases were manually recoded on the assumption that they were reporting the name of the fertilizer correctly but had misreported its formula.

Another challenge is the presence of 'Deep Fertilizer Placement', where the fertilizer is encapsulated before being placed in the soil. It is difficult to identify the Nitrogen amount when farmers use this method of application. We therefore impute a common 25-0-27 NPK formula to all households that report this method. It is also common for farmers to refer to fertilizers by their brand names. For example, "buffalo head" refers to a type of fertilizer produced by the Binh Dien company, which uses a buffalo head as its logo. Although most of this company's products are NPK fertilizers, the exact formula cannot be determined as it varies across different products. Besides, farmers often mix different fertilizers in a single application, making it difficult to identify the specific formula used. These cases are left as "other type of fertilizer" with an unknown Nitrogen component. Overall, values are imputed for 0.6% of the observations in the dataset, while 4.3% of the observations are classified as "unknown".

3R: Pesticide

Just as in the fertilizer module, farmers were asked about their applications of insecticides and fungicides chronologically with the help of the visual aid: how many applications, the stages of the rice when the applications take place, and how many drugs they mix per application.

The term "pesticides" in Vietnamese normally refers to all plant protection drugs, including insecticides, fungicides, rodenticides, herbicides, and molluscicides. In this module, we only collected applications of insecticides and fungicides, in accordance with the 1M5R/3R3G recommendations. Separate questions were asked about the number of applications for each category (plant protection drugs versus insecticides and fungicides) to avoid misinterpretation.

As we saw in Table 4 the 3R3G/1M5R recommendations are also about the timing of these applications, for example, no applications for 40 days after transplanting or after flowering. Since different rice varieties grow at different rates, the 40-day window could fall into different stages for different varieties. We therefore simplify by considering the reproductive period, which lasts from panicle initiation to flowering stage, as the most likely window for the first 40 days after sowing.

Appendix E. Overview of Variables Associated with the Adoption of Agricultural Innovations, Including Region-level Fixed-effects

Table 23: Overview of variables associated with adoption of agricultural innovations

Innovation	Age of HH head (std)	Annual income (std)	HH head from an ethnic minority	HH Head highest completed grade (std)	HH head is female	Household has internet	Household size (std)	Main road is asphalt	Total agricultural land (in ha)
Aquaculture and capture fisheries									
GIFT-derived tilapia strains	0.00	0.00	-0.17 *	0.03	-0.01	-0.07	0.02	NA	0.02
Breeding innovations									
CGIAR-related cassava varieties	0.00	-0.09 *	0.11	-0.02	-0.15 *	0.26 ***	0.07 **	NA	-0.02
CMD-resistant cassava varieties~	0.07 **	0.01	0.11	0.04	0.11 *	-0.12 *	0.01	NA	0.01
CGIAR-related rice varieties	0.01	0.03	0.06	0.01	0.04	0.05	-0.03	-0.08	0.00
Salt-tolerant rice varieties~	-0.01	-0.03	0.06	-0.02	-0.06	0.1 **	0.00	-0.11	0.03
Climate Change Adaptation Options									
CS-MAP	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mechanization									
Laser land leveling	-0.01	0.01 *	-0.03 **	0.00	-0.01	0.00	0.00	NA	-0.01 **
Seed blower	-0.01 **	0.00	-0.03 ***	0.00	0.01 *	0.00	0.00	NA	0.02 ***
Combine harvester	0.03 ***	0.04 ***	-0.39 ***	0.01 **	0.02 *	0.04 ***	-0.01 **	NA	-0.03 ***
Rice straw baler	0.00	0.01	-0.01	0.00	-0.01	0.00	0.00	NA	0

Innovation	**Age of HH head (std)**	**Annual income (std)**	**HH head from an ethnic minority**	**HH Head highest completed grade (std)**	**HH head is female**	**Household has internet**	**Household size (std)**	**Main road is asphalt**	**Total agricultural land (in ha)**
Sustainable Intensification practices									
Components of 1 Must-Do, 5 Reductions									
1R: Seed rate	0.01	0.01	0.01	0.03 ***	0.02	0.00	-0.01 **	NA	-0.01
2R: Fertilizer use	0.01	0.02 **	-0.02	0.02 **	0.03	-0.01	0.01	NA	0.00
3R: Pesticide use	-0.02 **	-0.01	0.11 ***	0.00	0.02	-0.04 **	0.02 **	NA	0.01 **
3R3G	0.00	0.00	0.04 **	0.01	0.01	-0.02 *	0.00	NA	0.00
Alternate Wetting and Drying	0.01 **	0.00	0.01	0.01 *	-0.01	0.01	-0.01 *	NA	0
Drum seeder	0.00	0.00	0.00	0.00	0.00	0.00	0.00	NA	0.003 **
Sustainable Water for Coffee Production	NA	NA	NA	NA	NA	NA	NA	NA	NA

Note: *** p < 0.01; ** p < 0.05; * p < 0.1. NA = Non-available, data was collected in a single region. . ~ = Traits related to cassava-mosaic disease tolerance, salt tolerance, and submergence tolerance are also found in land races/non-CGIAR-related varieties. Each cell displays the coefficient estimate from a multivariate regression of the row variable on all column variables. The dependent variable is a dummy variable equal to one if the household is an adopter. Standard errors were clustered at the EA level. Cells are colored if the estimated coefficient is statistically different from zero. Green cells indicate a positive relationship, whereas red cells show a negative relationship. All estimates are based on the most recent year for which this innovation was collected in the VHLSS. Annual income and total agricultural land were winsorized at the 99th percentile. Age, annual income, education, and household size were standardized using z-scores. NA indicates that data for this innovation was collected for one region only. The analysis excludes innovations adopted by fewer than 3 percent of households.

Appendix F. Digital Tools

The field of digital tools for sustainable agricultural and environmental practices encompasses ten distinct innovations that support climate change mitigation, crop management, and health outcomes in various contexts. Some tools were designed for policymakers, while others directly targeted farmers as a user group. While more details are provided in the Repository, this section summarizes the innovations that are available in Viet Nam.

1. Plant Village Food Recognition Assistance and Nudging Insights (FRANI). The FRANI Application is an AI-driven smartphone application. Designed to identify food types and serving sizes, it enhanced dietary evaluations for teenage girls living in Vietnamese cities under a project funded by the Botnar Foundation (2020-2024). In an IFPRI evaluation, efficiently measuring daily nutrient consumption often surpassed the performance of the 24-hour-recall method.
2. Plantix[96]. This smartphone application is a tool for plant health diagnostics developed by PEAT (Germany). It can identify approximately 400 pests and diseases in over 30 crops through advanced recognition techniques. In 2022, researchers from CIP and IFPRI carried out a trial involving 12 vegetable farmers in the Van Duc commune, located in the Gia Lam district of Hanoi Province. The app has seen widespread adoption, boasting over 10 million global downloads.
3. Rice Doctor[97]. This smartphone application, originally developed in Odisha, India, was designed to assist farmers in detecting and controlling rice pests and diseases. It was created under the Increasing Productivity of Rice-Based Cropping Systems and Farmer's Income in Odisha project in 2019 and provides practical advice on maintaining the health of rice crops. The application is available on both Google Play and Apple Store, with over 10,000 users worldwide at the time of writing.
4. RiceMo and COMPARE. Developed under the CGIAR CCAFS CRP (2019-2021), these two innovations are practical tools for policymakers. RiceMo is a prototype tool that standardizes the measurement, reporting, and verification (MRV) of emissions in rice cultivation. It integrates GIS to generate data and maps that support climate-conscious planning in Can Tho Province. RiceMo facilitates climate-responsive action planning and decision-making. COMPARE[98] is an innovation that applies a cost-benefit analysis to mitigation strategies in rice production. Developed using a participatory approach, this highlights the integration of economic analysis with environmental sustainability. The tool is available online and is accompanied by a Vietnamese user manual, promoting ease of use and local adoption.

[96] Plantix: The app is available at https://play.google.com/store/apps/details?id=com.peat.GartenBank&hl=en&referrer=utm_medium%3Dweb_en%26utm_campaign%3Dhomepagetops_en%26utm_content%3Den%26utm_term%3Dhomepagetops%26utm_source%3Dweb_landingpage_en

[97] Rice Doctor: http://www.knowledgebank.irri.org/decision-tools/rice-doctor.

[98] RiceMo: https://www.google.com/url?q=https%3A%2F%2Fbit.ly%2FCompareDownload&sa=D&sntz=1&usg=AOvVaw1NbDTrktOnhacF806rXA0Q

5. SECTOR[99], CF-Rice, MapAWD. Also developed under the CCAFS CRP (2019-2021), these Excel-based tools provide practical solutions for monitoring, managing, and reducing GHG emissions from rice cultivation. The target users are policymakers in Viet Nam. SECTOR (Source-selective and Emission-adjusted GHG CalculaTOR for Cropland) uses tailored input data on crop management practices such as 1M5R and Alternate Wetting and Drying (AWD) to estimate GHG emissions from rice fields based on the IPCC Tier-2 approach. CF-Rice[100] is an Excel-operated carbon footprint calculator specifically for rice. This tool enables users to calculate greenhouse gas emissions based on factors such as crop yields and management inputs, utilizing the IPCC equations. MapAWD[101] was designed to evaluate the biophysical suitability of AWD, a water-saving technique for rice production. It allows users to input relevant data and generate maps that illustrate areas best suited for implementing AWD.
6. Terra-I. Terra-I is a satellite-based tool that uses Sentinel and Landsat data to monitor deforestation and vegetation changes almost in real time. This tool has been incorporated into five projects designed to increase the participation of civil society organizations (CSOs) and Local Communities (LCs) in emission reduction programs. Specifically, it has been utilized in various initiatives including the UN-REDD Phase II (2017-19) in Di Linh district, Lam Dong province; the ER-PSRD (2019) in Tuong Duong district, Nghe An province; the Coffee Agroforestry and Forest Enhancement for REDD+ (CAFÉ-REDD) project (2020) in Lac Duong district, Lam Dong province; the REDD+ programs in Viet Nam (UE, 2021-23) in Ky Son and Tuong Duong districts, Nghe An province; and the Sustainable Landscape Management project in Lam Dong province (Di Linh and Lac Duong districts) and Dak Nong province (Dak G'Long and Dak R'Lap districts) from 2022-26. The upscaling of the tool was ongoing at the time of writing.
7. WEFOCOS Climate Advisory Application for Coffee Farmers (rtWork)[102]. Developed between 2018 and 2022, this smartphone application was designed to assist coffee farmers by providing weather predictions and farm management guidance. In 2021, the app was distributed to a selected group of 140 active users across four districts in the Dak Lak and Lam Dong provinces. This was done under two projects: Improved Business through Seasonal Forecasting for Coffee Systems in Viet Nam (NCF, 2018-22), and Weather Forecasting for Coffee Sustainability (WEFOCOS).

[99] Sector tool: https://www.google.com/url?q=https%3A%2F%2Fbit.ly%2FSECTORdownload&sa=D&sntz=1&usg=AOvVaw1gdMlWxFyZJ7e1OVyvtmD2

[100] CF-Rice tool: https://www.google.com/url?q=https%3A%2F%2Fbit.ly%2FCFRicedownload&sa=D&sntz=1&usg=AOvVaw0YEVlyY_MlUDStR79UmHrJ

[101] MapAWD: https://www.google.com/url?q=https%3A%2F%2Fbit.ly%2FMapAWDDownload&sa=D&sntz=1&usg=AOvVaw3s7pI8ci4CwtQGwWbQGtuY

[102] rtWork: https://play.google.com/store/apps/details?id=vn.rta.rtwork&hl=vi&gl=US

Appendix G. Livestock and Human Health

We identified eight innovations, and two policy influences related to livestock and human health. We summarize these findings here with more details provided in the stocktake and policy influence documents.

1. Food Safety Practices for Pork Retailers and Slaughterhouses. Two innovations have focused on improving food safety in pork retail and slaughterhouse operations. For pork retailers, better hygiene standards were applied to ensure safer food-handling practices. In slaughterhouses, off-ground slaughter methods, such as using metal grids or tables, have been introduced to enhance hygiene and reduce contamination risks.
2. Eco-Efficient Livestock-Crop Integration and Livestock-Based Interventions. In the Chieng Ching and Chieng Luong communes, located in the Mai Son district of Son La province, livestock-based interventions were implemented to integrate livestock and crop production. This system approach, part of the CGIAR Research Program on Livestock, aims to increase productivity, improve animal husbandry practices, enhance environmental sustainability, and facilitate market access for local farmers, thereby contributing to more sustainable and eco-efficient agricultural practices.
3. Conservation and Sustainable Utilization of Indigenous Farm Animal Genetic Resources (FAnGR). This innovation focused on developing and enabling breeding tools for low-input livestock systems. The tools aimed to conserve and sustainably use indigenous farm animal genetic resources, support biodiversity, and improve resilience in local production environments.
4. Zoonoses and Hotspot Mapping. Zoonotic disease hotspot mapping was carried out using predictive models to forecast the spread of diseases such as Japanese encephalitis, leptospirosis, and classical swine fever. The models also identified the responsible vectors, providing valuable information for targeted interventions in disease control and prevention.
5. Certification and Branching of the Ban Pig Breed. In Da Bac District, Hoa Binh Province, a certification and branding initiative was undertaken for the Ban pig breed. This effort aimed to enhance the market value of the breed and improve the livelihoods of local farmers by positioning the Ban pig as a premium product.
6. Rope-Based Oral Fluid Collection Method for African Swine Fever (ASF) surveillance. A rope-based method for collecting oral fluids was introduced as a noninvasive technique to detect African swine fever in remote areas (Lee et al., 2021). This innovation provided a practical and cost-effective solution for ASF surveillance, improving early detection capabilities.
7. Improving Chicken Strains for Smallholder Farmers. Research was conducted to define the preferred breeds and phenotypes of chickens that smallholder farmers could adopt to increase productivity. Although this innovation is still in the research phase, it aims to develop genetically superior strains adapted to diverse agroecological zones.
8. Portable Ozone Machines for Wet Market Disinfection. Portable ozone machines were tested as a method for wet-market disinfection, specifically in the Soc Son slaughterhouse.

However, the results indicated that this approach was not sustainable, limiting its potential for broader application in improving market hygiene.

These eight innovations show the potential role that CGIAR centers have played in advancing livestock health and sustainability. Most innovations were not included because they target public health authorities (innovations 4,6 above), breeders (innovation 3), were implemented on a small scale (e.g. innovations 2,5), or were still at the research stage (innovations 7-8).

Appendix H. Household vs. Community-Level Analysis of Measurement Errors in Mechanization Device Use

When collecting data on adoption rates, stakeholders and researchers are faced with different methodological choices. On one side, there is the option of conducting household surveys, which, while still prone to measurement errors, offers the potential for precise and comprehensive data collection. These surveys can capture detailed information directly from the farmers, allowing for in-depth analysis of adoption patterns and barriers. On the other hand, a less costly option involves expert elicitation, which leverages the knowledge and experience of local experts, such as community leaders, to estimate adoption rates. Although this method is more economical and faster to implement, it may introduce biases related to the expert's perceptions or the limited scope of their observations. The choice between these methods represents a cost-benefit analysis, therefore shedding light on the disparities between these two methods, may be a valuable input for stakeholders and researchers.

One notable application of expert elicitation in Viet Nam is the use of the Delphi[103] method to assess agricultural practices and identify constraints related to crop varieties. A study on mungbean in Southeast Asia employed expert elicitation to quantify the adoption of improved varieties and agricultural practices, demonstrating the effectiveness of this method in gathering expert opinions at subnational levels and aggregating them to inform national policies (Sequeros et al., 2021). Moreover, the International Center for Tropical Agriculture (CIAT) collaborated with research and development partners across nine countries in South and Southeast Asia to document cassava variety adoption. Cassava experts from Viet Nam, among other countries, participated in country-specific workshops to discuss the usage of different cassava varieties and estimate their adoption at both major production zones and national levels. This collaborative effort drew from diverse disciplines, including breeding, seed production, extension, economics, and plant protection, providing many countries with their first adoption estimates for cassava. The broader the range of disciplines and production areas represented, the more consistent and reliable the resulting estimates were (Labarta, Wossen, & Phuong Le, 2017).

On the other hand, Tsusaka et al. (2015) demonstrated the effectiveness of expert elicitation in assessing the adoption of improved rice varieties in South Asian countries, highlighting the reliability of expert panels in providing estimates that align with household survey data. By comparing information from expert elicitation assessment and household surveys, it was found that organized panels of agricultural experts can provide reliable estimates of the area planted for modern varieties of rice.

[103]Delphi Method is a systematic, iterative procedure that collects and refines insights from a group of subject-matter experts. The purpose of the Delphi Method is to methodically gather, combine, and reach consensus on expert opinions.

In 2024, the Viet Nam Household Living Standards Survey (VHLSS), in collaboration with CGIAR-SPIA, has been collecting data at the community level to understand the dynamics and mechanisms operating within these communities. To achieve this, an additional questionnaire was developed to gather specific information from community representatives who respond on behalf of their communities. This questionnaire included a section specifically focused on mechanization, investigating the use of several innovations from SPIA stocktake, namely drum seeders, mini-combine harvesters, combine harvesters and rice straw balers. Community representatives were asked about the adoption of these innovations, the percentage of farmers using them, and the nature of the providers offering these rental services.

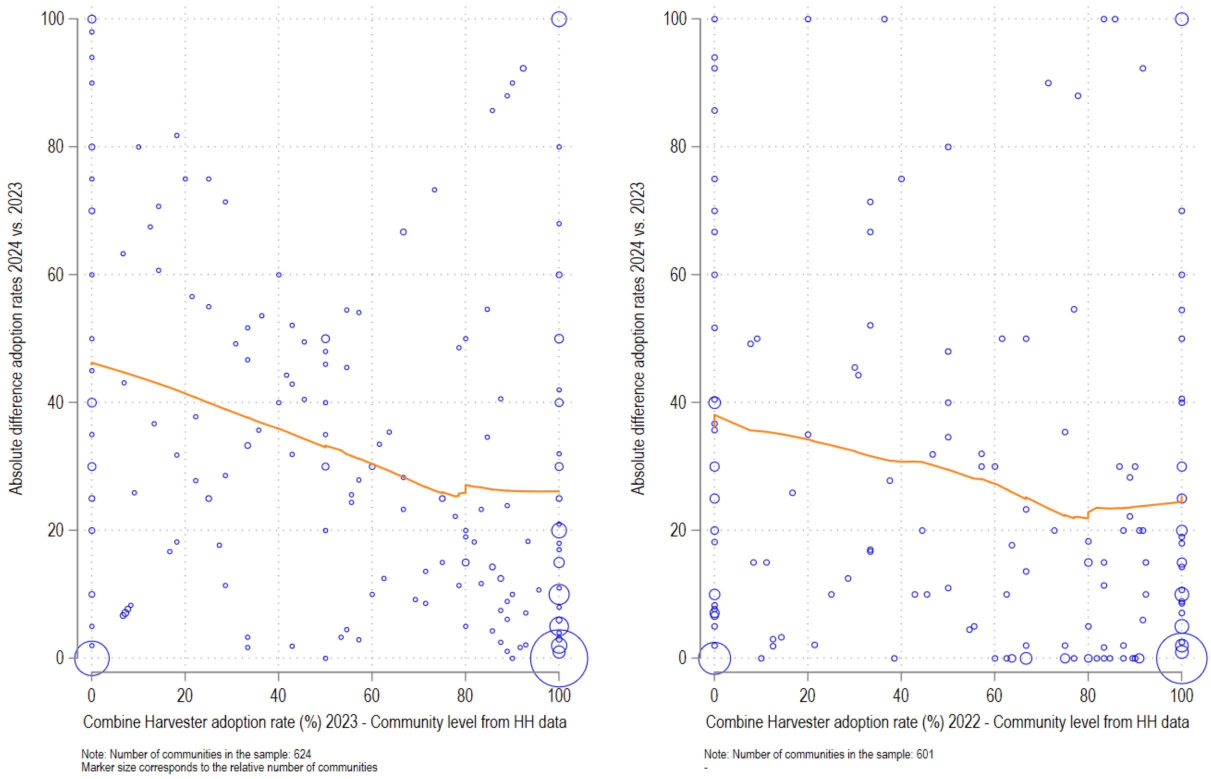
The community-level data, available for the first, second and third quarters of 2024 at the time of this report's release, presents an interesting opportunity to analyze the discrepancy that may emerge between these two sources. Since only one representative provides information on behalf of the entire community, the responses are subjective and potentially prone to error. For instance, possible explanations could be that community representatives may not be fully aware of all the decisions made by farmers, weak communication channels within the community can lead to inaccurate reporting, or social desirability bias might influence the representatives' responses.

It is important to bear in mind that one limitation of this analysis is the inability to compare adoption rates for the same year. Therefore, the best possible comparison is between the 2024 community data and the 2022 and 2023 household-reported data. A fair comparison under this approach relies on the assumption that adoption rates do not vary significantly each year. These potential inaccuracies raise questions about the disparity between the adoption rates reported by community representatives and those observed in household-level data. Box 1 discusses the findings from comparing these two sets of adoption rates for two selected CGIAR-related innovations: first, the Combine Harvester, which shows a wide variability in adoption rates across communes; and second, the rice straw baler, which presents lower adoption rates.

The absolute difference between the adoption rates reported by community representatives in 2024 and those reported by households in either 2022 or 2023 is used to measure discrepancies. This difference is plotted on the y-axis, while the x-axis represents the adoption rates reported by households. To facilitate the interpretation, the size of each marker reflects the relative number of communes. A smoothed line is also included to estimate the overall trend between each pair of adoption rates.

Notably, in both pair of years, there is a cluster of a sizeable group of communities with a full adoption rate of combine harvesters reported by the households and an absolute difference equal or close to zero. This indicates that the reported adoption rates are highly consistent, with minimal discrepancies. Near the origin, there is a relatively large group of communities with no discrepancies and where the adoption of combine harvesters has not yet occurred. Remaining communities are more dispersed, although the smoothed line suggests a downtrend in the absolute difference as the adoption rates reported by households increase, indicating that higher household-reported adoption rates are generally associated with smaller discrepancies.

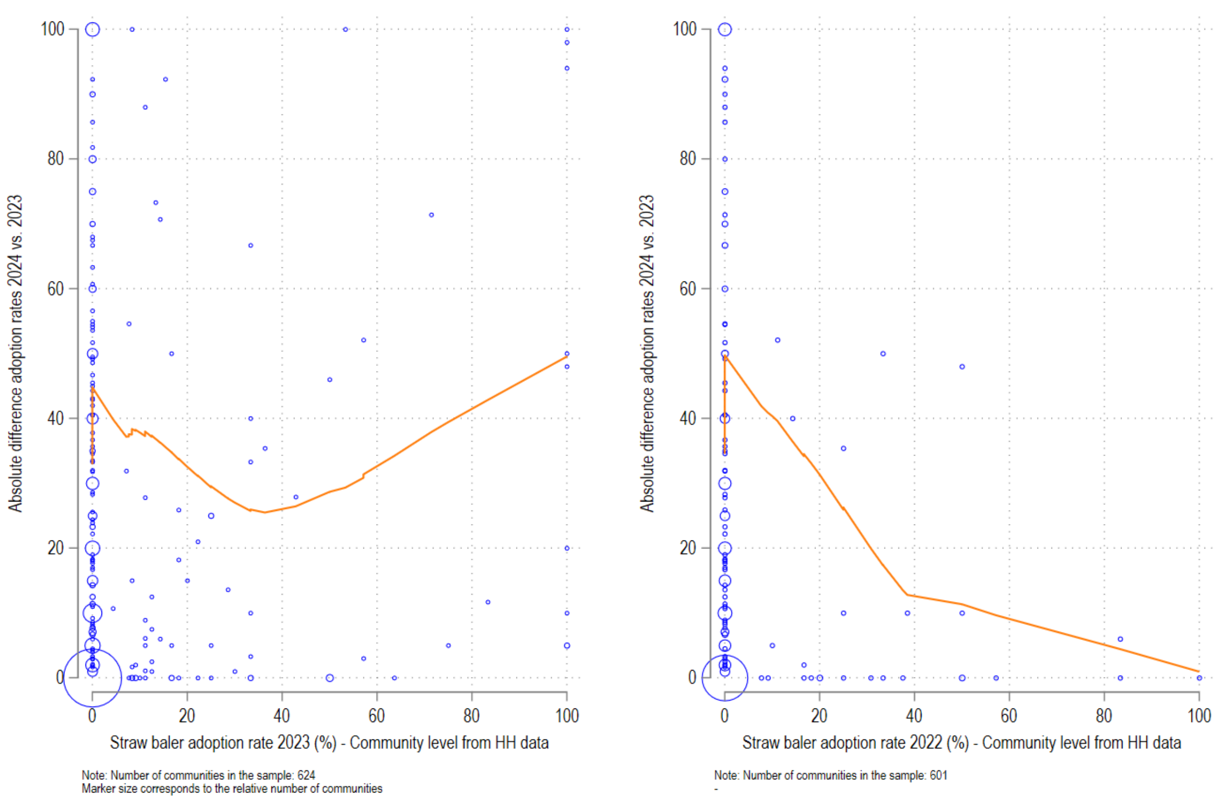
Figure 47: Adoption of large ruminants



Source: VHLSS 2023, VHLSS 2022 & VHLSS 2024 community questionnaire. Note: preliminary results based on the first three quarters for data.

In the case of the rice straw baler, for both pairs of years examined, the majority of communities lie along the y-axis, where the adoption rate reported by households is zero, while the adoption rates reported by community representatives range from 0 to 100%. This suggests that, although community representatives report varying levels of adoption, many households have not adopted a rice straw baler. There is, however, a cluster of communes near the origin, indicating that discrepancies in these cases are either non-existent or relatively low. Additionally, a few communes are scattered across the positive values of household-reported adoption rates, showing a downward trend near the origin and an upward trend as household-reported adoption rates increase in 2024-2023, while a downward trend is observed in 2024-2022. However, the direction of these trends appears to be highly sensitive to the few communities with high household-reported adoption rates, indicating that these outliers significantly influence the overall trend.

Figure 48: Community and household rice straw baler adoption rate comparisons



Source: VHLSS 2023, VHLSS 2022 & VHLSS 2024 community questionnaire. Note: preliminary results based on the first three quarters for data.

The two cases suggest that discrepancies between adoption rates reported by community representatives and households tend to be lower when these rates take extreme values. Specifically, when adoption rates are either very high or very low, the reports from both sources are more likely to match. For communes with mid-range adoption rates reported by households, the discrepancies tend to decrease as the adoption rates reported by households increase.

A rice planting nursery, Yen Bai, northern Vietnam.
Credit: CIAT/Georgina Smith

Standing
Panel on
Impact
Assessment

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