CGIAR Standing Panel on Impact Assessment

Preliminary Insights into the Adoption of CGIAR-Related Agricultural Innovations in Vietnam

Frederic Kosmowski, Thao Bach, Oanh Nguyen, James Stevenson, Sujata Visaria

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The Standing Panel on Impact Assessment

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Authors

Frederic Kosmowski, Thao Bach, Oanh Nguyen, James Stevenson, Sujata Visaria

Editor

Samantha Collins

Design and layout

Macaroni Brothers/Luca Pierotti

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Cover Photo: A farmer spreads fertilizer in a paddy field.
Credit: ILO/Truong Van Vi

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Abbreviations and Acronyms

1M5R	One Must Do, Five Reductions
3R3G	Three Reductions, Three Gains
AGI	Agricultural Genetics Institute
AW	Autumn-Winter Season
AWD	Alternate Wetting and Drying
BLB	Bacterial Leaf Blight
BPH	Brown Planthopper
CAPI	Computer-Assisted Personal Interviews
CCAFS	Climate Change, Agriculture and Food Security CGIAR Research Program
CH	Central Highlands
CIAT	International Center for Tropical Agriculture
CIFOR	Center for International Forestry Research
CIP	International Potato Center
CLRRI	Cuu Long Rice Research Institute
CLUES	Climate Change Affecting Land Use
CORIGAP	Closing Rice Yield Gaps
CRPs	CGIAR Research Programs
CS-MAP	Climate-Smart Mapping and Adaptation Planning
CURE	Consortium for Unfavorable Rice Environments
DARD	Department of Agricultural and Rural Development
DNA	Deoxyribonucleic acid
DSTE	Department of Science, Technology, and Environment
EA	Enumeration Areas
ENSO	El Niño–Southern Oscillation
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GIFT	Genetically Improved Farmed Tilapia
GSO	General Statistics Office
HCM	Ho Chi Minh City
IAS	Institute of Agricultural Science
ICD	International Cooperation Department
ICRAF	World Agroforestry Centre

ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
IPCC	International Panel on Climate Change
IPM	Integrated Pest Management
IPSARD	Institute for Policy and Strategy for Agriculture and Rural Development
IRRC	InterRice Research Consortium
IRRI	International Rice Research Institute
ISFM	Integrated Soil Fertility Management
IWMI	International Water Management Institute
MARD	Ministry of Agriculture and Rural Development
MAS	Marker-assisted selection
MoNRE	Ministry of Natural Resources and Environment
MRD	Mekong River Delta
NARS	National Agricultural Research Institutes
NC	North Central and Central Coastal Areas
NCVESC	National Center for Variety Evaluation and Seed Certification
NDC	Nationally Determined Contributions
NES	No Early Spraying
NM	Northern Midlands and Mountain Areas
PSO	Province Statistics Office
PSU	Primary Sampling Unit
QTL	Quantitative Trait Locus
RIA1	Research Institute for Aquaculture 1
RIA2	Research Institute for Aquaculture 2
RiCA	Rice Custom Amplicon panel
RRD	Red River Delta
RSV	Rice Stripe Virus
RTBV	Tungro bacilliform virus
RTSV	Tungro spherical virus
SA	Summer-Autumn season
SDGs	Sustainable Development Goals
SI	Sustainable Intensification

SNP	Single Nucleotide Polymorphism
SPIA	Standing Panel on Impact Assessment
SRI	Sustainable Rice Intensification
SSNM	Site-Specific Nutrient Management
TILV	Tilapia Lake Virus
UNEP	United Nations Environment Program
VHLSS	Vietnam Household Living Standard Survey
VietGAP	Vietnamese Good Agricultural Practices
WIDER	World Institute for Development Economics Research
WS	Winter-Spring Season

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Executive Summary

Over the past two decades, Vietnam's GDP per capita has grown ninefold. Concurrently, its agricultural sector has transformed to a strong commercial orientation. At the same time that the share of agriculture in GDP fell from 24.5 percent to 12.6 percent, agricultural value-added grew sixfold from USD 7.5 bn to USD 46 bn (World Bank, 2022). This suggests that Vietnam could provide contemporary insights into agricultural innovation coinciding with – and possibly contributing to – economic growth.

Vietnam is also a high-priority country for CGIAR research. Since 2021, the Standing Panel on Impact Assessment (SPIA) has been conducting a country study of the impact of CGIAR-related agricultural innovations in Vietnam. As in the other countries where this country-level approach was pioneered and developed, this process began with desk research and key informant interviews to generate a stocktake or information about all CGIAR-related innovations that may have been disseminated or adopted at scale. **From a longlist of 79 innovations across multiple domains, the SPIA Vietnam team found indications that 18 may have diffused at scale.**

A key determinant of an innovation's impact is its reach, or the number of individuals who adopt or otherwise benefit from it. To obtain high-quality estimates of the reach of CGIAR-related innovations in Vietnam, we have collaborated with the General Statistics Office (GSO) since 2022 to incorporate new modules into the annual, nationally representative Vietnam Household Living Standards Survey (VHLSS). In the VHLSS 2022, 32,340 rural households in 2,156 enumeration areas (EAs) were interviewed. The VHLSS sample follows a rotating panel design at the EA level, making it possible to build a panel of households over time. Newly integrated modules include questions designed to measure Vietnamese farmers' adoption of a variety of different CGIAR-related innovations, comprising improved rice, cassava, and tilapia varieties, sustainable intensification practices in rice cultivation, and climate change adaptation and water-saving practices in rice and coffee. **SPIA incorporated questions about 10 innovations in the VHLSS 2022, and this report presents our preliminary findings about 6 of these.** Thus, this first report is a partial study of the reach of CGIAR in Vietnam, with a broader range of innovations to be covered in later rounds of survey data collection and reporting.

The VHLSS sample includes approximately 47,000 households annually. To measure adoption as rigorously as possible at this scale of operation, our measurement efforts span a range of specific data collection methods. Not only is it important to correctly capture farmers' choices, actions, and practices on the farm, in many cases we must also grapple with how to translate these into an indicator of whether they have adopted the innovation.

For example, farmers will often be unaware of the scientific name or the genetic lineage of the crop variety they are growing. To correctly identify if it is a CGIAR-related variety, the gold standard measurement method is to fingerprint the DNA from a sample of their crop and compare this against a reference library of genetic profiles of known identity. We intend to eventually estimate the adoption of CGIAR-related improved rice varieties, cassava varieties and tilapia strains. In this report, we restrict our analysis to the distribution of key marker traits in the DNA of rice leaf samples and extrapolate to estimate the number of households in Vietnam that are growing rice with these traits. **The evidence suggests that several key marker traits that have been the focus of CGIAR research can be found in the rice crops currently planted in Vietnam.** We estimate that 7.6 million households in Vietnam grow rice with yield-enhancing traits, and 7.9 million grow rice with high-grain quality traits. Markers for resistance to particular pests are found less commonly but are still widespread – we estimate that 2.7 million households are growing rice resistant to the brown planthopper (BPH). Furthermore, we estimate that 2.4 million households are cultivating rice that is salinity tolerant. These estimates of the reach of CGIAR research on rice traits provide an upper bound that will certainly be refined as this line of work progresses.

We also find evidence that a significant number of farmers may be unable to report accurately the major traits of the rice varieties they grow. For example, about a third of farmers in our sample did not report that their rice was salt tolerant, although it did possess the main marker for that trait (*saltol*). A similar magnitude of misclassification occurs with drought tolerance. Additionally, approximately one-third of farmers reported that their variety was tolerant to heat or cold when the genotyping results for samples of their rice crop did not confirm this. These findings highlight the value of measuring traits and genetic markers to establish objective measures, rather than relying on farmer-reported data alone.

It is unclear why some farmers fail to identify the traits of their rice crop. One possibility is that they assess traits by observing how their crop fares in different circumstances, and that the effect of variation in environmental conditions may dominate genetic effects in determining outcomes. Another possibility is that these traits have not been specifically sought out by farmers when choosing varieties, but rather that the traits have been bred into varieties that have other more salient characteristics valued by farmers. We present spatially explicit data on the distribution of specific resilience-related traits, showing that in some locations there is a seeming geographic mismatch between the main features of the agroecology and the traits of the rice varieties cultivated.

The measurement problem is different when it comes to assessing the adoption of packages of recommended practices, such as for sustainable intensification in rice cultivation. Over the years CGIAR research has informed the development of rice management packages such as 'Three Reductions, Three Gains' (3R3G) and 'One Must Do, Five Reductions' (1M5R) which include recommendations related to the choice of input, and its proportion, timing, and order of application in different cultivation-related domains such as seeds, fertilizer, pesticides, water, and harvesting method. Specifically, when it comes to water use in rice, CGIAR has developed and promoted the practice of Alternate Wetting and Drying (AWD), which reduces water use and related methane emissions, while maintaining rice yield. In VHLSS 2022 we attempted to measure farmers' self-reported adoption of the 3R3G, 1M5R, and AWD practices.

For AWD we also included an alternative measurement approach where we asked farmers about their observed irrigation pattern and whether they dried their field during certain stages of the rice plant growth. **Accordingly, we have two different estimates for the number of adopters of AWD. Using self-reported data, we estimate about 400,000 households practice AWD. However, based on their reported behavior of drying-down their fields, we estimate that 1.2 million households may be practicing AWD.** Although more definite statements must await further analysis, there are indications once again that relying solely on farmer self-reports alone may lead to underestimates of true adoption, possibly reflected by a lack of familiarity with the term AWD (including when translated to Vietnamese) rather than the practice. When it comes to 1M5R, our survey module in VHLSS 2022 simply asked rice farmers if they had heard of the package and if so, whether they had applied it in their farms. However, we consider this strategy to potentially result in significant under-reporting of adoption. We determined we needed to design a new survey module that would capture what farmers actually practice on their farms, and then assess to what extent the practices they report are consistent with the recommendations of 1M5R. The SPIA team conducted in-depth qualitative fieldwork in the Mekong River Delta (MRD) in the summer of 2022 and used this to develop, field test, and then further refine survey questions in each of the six rice cultivation domains to which the 1M5R package pertains. These new questions have now been incorporated into VHLSS 2023, and we expect they will allow us to produce more definitive estimates of adoption.

Finally, we also report here on the use of geospatial data to inform climate change adaptation planning. Since 2017, Vietnam has been using Climate-Smart Mapping and Adaptation Planning (CS-MAP) developed by CGIAR to assess annual climate risk for crops and select adaptations that can help minimize losses and promote resilience. Two key adaptations are to change the rice varieties sown and to adjust the rice sowing calendar. To assess the degree to which farmers actually receive the advice to make these changes, VHLSS 2022 included survey questions to ask if they had been given advice about which varieties to sow, and to change their sowing/planting dates, and further, whether they had followed this advice. Although more work will be conducted in 2023 to accurately attribute such advice to the CS-MAP initiative, **our preliminary estimates are that the potential reach of such climate change adaptation options is 4.5 million households. We estimate that 3.2 million households have applied the advice to change their rice variety, and 1.4 million households have changed their rice planting/sowing dates.**

The VHLSS 2023 will include improved measurement of some innovations that were assessed in VHLSS 2022 and will also repeat questions about certain innovations unchanged from their original form. This has the advantage of allowing us to build a panel of households and enumeration areas across these two years, and to measure changes in adoption rates and how they correlate with dissemination efforts. In addition, VHLSS 2023 includes measurements of the adoption of innovations, including Genetically Improved Farmed Tilapia (GIFT) developed by WorldFish and high-starch and mosaic disease-resistant cassava varieties originating from the CIAT Genebank, both of which will be measured through DNA fingerprinting techniques. Through this ongoing partnership with the General Statistics Office (GSO), we hope to provide high-quality estimates of the reach of CGIAR innovations in an important middle-income country where agricultural innovations have the potential to have a significant impact. We expect to draw several insights on the role played by CGIAR in this rapid rural transformation, and the role CGIAR may play in increasing countries' resilience to global environmental changes. The methodological innovations we develop and introduce through this work can also provide a guide for similar measurement exercises by SPIA in other country studies, as well as the wider community of social scientists.

Rice drying in Vietnam.
Credit: IRRI

1. Introduction

CGIAR – the largest global research partnership for a food-secure future – celebrated its 50th anniversary in 2021. CGIAR aims to contribute to the transformation of the world's food, land, and water systems in a climate crisis, towards and beyond the 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[1] sets out five thematic impact areas: nutrition, health, and food security; poverty reduction, livelihoods, and jobs; gender equality, youth, and inclusion; climate adaptation and mitigation; environmental health and biodiversity. Its work now spans 50 countries in six regions, drawing on expertise in multiple disciplines across its research centers.

Within CGIAR, 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 and their potential to contribute to its goals. SPIA's approach is rooted in the recognition that to have an impact at scale, it is often necessary (although not sufficient) to reach a large number of beneficiaries (SPIA, 2020). Since 2015, SPIA's national data system team has been developing a country-level approach to generate evidence of reach and impact at a national level. The objective is to generate independent estimates of the reach of CGIAR innovations while furthering understanding of the characteristics of CGIAR's intended beneficiaries, and to examine the synergies between different innovations (i.e., where they are adopted together as a bundle). In each country, the team begins with a stocktaking exercise that identifies the list of innovations that may have diffused. This is followed by efforts to generate evidence about their reach through the integration of new survey modules into existing national-level data collection efforts and partnerships with national statistics institutes. The most recent six-year workplan (2019-2024) gave SPIA the remit to carry out this country-level work in four countries: Bangladesh, Ethiopia, Uganda, and Vietnam. In May 2023, the CGIAR System Council approved a new workplan for SPIA (2024-2030) to continue data collection in these four countries while adding Colombia, Egypt, India, and Nigeria for the full model of implementation, with a further twelve countries added for just the stocktaking component.

Over the past two decades, seven different CGIAR Research Centers have operated in Vietnam, thus Vietnam 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), the International Potato Center (CIP), and the International Livestock Research Institute (ILRI). Other centers, including Bioversity International[2], the International Food Policy Research Institute (IFPRI), the International Water Management Institute (IWMI) and WorldFish, have engaged in collaborative activities with Vietnam. During the period when CGIAR's research was organized in CGIAR Research Programs (CRPs), Vietnam was one of six countries around the world (and the only one in Southeast Asia), considered for 'site integration++', indicative of an extensive staff

[1] CGIAR 2030 Research and Innovation Strategy.

[2] Bioversity International and CIAT merged in 2020 to become the Alliance of Bioversity International and CIAT.

presence from multiple CGIAR centers (CGIAR Consortium Office, 2015). Since 2022, nine CGIAR Initiatives have been operating in Vietnam[3].

This report offers a first glimpse at SPIA's efforts and showcases our preliminary findings about ten innovations, based on data collected during the first two years of our workplan in Vietnam. Since 2022, SPIA has partnered with Vietnam's General Statistics Office (GSO) to collect household-level data about the dissemination and uptake of certain priority agricultural innovations. This data complements GSO's existing survey on Vietnamese households[4], is recognized as a legal data source, and can thus inform Vietnam's policies.

In this report, we discuss our findings based on exploratory measurement efforts via questions added to the Vietnam Household Living Standards Survey (VHLSS) modules. The report highlights the challenges of accurately measuring the adoption of sustainable intensification (SI) practices and the dissemination of climate change adaptation recommendations. We also report on a novel exercise to measure the adoption of rice traits developed through CGIAR research that relies on objective assessment using genetic markers.

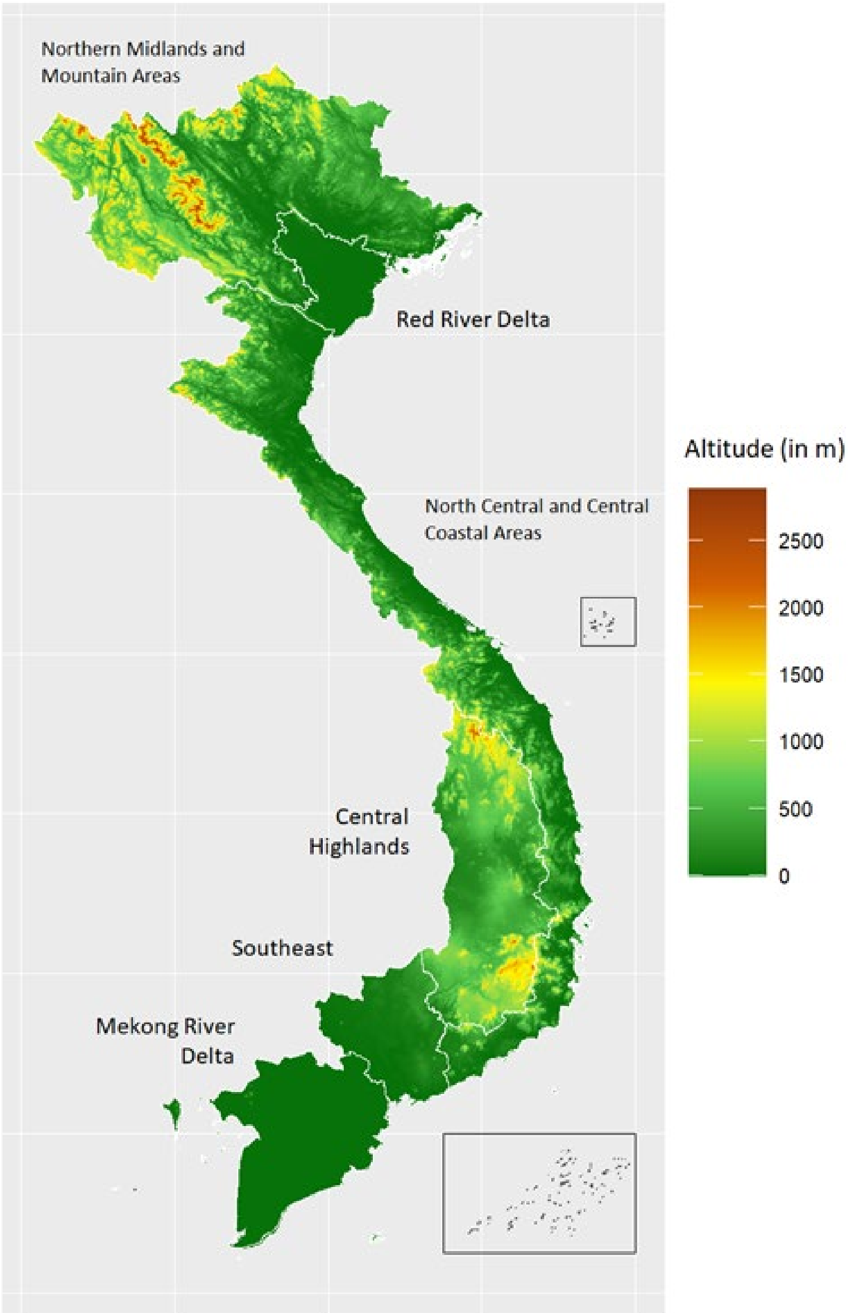
[3] Low Emission Food Systems, Sustainable Healthy Diets, Gender Equality, Asian Mega-Deltas, Sustainable Animal Productivity, Plant Health, Nature-Positive Solutions, Excellence in Agronomy and One Health.

[4] Each year the GSO conducts the Vietnam Household Living Standard Survey (VHLSS) with a rotating sample of approximately 47,000 households. The data are representative at the province-level.

1.1 Context

Vietnam has a large coastline as well as mountainous regions primarily located in the northern and central regions of the country (Figure 1). The country's six main 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) – encompass 63 provinces and cities.

Figure 1. Map of Vietnam's six regions and their agroecology



Source: CGIAR SPIA

Administrative divisions below the province level are composed of districts and communes. Vietnam's government structure is partly decentralized. The Communist Party of Vietnam sets the direction of policy at the national level. Province, district, and commune-level governments are responsible for implementing policies and have some autonomy in decision-making and budgeting. The Ministry of Agriculture and Rural Development (MARD) is responsible for overall agricultural planning – strategy, targets for growth, productivity, and output of agricultural products, investments, and management of agricultural infrastructure. Based on MARD's planning, the Department of Agricultural and Rural Development (DARD) of each province designs its planning, targets, and strategy, to implement these policies while also fulfilling the objectives of the Provincial People's Committee[5]. DARD planning is carried forward, delineated, and implemented by the Sub-Department of Agricultural and Rural Development at the district level, and finally implemented by communal agricultural staff with other agencies, organizations, and associations such as agricultural extension services, cooperatives, the Farmers' Union, the Women's Union, and local cells of the Communist Party. This extensive governmental architecture, coupled with the emergence of private actors in the last two decades, suggests that there are several potential scaling mechanisms through which agricultural technologies can be disseminated.

Vietnam represents an interesting case to study agricultural innovation. First, Vietnam's development pathway has been impressive. Since 2010 Vietnam has been a middle-income country (World Bank, 2013). Its GDP per capita has increased ninefold over the past two decades and reached USD 4,109[6] in 2021 (General Statistics Office, 2023). The annual GDP growth rate has remained above 5.5 percent throughout. Evidence suggests there have been significant increases in household welfare (Tarp, 2017). Concurrently, Vietnam'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 the share of the agricultural sector in GDP has fallen from 24.5 percent to 12.6 percent (World Bank, 2022). According to the Statistical Yearbook of Vietnam, the value-added from the agricultural sector contributed to 5.1 percent of GDP growth (General Statistics Office, 2023). There is evidence that Vietnam'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 Vietnam have major implications for the role of agricultural research in supporting further development.

Second, the Vietnamese context brings a very different set of innovations and, as alluded to above, entirely different scaling pathways compared to the studies in Ethiopia (Kosmowski et al., 2020) and Uganda (ongoing). Rice, rice-focused management practices, and aquaculture innovations are all new areas of focus for Vietnam that SPIA did not tackle in sub-Saharan Africa.

Third, there are challenges on Vietnam's path to future prosperity that require an explicit environmental orientation in CGIAR's research portfolio. Projected increases in the frequency and severity of climate hazards pose significant threats to agricultural production (IPCC, 2014;

[5] 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.

[6] In current USD.

Shukla et al., 2022; WIDER, 2012). Vietnam is also highly vulnerable to rising sea levels. It has been estimated that an 80cm increase could leave close to one-third of the Mekong Delta permanently flooded (MoNRE, 2022). Vietnam has also made commitments to reduce greenhouse gas emissions from rice production[7]. Recent data from GSO has shown that fulfilling these commitments remain challenging: the percentage of land under productive and sustainable agriculture[8] in 2020 was 38 percent which means 62 percent of agricultural land is still under unsustainable use. In 2020, the proportion of agricultural land meeting the national requirements for sustainable use was 79 percent for fertilizer use, and 39 percent for pesticide use (General Statistics Office, 2022b). CGIAR research has focused on finding agricultural research innovations that both adapt food production systems to environmental challenges and mitigate negative impacts. It is of strategic importance for CGIAR's global work to document whether these innovations have scaled, and if so, how this scaling was achieved.

Overall, Vietnam's diffusion of agricultural technologies could hold relevant lessons for other countries that aspire to replicate a similar path. In line with Vietnam's approach to engaging with multilateral partners (Do, 2022), its access to technology and diffusion have been influenced heavily by its trade partners, notably China, Japan, Korea, and USA[9]. In this context, CGIAR-related innovations may have been less influential in Vietnam than found in the country-level studies that SPIA has previously conducted in Ethiopia and Uganda. Nonetheless, we expect to draw several insights about the role that CGIAR has played in this rapid rural transformation and the future role it may play in increasing different countries' resilience to global environmental changes.

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

8 This indicator corresponds to SDG indicator 2.4.1. See https://www.fao.org/3/ca5157en/ca5157en.pdf

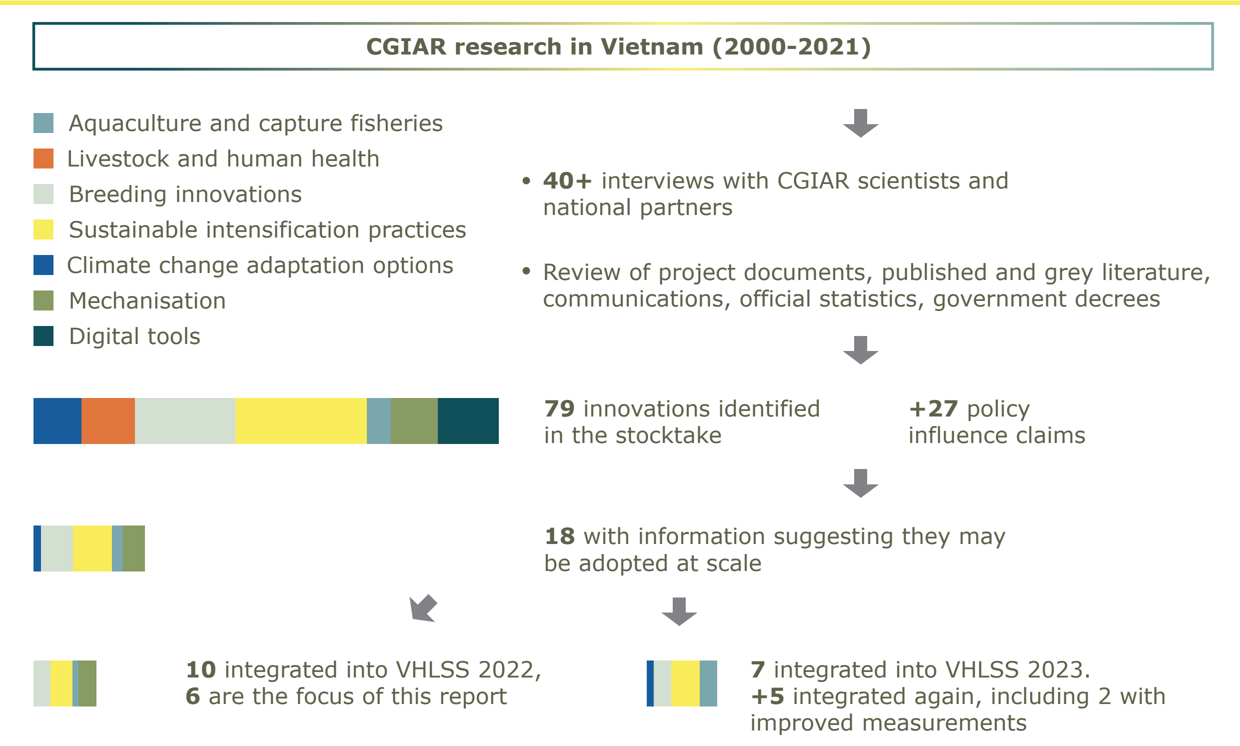
9 This is true of several innovations documented in the stocktake including rice hybrid seeds in the North (until early 2000), improved potato seedlings, and improved tilapia strains.

2. Methods and Data

SPIA's country study approach aims to document the adoption and diffusion of agricultural innovations originating from CGIAR research (Kosmowski et al., 2019). The rationale for this approach is that the majority of CGIAR research efforts target a relatively concentrated set of countries. National statistical institutes collect and report data from the agricultural sector, and in most countries where CGIAR is active, they also implement nationally representative household surveys. SPIA partners with these institutes to leverage these existing surveys as a data source to document the reach of CGIAR-related innovations. This approach has multiple benefits as the resulting high-quality information can be useful for government decisions about agricultural policies and deliver valuable insights for the CGIAR system. Moreover, these data can often be used together with data from other sources. By combining them with those from individual projects, administrative data, or remote sensing data, researchers can investigate important questions related to the reach and impact of specific innovations.

SPIA started its Vietnam country study in 2021 to comprehensively document CGIAR-related innovations by 2024. An overview of the process followed can be seen in Figure 2. Starting with CGIAR research conducted in Vietnam from 2000 to 2021, we identified 79 innovations belonging to seven core domains: aquaculture and capture fisheries; livestock and human health; breeding innovations; sustainable intensification practices; climate change adaptation options; mechanization; and digital tools. These domains represent the strands of research conducted by CGIAR centers in Vietnam over the last two decades. Out of these 79 innovations, we found indications that 18 may have diffused at scale. We attempted to measure the reach of 10 of these via the VHLSS 2022, and this report focuses on our findings related to six.

Figure 2. Schematic diagram of the process to identify priority innovations for data collection



2.1 Identifying CGIAR-Related Innovations

The full version of the stocktake, which includes all 79 innovations identified in Vietnam, is available here[10]. When stocktaking, we considered the different components of CGIAR research efforts in Vietnam, the translation of these efforts into specific innovations, and indications of the likelihood that households had adopted these innovations. The approach takes a retrospective approach and intends to comprehensively include all CGIAR's research activities in the previous two decades[11].

To capture the full diversity of CGIAR research efforts, we broadly define an *innovation* as one that includes any technology, practice, decision-support tool, or policy/institutional design that required input from research for its design and/or promotion and was novel to its users. *CGIAR-related efforts for development and/or dissemination* relate to CGIAR Research Programs (CRPs) and/or bilaterally funded projects that developed research outputs that contributed to the development or dissemination of the innovation. Finally, an *observable feature* is a clear and distinctive feature that allows the innovation to be measured with a reasonable level of accuracy in a survey setting.

To identify innovations likely to be at scale, we relied primarily on interviews with CGIAR scientists and national partners. We investigated and documented progress along the adoption pathway, as highlighted in Table 1. For each identified innovation (column *i*), we started by describing CGIAR-related efforts for development and/or dissemination (columns *ii* and *iii*), an observable feature and how it could be identified/measured level (column *iv*), the scale and location of activities (*column v*) and known dissemination strategies/pathways (*column vi*). Taken together, this information can indicate whether an innovation is likely to be diffused at scale. Table 1 provides an example for three innovations: Genetically Improved Farmed Tilapia (GIFT) Derived Strains, Sustainable Water Use for Coffee Production, and Climate-Smart Mapping and Adaptation Planning (CS-MAP).

[10] https://raw.githubusercontent.com/CGIAR-SPIA/Vietnam-pre-report-2023/main/VN_Stocktake.xlsx

[11] Following the One CGIAR transition, the World Agroforestry Centre (ICRAF) and the Center for International Forestry Research (CIFOR) and ICRISAT no longer participate in CGIAR Initiatives (which superseded the CGIAR Research Programs) but retain local offices in Vietnam. We made the decision to keep in the stocktake all innovations originating from research conducted in 2000-2020.

Table 1. Examples of stocktaking entries for three CGIAR-related innovations for inclusion in Vietnam'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 Vietnam (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 and made available by WorldFish since 1988. 1. GIFT-derived strains in Vietnam include: - Cold tolerant tilapia (RIA1, 1999) - NOVIT-4 Nile tilapia (2004) - derived from the Genetically Improved Farmed Tilapia (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 (Luan et al., 2008). - Saline-tolerant Nile tilapia (2014): Base population of the selective breeding program 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., 2014). 2. Seven generations (G10 to G17) of male/female tilapia were released. Clean seeds free from Tilapia Lake Virus (TiLV) disease 3. Mono-sex 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%). • Vietnam 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". • Vietnam's fisheries development strategy 2010-20 (Decision No. 1690/QD-TTg)[12]: Tilapia is 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. • Vietnam aims to reach 400,000 tonnes of tilapia in 2030 (MARD, 2017). Cages farming in rivers and lakes and intensive farms in delta areas

[12] Prime Minister Decision 1690/QD-TTg on the approval of Vietnam's fisheries development strategy to 2020: https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Quyet-dinh-1690-QD-TTg-phe-duyet-Chien-luoc-phat-trien-thuy-san-Viet-Nam-111876.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)*
Sustainable water use for coffee production	1. More coffee with less water - towards a reduction of the blue water footprint in coffee production (Nestle & SADC, 2017-2019) 2. Water, Land & Ecosystems CRP (2014-19)	In coffee-producing areas, levels of groundwater development are reaching their limits, and improving agricultural water use efficiency is key. Confirming results from D'Haeze's work in the early 2000s, IWMI worked with Hanns Neumann Stiftung and Nestle on coffee water footprint calculations. Results indicated that under normal climate conditions, 70% of the locally recommended level by the MARD (400 liter/plant/irrigation) was sufficient to sustain yields up to 4 tonnes/ha. Using a case study in Dak Lak Province (Dave et al., 2015) additionally recommend an irrigation supply of 120 or 150 mm between January and April in a year preceded by good or average rainfall respectively, in November and December.	Households have used a maximum of 400 liters per coffee plant/ irrigation round during the rainy season (3 rounds)	1. Dak Lak, Dak Nong, Gia Lai, Kon Tum, Lam Dong provinces	1. In 2019, IWMI claimed 20,000 farmers were reached through the Nestle Farmer Connect network
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 System under Climate Change (TFCC)	1. Develop and test a participatory approach for mapping climate risks and adaptive interventions (Yen 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 South Central Coast provinces and 12 Northern Midlands and Delta provinces. 3. Downscaling at the commune level. CS-MAP is currently being used to identify areas of rice production that are not adaptable in 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 South Central Coast provinces and 12 Northern Midlands and Delta 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 1438/ BC-TT-VPPN[13] 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 follow: 1) Participatory mapping exercise with stakeholders leading generated: 2) Adaptation plans that are risk, season, and location-specific and 3) the 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.

[13] MARD Decision No. 1438/ BC-TT-VPPN regarding the recognition of the scope of influence and effect at national and ministerial levels of initiatives, and scientific research projects: https://drive.google.com/file/d/1qCpQ6u4eY-mfS-DLyGVNsSTUTk4AFUYh/view. English translation: https://drive.google.com/file/d/1i-w1dhNFtxTwKfCBo1_6J64nCipYA3Ud/view

Preliminary results from this stocktaking exercise were presented at a consultation meeting in June 2022 that SPIA co-organized with the Institute for Policy and Strategy for Agriculture and Rural Development (IPSARD) and IRRI. The meeting was chaired by the former Minister of Agriculture and Rural Development of Vietnam, Dr. Cao Duc Phat, and SPIA Chair, Prof. Karen Macours. The General Statistics Office of Vietnam was represented by their Deputy Director-General, Mr Nguyen Trung Tien. Several stakeholders, including Dr. Nguyen Do Anh Tuan (ICD Director, MARD), Dr. Tran Cong Thang (IPSARD Director, MARD), and Dr. Nguyen Thi Thanh Thuy (DSTE Director, MARD) offered a strong endorsement for the GSO-SPIA partnership.

1.1 The Vietnam Household Living Standard Survey (VHLSS)

The stocktake represents the first step in the documentation of the adoption and diffusion of agricultural innovations originating from CGIAR research. It is accompanied by a search for relevant, nationally representative survey instruments that could be leveraged to measure the adoption of the innovations identified. In Vietnam, SPIA and the General Statistics Office have built a partnership that allows these measurements to take place through the Vietnam Household Living Standard Survey (VHLSS).

Since 1993, the GSO has collected household survey data through the VHLSS to systematically monitor living standards and evaluate comprehensive poverty reduction programs to inform Vietnam's national policymaking and socio-economic development planning. The data also help to assess progress toward meeting SDG targets and Vietnam's socioeconomic development goals and growth strategy (General Statistics Office, 2021a). Since 2011, the VHLSS has been conducted annually.

The survey includes questions about (1) Basic demographic characteristics; (2) Education; (3) Health and Healthcare; (4) Employment and Income; (5) Consumption expenditures[14]; (6) Durable goods; (7) Housing, electricity, water, and sanitation facilities; (8) Participation in poverty alleviation programs; and (9) Household businesses. In addition, a commune-level module is used to collect data about general characteristics (such as the main economic activities, agriculture and land types, and infrastructure). Of relevance to our purpose is the Employment and Income section, which collects data on household-level production of crops, animals, fish, and forest products. For crop production, data on whole-year cultivation area, outputs, and income are collected.

The VHLSS sample is representative at the provincial level and for rural areas within the six geographical regions, each of which is comprised of 5 to 14 provinces. The sample is selected following a two-stage stratified sampling procedure. The primary sampling units (PSUs) are called enumeration areas (EAs - derived from the Vietnam Population Census) and are usually villages or residential units. The 2019 Population Census EA list serves as the sampling frame for the 2020-2029 VHLSS rounds. Around 68 percent of the sample EAs are rural, although the proportions vary by region (Table 2).

[14] The household consumption expenditure and community modules are only collected in even years.

The VHLSS sample follows a rotating panel design at the EA level. Each year, one-half of the EAs from the previous year are re-sampled while others are rotated out[15]. This design also applies to the subsequent survey rounds: one-half of the EAs surveyed in 2022 (n=1,566) are also included in the VHLSS 2023. In EAs that are repeated from previous survey rounds, enumerators interview the same 15 households that were interviewed previously. For the new EAs introduced in a given survey round, the Provincial Statistics Offices (PSOs) randomly select 15 households (General Statistics Office, 2022a).

Table 2. VHLSS 2022 sample size by regions, urban/rural areas

Regions	Number of EAs			Number of households		
	Total	Urban	Rural	Total	Urban	Rural
Red River Delta	664	210	454	9,960	3,150	6,810
Northern Midlands and Mountain areas	554	119	435	8,310	1,785	6,525
North Central and Central coastal areas	689	210	479	10,335	3,150	7,185
Central Highlands	217	65	152	3,255	975	2,280
Southeast	374	208	166	5,610	3,120	2,490
Mekong River Delta	635	165	470	9,525	2,475	7,050
Total	**3,133**	**977**	**2,156**	**46,995**	**14,655**	**32,340**

SPIA's collaboration with GSO started in November 2021, with new modules about rice-related innovations included in the VHLSS 2022 questionnaire (See Appendix C). Under the VHLSS 2022, the GSO collected data over 11 months from February to December 2022. Nearly 260 EAs and 4,000 households were interviewed every month.

In 2021, GSO started to use Computer-Assisted Personal Interviews (CAPI) to conduct the VHLSS, significantly decreasing data processing time while improving data quality. The VHLSS CAPI tools were developed by in-house programmers. The application was made available to GSO enumerators through the Google app store and GSO enumerators were provided with a personal account to download it and log in to the system using their mobile devices (Android operating system only) to collect data from households assigned to them. Data were uploaded by enumerators directly to GSO servers. GSO statisticians systematically checked data consistency and quality. Each Province Statistics Office (PSO) received two days of training on using survey instruments in February 2022. Training materials were also developed in the form of a manual accessible to all enumerators.

[15] 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.

1.2 Measurement Approaches and Limitations

The new modules introduced into the VHLSS questionnaire pertained to three core domains of innovations related to rice: breeding innovations, sustainable intensification practices, and climate change adaptation innovations. The entry point to integrate the new modules was a variable from the standard VHLSS questionnaire, asking if the household had planted rice in the last 12 months.

Close to one third of the 46,995 households surveyed in the VHLSS 2022 reported that they had planted rice in the previous 12 months (n=13,857). We define a rice EA as an EA where at least one household reported planting rice in the past 12 months. The distribution of rice EAs and households is presented in Table 3.

Table 3. Distribution of sampled rice EAs and households in VHLSS 2022 by region, urban and rural

	Number of EAs		Number of households	
	Urban	Rural	Urban	Rural
Red River Delta	44	363	203	2,500
Northern Midlands and Mountain areas	64	406	334	4,710
North Central and Central coastal areas	85	372	456	3,245
Central Highlands	14	82	67	692
Southeast	3	29	3	97
Mekong River Delta	41	264	136	1,414
Total	**251**	**1,516**	**1,199**	**12,658**

Below, is an explanation of the innovations SPIA attempted to measure and the approach to estimating their reach.

1.2.1 Breeding Innovations (Three Innovations)

Rice is a major crop in Vietnam. The stocktake suggests that breeding programs in Vietnam have commonly used IRRI-related germplasm originating from IRRI headquarters, which have benefited from IRRI research efforts to maintain elite rice lines. Although their number is as yet unknown, varieties released with an IRRI parent represent the first breeding innovation[16]. In addition, there have been collaborative research efforts between the Vietnamese national agricultural research institutes (NARS) and IRRI on breeding of rice varieties that are salinity- and submergence- tolerant. These two innovations are also documented in the stocktake.

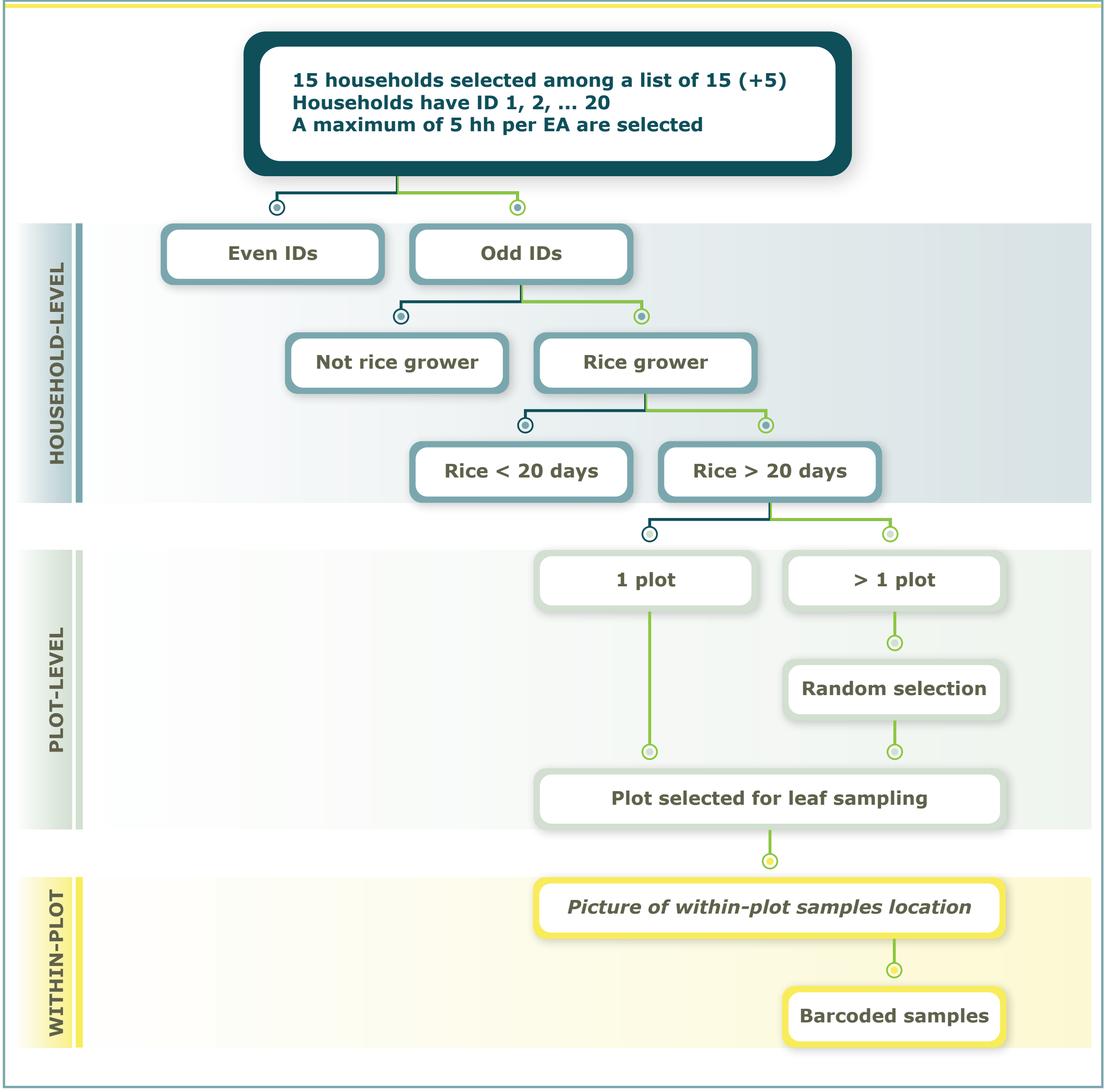
It can be notoriously challenging to use standard survey-based measures to correctly identify the extent to which these new varieties have spread among rice farmers (Walker, 2015) due to the instances where farmers might inadvertently provide imprecise or inaccurate variety names. Recent technological advances and a decrease in costs have enabled accurate varietal assessment through DNA fingerprinting (Stevenson et al., 2023). In several contexts, including

[16] From 1977 to 2022, the IRRI Genebank received 8,046 seed requests from Vietnam. It is established that part of this material has been used in breeding, and that an indeterminate number of varieties released have an IRRI parent.

Ethiopia and Uganda, researchers have successfully integrated DNA collection components into existing surveys by collecting samples from standing crops.

Since the standard design of the VHLSS does not collect plot-level data or include visits to plots, we collaborated with GSO to design a new questionnaire component that was administered to randomly selected rice-growing households and plots, to enable crop sampling (Figure 3). In each EA, this component was only administered to households assigned GSO IDs that were odd numbers (thereby generating a random sub-sample of households). If the odd-ID household had planted rice in the past 12 months, and if at the time of the survey they had at least one plot planted with rice at least 20 days prior, then enumerators collected a crop sample. Crop samples were collected in this way from a maximum of five households per EA.

Figure 3. Sampling procedure for rice DNA fingerprinting in the VHLSS 2022

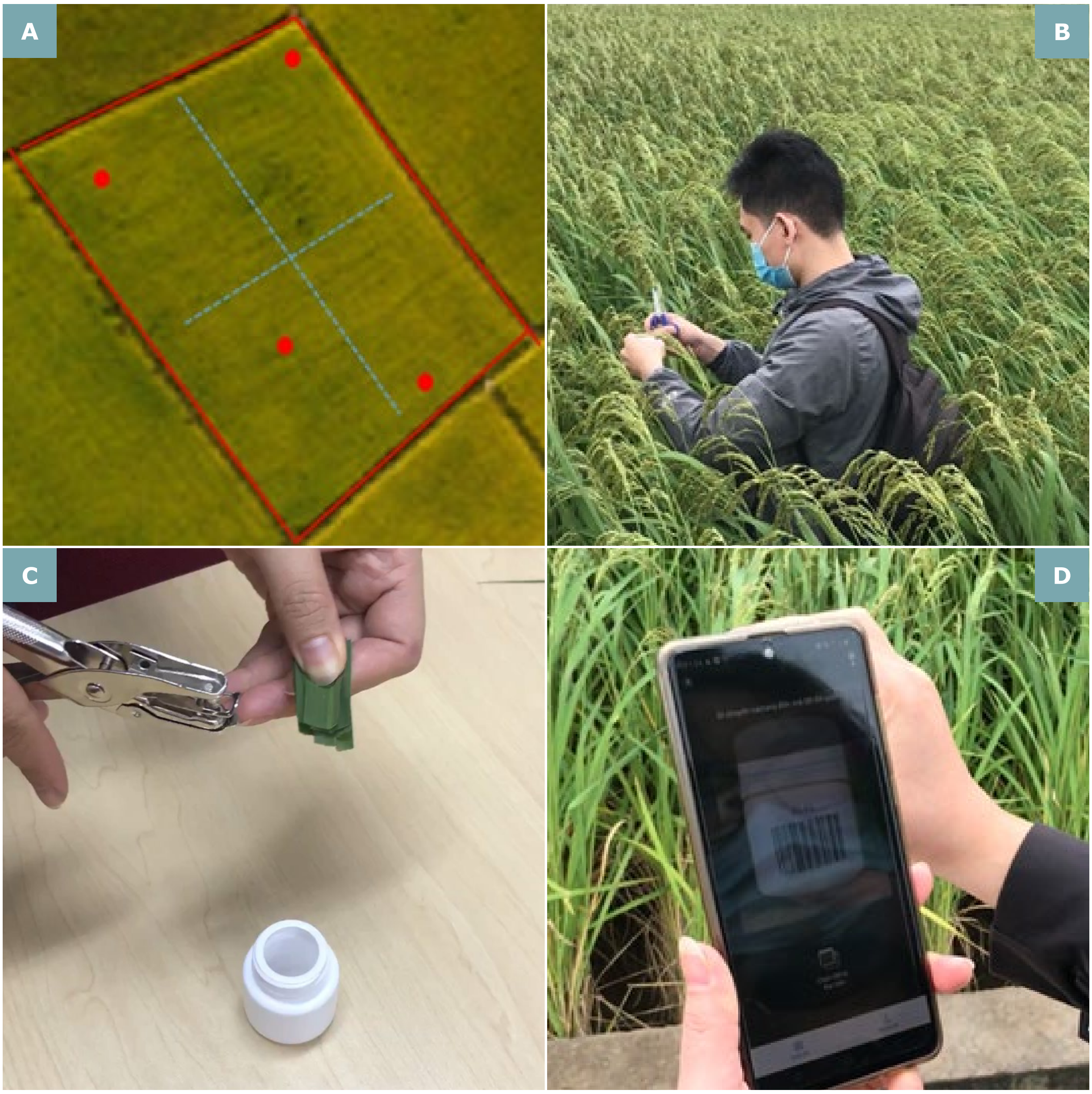


Source: CGIAR SPIA

For each farmer who was screened in, the eligible rice plots were listed on a plot roster. If more than one rice plot qualified, then the CAPI program randomly selected one plot. On the selected plot, four plot quadrants were demarcated and one rice plant was randomly selected within each quadrant. A stack of leaves plucked from this plant was stacked and samples were taken with a hole puncher.

Figure 4 provides images showing the procedure. Enumerators received specific training before they were deployed.

Figure 4. 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 in each subplot (B). Collected leaves were stacked before taking the sample with a 6 mm hole puncher (C). The bottle containing the four samples and 4 gr of silica gel was closed, and the sample barcode was scanned with the VHLSS CAPI program (D). Photo credits: Oanh Nguyen.

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

Samples collected by enumerators were checked by the PSOs and shipped to the Agricultural Genetics Institute (AGI) in Hanoi where they were checked for quality and arranged into plates. From the 832 samples collected by the PSOs, 770 could be matched to a sample household[17] and were sent for genotyping. Twelves samples failed to achieve a >66 percent call rate[18] and were discarded due to insufficient amounts of DNA. Table 4 presents the final sample size of households and EAs from which we have DNA fingerprinting data, by region and cropping season.

Table 4. Distribution of DNA fingerprinting samples of rice EAs and households in VHLSS 2022

Region	Cropping season			Total		
	Winter Spring (WS)	Summer Autumn (SA)	Mua/ Autumn Winter (AW)	EAs	Households	Rice plots/ Household
Red River Delta	148	0	7	57	155	1.52
Northern Midlands and Mountain Areas	144	0	34	46	178	1.72
North Central and Central Coastal Areas	149	18	4	46	171	1.46
Central Highlands	31	0	9	11	40	1.05
Southeast	14	6	4	8	24	1.08
Mekong River Delta	68	56	66	79	190	1.06
Vietnam	**554**	**80**	**124**	**247**	**758**	**1.4**

Note: By region and cropping season, rural EAs only

Genotyping was performed using the Agriplex Genomics' PlexSeq platform, a mid-density SNP[19] panel by high-level multiplexing. We used Version 4 of the IRRI Rice Custom Amplicon SNP panel (Arbelaez et al., 2019), which comprises 1,040 markers. This includes 797 SNPs originating from the Cornell 6KArray Infinium Rice chip (Thomson et al., 2017), 205 trait-related SNP markers, and 22 purity SNP markers. Through pairwise matching on the 797 Cornell

[17] 62 samples could not be tracked to a VHLSS rural households because these were collected in urban EAs, or because the enumerator did not record the barcode on CAPI.

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

[19] 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) – can vary across individual plants in such a way that, when information about many of them is used together, can help us build a profile of the plant's genetic identity.

SNPs, we can identify the variety that the farmer was growing. In addition, we can identify the presence or absence of markers that have been linked to specific rice traits.

Analysis is ongoing to identify the rice varieties that were found on farmers' plots. Those results will be included in the 2024 Vietnam report, along with updated results from the survey module integrated into the VHLSS 2023. In this first report, we present our findings on the CGIAR contribution to the spread of specific rice traits in Vietnam. Note however that at this stage, it is not possible to make a distinction between those markers and traits that were newly introduced in Vietnam likely through the use of IRRI Genebank material, and those that were endemic to Vietnam, and present before these new introductions. Thus, the figures provided in this report represent the *potential* contribution of CGIAR to rice traits in Vietnam and should be understood as upper bounds.

1.2.2 Sustainable Intensification Practices (Two Innovations)

A sustainable intensification (SI) innovation is usually a package of multiple practices, which when adopted together can maintain agricultural yields while reducing environmental impacts (Petersen & Snapp, 2015). CGIAR has researched several SI practices including Integrated Soil Fertility Management (ISFM), Site-Specific Nutrient Management (SSNM), and Conservation Agriculture. In Vietnam, CGIAR-related research formed the basis for 'One Must Do, Five Reductions' (1M5R), which was disseminated on a large scale in Vietnam. In the 1M5R package, farmers must use certified seeds (1 must do), and reduce seed rates, nitrogen fertilizer inputs, pesticide use, water use, and post-harvest losses (5 reductions). A second SI practice, Alternate Wetting and Drying (AWD), is a water-saving approach that involves irrigation of a rice paddy field, after which it is allowed to dry out before irrigating again when the crop is flowering, and then allowing it to dry out again. The practice was introduced to Vietnam through CGIAR research in the early 2000s.

It is particularly challenging to measure the adoption of such packages in a household survey (Stevenson et al., 2019), and there is currently little evidence on what can be reliably measured, and how[20]. These measurement challenges are four-fold. First, 'packages' of practices often have overlapping recommendations – when the same practice is common to multiple different packages. The set of actions recommended may also evolve, and extension services may also modify them to provide context-specific agronomically sound solutions. As a result, there may be large gaps between the original research outputs and the actual recommendations delivered in each context. Second, these recommendations often call for the application of precise quantities of inputs, at specific crop growth stages. Survey respondents may be subject to recall bias, forgetting certain events altogether, or inaccurately remembering the details of particular actions. Recall biases of a significant magnitude have been reported in the context of agricultural labor measurements (Arthi et al., 2018), but there are reasons to think that inputs with salient financial costs, such as fertilizer use, may be less subject to recall bias (Beegle et al., 2012). Third, technology packages are often adopted in a step-wise manner (Munguia et al., 2021). Households may have memorized the recommendations while

[20] A notable exception includes Kondylis et al. (2015) which assess differences in adoption and knowledge of intercropping, mulching, and strip tillage practices in Mozambique.

only applying a subset of them. If so, it is inaccurate to measure adoption as a binary variable. Fourth, households may not be in charge, or fully in charge of, certain decisions required to comply with SI recommendations (Stevenson et al., 2019). For example, under contract farming, cooperatives and buyers closely instruct and monitor farmers' pesticide applications. Alternatively local governments and the cooperative together can heavily influence the timing of applications and choice of products through extensive communication about potential pests and pathogens expected in the upcoming period and pesticide recommendations. Similarly, irrigation schedules may be managed at the communal level.

While recognizing these challenges, in the VHLSS 2022 we attempted to measure farmers' adoption of SI practices through self-elicitation, by referring to the packages by the same name that extension services and agricultural officials used when promoting them.

There have been large mass media campaigns in Vietnam to promote these SI packages and we expect that farm households may be aware of the relevant terms. Our approach could lead to under-reporting for various reasons: adopters who have learned about the practices from other farmers may have applied the package without knowing or remembering the officially-used term for the package; adopters may have learned about the packages but not the official terms for them and so may not recognize them when asked in a survey; and in cases where households do not exert control over some decisions, they may still be unintentional adopters. For these reasons, this exploratory data collection has likely estimated adoption with measurement error. It is difficult to know whether the adoption estimates are biased upward or downward.

1.2.3 Climate Change Adaptation Options (One Innovation)

Starting in 2017, several provinces in Vietnam designed new location-, risk-, and season-specific climate change adaptation plans (Tan et al., 2019). These efforts were part of the Climate-Smart Mapping and Adaptation Planning (CS-MAP) initiative. Through this project, risks such as drought and saltwater intrusion were identified at different locations on the map of the province, and specific recommendations were made so that farmers could adapt accordingly. In the agricultural domain, recommendations included shifting from rice to another crop, planting different varieties (e.g. shorter-duration varieties), changing planting dates, or changing the schedule of irrigation. These agricultural recommendations were likely derived from collaborative research between Vietnam's MARD and CGIAR centers. It was envisioned that these recommendations would be disseminated to households through agricultural extension services and annual crop plans.

We included questions in the VHLSS 2022 questionnaire to ask if households had heard of these climate-change adaptation recommendations[21]. However, Vietnam 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. Thus, even though our questions were specifically about recommendations that the CS-MAP program would have made, such as advice to change the planting schedule or the variety planted, such recommendations could also have come from other initiatives unconnected to the CS-MAP program, and so it can be difficult to attribute an affirmative response directly to this particular innovation. Therefore, the adoption

[21] The same questions were also integrated into the VHLSS 2023 questionnaire.

figures presented in this report should be considered the potential reach, or upper bound of the true adoption estimates.

1.3 Data Analysis

Analysis was conducted using the raw VHLSS datasets available here[22]. The sample consists of 13,857 rice-growing households in Vietnam. Adoption estimates relate to the Winter-Spring season immediately before the time of data collection. Statistics on adoption are calculated at two levels: 1) the EA-level[23]: when at least one household claims to use/follow an innovation; and 2) the household-level: when a household has adopted an innovation. Both levels are informative of the geography of diffusion, indicating particular places where adoption is concentrated.

All statistics are self-reported by farmers, with two exceptions. When measuring the adoption of Alternate Wetting and Drying (AWD), in addition to self-reporting, we attempted an alternative measurement method by asking about the number of dry-downs between the transplanting and flowering stages; and the average length of these dry-downs. Previous studies in Vietnam indicate that farmers adopting AWD typically leave the field dry for ten days (Dong et al., 2012), with variations related to local ecological factors and infrastructure. Accordingly, we conservatively classify a farmer as adopting AWD if their average dry-down was ten days long.

The second exception is the reach of rice traits, which uses data from the DNA fingerprinting work. Within our sample of 13,857 households are 758 from whose rice plots we took rice leaf samples. We use these data to compute the extent to which certain major quantitative trait loci (QTLs[24]) are found in the material currently grown by Vietnamese rice growers. These QTLs reveal allelic variations that have been exploited in plant breeding, with the expectation that they would cause specific traits to be expressed when the plants are cultivated. However even if a certain QTL is present, it is not straightforward to determine the origin of the trait. This is because the genes leading to this trait could have been naturally present in landraces, or they could have originated from conventional breeding methods, or they could have been introgressed – when genetic material is transferred from one plant to a closely related one using marker-assisted methods. Appendix A documents the entire set of markers identified by the RiCA v4 platform, organized into four categories: yield-enhancing QTLs, grain quality QTLs, disease resistance QTLs, and stress-tolerant QTLs.

The weighted estimates of adoption are calculated using the sampling weight of VHLSS 2022. In each of the 63 provinces of Vietnam, the VHLSS sampled both rural and urban EAs (a different number in each province totaling 3,133 EAs across the country). Each province was assigned a weight equal to the ratio of the square root of the population in the province to the sum of the square roots of the populations of all 63 provinces. Within each EA the VHLSS sampled

[22] https://github.com/CGIAR-SPIA/Vietnam-pre-report-2023/tree/main/datasets.

[23] 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).

[24] A quantitative trait locus (QTL) is a region in the DNA of the rice genome that varies within a population ('allelic variation') and is associated with a particular trait. In our case, the traits of relevance relate to salt tolerance, different dimensions of grain quality and pest resistance.

15 households. In the VHLSS dataset, the '*hhwt*' variable is calculated as the inverse of the probability that a household is selected in the sample, or the number of households that each observation represents.

These standard VHLSS weights, however, do not account for the fact that the population of rice-growing households mostly resides in rural enumeration areas. As a result, quantifications of the reach in terms of the number of households are likely to be underestimated when using standard VHLSS weights.

To correct this bias, we multiplied the weighted estimates of adoption with the number of rice-growing households extrapolated from the mid-term rural and agricultural survey 2020. This mid-term survey covered 1.6 million households having activities in agriculture, forestry, and aquaculture in both rural and urban areas across Vietnam (General Statistics Office, 2022b). This results in a more precise estimate of the number of rice-growing households reached by CGIAR-related innovations at the national level, or across a subset of provinces[25]. It should be noted however, that this estimate is based on data collected in 2020 and does not take into account the decline in the number of growing households likely to have occurred between 2020 and 2022.

Reproducible Rmarkdown documents that generate the report tables, figures, and maps are available here[26].

[25] Climate change adaptation options were disseminated in a subset of provinces only (See Section.3.3)

[26] https://github.com/CGIAR-SPIA/Vietnam-pre-report-2023/tree/main/analysis

2. CGIAR-Related Innovations: Modules Integrated into VHLSS 2022

In this section, we present adoption rates and estimates of reach for the CGIAR-related innovations collected in 2022. These descriptive statistics provide insights into the adoption patterns of various agricultural innovations across the country. There are nine breeding innovations, one sustainable intensification practice, and six climate change adaptation options.

An overview is provided in Table 5. The table reports nationally representative estimates drawn from the VHLSS 2022. For each innovation, we present the percentage of rural EAs with at least one adopter (column 1) and the percentage of household adopters at the national level (column 2). The conditions applied to estimate adoption rates differ because the most relevant subpopulations differ between groups of innovations, and because genetic information on QTL markers is only available for a subsample of rice-growing households. In column 3, we quantify the estimated number of households reached for each innovation. These numbers represent the estimated total number of households in rural Vietnam reached by each innovation[27]. It should be noted that these estimates correspond to the potential reach: further work is ongoing to increase the precision of these estimates in an upcoming country report. Additionally, we also report adoption rates at the regional levels (Table 6 and Table 7).

The rest of the section dives into each group of innovations. It describes the extent of CGIAR-related efforts for each innovation and introduce the findings from the VHLSS 2022 newly integrated modules.

[27] As specified in Section 2.4, weights were corrected using the number of rice-growing households in 2020, which does not consider the decline in the number of growing households likely to have occurred between 2020 and 2022.

Table 5. Overview of adoption rates for breeding innovations, sustainable intensification practices, and climate change adaptation recommendations in 2022

	% of rural EAs	% of households with innovation	Estimated number of households (in millions)	Conditions applied
	(1)	(2)	(3)	(4)
Breeding innovations (previous Winter-Spring season)				
Household grew a certified variety (self-elicitation)	93.8	86.1	6.86	Rice-growing households selected for leaf sampling (n = 758 households in 247 EAs)
Household grew rice that has QTLs associated with yield-enhancement traits (*Gn1a, ehd1, RFT1, Hd1, GFR1, Hd2, Ghd7, NGR5, NAL1,* or *Hd3a*)	100	98.8	7.88	
Household grew rice that has QTLs associated with grain quality traits (*SLG7, Alk, Chalk5, GS3, NAS3,* or *TGW6*)	98.4	95.8	7.64	
Household grew rice that has a major QTL for salinity tolerance (*Saltol*)	48.6	29.9	2.39	
Household grew rice that has a major QTL for submergence tolerance (*Sub-1*)	3.2	1.5	0.12	
Household grew rice that has QTLs associated with drought tolerance (*DTY12.1, DTY3.2, DTY3.1*)	89.1	77.2	6.16	
Household grew rice that has QTLs associated with brown planthopper resistance (*BHP32* or *BPH17*)	46.2	33.9	2.7	
Household grew rice that has QTLs associated with blast resistance (*Pita, Pii,* or *Pi54*)	50.6	34.6	2.76	
Household grew rice that has QTLs associated with bacterial blight resistance (*qXa26* or *qXa4*)	98	95.4	7.61	
Sustainable Intensification (previous Winter-Spring season)				
Household practiced Alternate Wetting and Drying (AWD) (self-elicitation by name)	13.7	5.4	0.43	Households who planted rice in the last 12 months (n = 13,857 households in 1,767 EAs)
Household practiced Alternate Wetting and Drying (AWD) (plot-level dry-down duration)	46	22.7	1.16	
Climate change adaptation (any season in the last 12 months)				
Household adopted at least one recommendation (from list provided)	90.6	72.1	4.46	Households who planted rice in the last 12 months in the 41 provinces where CS-Maps were implemented (n = 9,252 households in 1,316 EAs)
Household adopted recommendation to not cultivate rice	24.4	10.4	0.65	
Household adopted recommendation to shift from rice to another crop	3.8	0.8	<0.1	
Household adopted recommendation to change rice sowing/planting dates	49.8	22.2	1.37	
Household adopted recommendation to change rice varieties	79	52.4	3.25	
Household adopted recommendation to shift to shorter duration rice varieties	25.4	10.2	0.63	
Household adopted recommendation to changes plot irrigation schedule	36.2	14.9	0.92	

Source: VHLSS 2022.

Note: Green cells indicate that improved measurements or adoption estimates will be forthcoming based on VHLSS 2023. Adoption rates of breeding innovations are based on DNA fingerprinting of rice-growing households selected for leaf sampling. Figures presented for Sustainable Intensification practices and Climate change adaptation rely on survey data collected from households who planted rice in the last 12 months.

Table 6. Overview of adoption rates for breeding innovations in 2022, by region

	Red River Delta		Northern Midlands and Mountains		Northern and Coastal Central		Central Highlands		Southeast		Mekong River Delta	
	%EA	%Hh	%EA	%Hh	%EA	%Hh	%EA	%Hh	%EA	%Hh	%EA	%Hh
Household grew a certified variety (self-elicitation)	98.5	92.3	97.4	91.7	92.1	84.1	83.3	63	87.9	88.2	88.5	74.5
Household grew rice that has QTLs associated with yield-enhancement traits (*Gn1a, ehd1, RFT1, Hd1, GFR1, Hd2, Ghd7, NGR5, NAL1*, or *Hd3a*)	100	100	100	96.6	100	98.2	100	100	100	100	100	100
Household grew rice that has QTLs associated with grain quality traits (*SLG7, Alk, Chalk5, GS3, NAS3,* or *TGW6*)	100	99.4	97.8	93.8	100	93.6	90.9	87.5	100	100	97.5	97.9
Household grew rice that has a major QTL for salinity tolerance (*Saltol*)	40.4	27.7	47.8	26.4	45.7	21.1	27.3	12.5	62.5	58.3	58.2	43.2
Household grew rice that has a major QTL for submergence tolerance (*Sub-1*)	0	0	0	0	6.5	2.3	18.2	7.5	0	0	3.8	2.1
Household grew rice that has QTLs associated with drought tolerance (*DTY12.1, DTY3.2, DTY3.1*)	96.5	87.1	82.6	64	82.6	67.8	100	87.5	100	79.2	88.6	87.4
Household grew rice that has QTLs associated with brown planthopper resistance (*BPH32* or *BPH17*)	7	3.2	8.7	5.1	34.8	13.5	72.7	62.5	100	95.8	93.7	90.5
Household grew rice that has QTLs associated with blast resistance (*Pita, Pii,* or *Pi54*)	35.1	20.6	37	23	50	30.4	27.3	12.5	75	79.2	70.9	59.5
Household grew rice that has QTLs associated with bacterial blight resistance (*qXa26* or *qXa4*)	100	98.7	100	96.1	100	93.6	100	100	100	87.5	93.7	93.7
Household grew a certified variety (self-elicitation)	98.5	92.3	97.4	91.7	92.1	84.1	83.3	63	87.9	88.2	88.5	74.5

Source: VHLSS 2022.

Table 7. Overview of adoption rates for sustainable intensification practices and climate change adaptation options in 2022, by region

	Red River Delta		Northern Midlands and Mountains		Northern and Coastal Central		Central Highlands		Mekong River Delta	
	%EA	%Hh	%EA	%Hh	%EA	%Hh	%EA	%Hh	%EA	%Hh
Sustainable Intensification (last Winter-Spring season in the last 12 months)										
Alternate Wetting and Drying (AWD) using self-elicitation by name	12.8	7.1	11.6	3.2	19.4	6.1	8.3	1.0	19.8	7.7
Alternate Wetting and Drying (AWD) using plot-level module	28.2	15.4	36.0	12.5	34.9	14.8	25.9	11.2	45.8	19.8
Adaptive rice-based systems and cropping calendars (any season in the last 12 months)										
Applied at least one recommendation above	94.5	76.3	96.6	70.9	94.8	77.5	77.9	41.8	88.9	59.1
Applied recommendation: Not cultivating rice	27.3	12.2	28.5	7.3	29.8	11.2	14.1	4.5	22.5	8.3
Applied recommendation: Shifting from rice to another crop	3.0	0.5	1.3	0.2	5.0	0.9	4.0	0.4	5.4	1.7
Applied recommendation: Change in rice sowing/ planting dates	52.2	23.5	48.6	19.9	58.6	22.7	21.8	8.0	61.1	24.1
Applied recommendation: Rice varieties to sow	83.0	51.2	91.7	49.6	89.6	62.3	67.8	32.6	72.1	35.8
Applied recommendation: Shifting to shorter-duration rice varieties	21.5	8.6	31.9	11.5	34.8	12.7	15.4	3.1	25.5	8.6
Applied recommendation: Changes in plot irrigation schedule	50.6	23.5	46.5	15.5	37.9	11.3	12.8	5.1	28.4	9.2

Source: VHLSS 2022

2.1 Breeding Innovations

2.1.1 Improved Rice Cultivars

Rice is of tremendous importance to the national economy of Vietnam. Following the Đổi Mới (1986)[28] reforms, Vietnam has 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 (General Statistics Office, 2023). About 55 percent of the rice was produced in the Mekong River Delta (MRD) region in the south. At the national level, 7,106 thousand tonnes of rice were exported in 2022, at an average selling price of USD 486 per tonne (General Statistics Office, 2023). Ninety percent of Vietnam's rice exports originate from the MRD.

In April 2021, Vietnam's Strategy for Sustainable Agriculture and Rural Development for the 2021-2030 period was approved under Decision No. 150/QD-TTg[29]. The national strategy is to increase the productivity and competitiveness of agriculture through the adoption of agricultural innovations, including certified rice varieties[30]. The policy specifically related to rice production is further elaborated in Vietnam's Rice Industry Development Strategy, with the current version approved in February 2021 (under Decision No. 555/QD-BNN-TT)[31]. This new sectoral plan builds on previous ones and aims to encourage the development and production of high-quality rice varieties, specifically fragrant and specialty rice. The new plan also recognizes the need to strengthen the resilience of rice production systems to climate change and natural disasters. The collaboration between CGIAR's International Rice Research Institute (IRRI) and the Government of Vietnam started in 1963. IR8 was introduced in 1966 in Tien Giang province under the name of Than Nong 8 (TN8) and two years later in the North (as Nong nghiep 8, or NN8). IRRI started to collaborate with the Cuu Long Rice Research Institute (CLRRI) in 1983 and an IRRI office was established in Hanoi in 1992, providing support to the production and commercialization of hybrid rice (Cuong, 2014). The stocktake suggests the common use of IRRI-related germplasms in Vietnam for breeding, along with collaborative research on salt-tolerant rice varieties conducted with NARS.

Vietnam's green revolution took off in the mid-1980s. The semi-dwarf genes (*sd-1*) allowed for shorter stems and stronger roots, and consequently higher yields[32]. The IR8 cultivar was later replaced by the IR36 cultivar which also contains the *sd-1* genes but is also more resistant to the brown plant hopper (BPH) pest. Over the following two decades, modern varieties spread

[28] The term "Đổi Mới" or "Renovation" in Vietnamese, refers to the economic reforms initiated in 1986 in Vietnam, from a centrally planned economy to a socialist-oriented market economy.

[29] Prime Minister Decision No. 150/QD-TTg on appoving the sustainable agriculture and rural development strategies for the period 2021 – 2030 with a vision toward 2050: https://lawnet.vn/en/vb/Decision-150-QD-TTg-2022-sustainable-agriculture-and-rural-development-strategies-7B2B6.html

[30] 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 the MARD to ensure its quality, productivity, and suitability before being officially recognized by the government.

[31] MARD Decision 555/QD-BNN-TT on approving scheme for restructuring of Vietnam's rice industry by 2025 and 2030: https://thuvienphapluat.vn/van-ban/Thuong-mai/Decision-No-555-QD-BNN-TT-2021-approving-scheme-for-restructuring-of-Vietnam-s-rice-industry-2025-2030-465306.aspx?v=d

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

and there was an increase in chemical fertilizer applications and an expansion of irrigation. Many companies – private, joint ventures, or foreign seed companies – were established. Improved cultivars were gradually diffused in less favorable areas (Tarp, 2018; Ut & Kajisa, 2006). It is believed that varietal turnover, with continuous replacement by superior rice varieties, has fueled the momentum of Vietnam's green revolution (Ut & Kajisa, 2006). Rice yield continued to increase over the first decade of the century, from 4.2 tonnes in 2000 to 5.3 tonnes per ha in 2010. Yield increased from 4.1 tonnes in 2000 to 5.2 tonnes per ha in 2010 in the Northern regions, and from 3.7 tonnes to 4.9 tonnes per ha in the Southern regions (General Statistics Office, 2011)[33]. In the 2010s, new cultivars were introduced that had been developed by improving existing varieties using marker-assisted selection (MAS[34]) with DNA markers originating from IRRI-related germplasms (examples: OM4900, BC15, Bac Thom 7, and dozens of others).

Importantly, there are large regional variations in terms of agroecology, irrigation infrastructure, varietal adoption, and productivity. In the northern regions, production is concentrated in the Red River Delta (RRD) and the northern highlands. Given the similarity between the agroecology of Southern China and Northern Vietnam in the 1990s hybrids originating from Southern China were released in Vietnam, particularly in the Red River Delta region (Hossain et al., 2003). The region has now moved on from its dependency on Chinese rice hybrid seeds, and 70-80 percent of hybrid-certified seeds are now produced locally. Most aromatic varieties in the North are of the japonica type, with some unique indigenous landraces.

In the southern regions, there has been a shift from high-yielding to high-quality rice over the past two decades. There has also been a shift from domestic food security concerns to growing exports. The rice exported from the MRD is mainly aromatic, specialty, and japonica rice (50%) and high-quality (30%) (MARD communication, 2023). 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 the MRD now also cultivate in the autumn and spring seasons.

There is limited evidence on the adoption rate of improved varieties. The MARD conducts annual surveys in the southern regions, where farmers self-report the seed variety they planted. These data suggest that in 2021 in the MRD, five main varieties were each planted on land totaling more than 100,000 hectares; these are OM5451, OM18, Dai Thom 8, IR 50404, and IR 4625. In addition, based on self-reported data collected across the country, GSO also finds that popular varieties planted in Vietnam are OM5451, Bac Thom 7 and IR 50404, comprising 10.3 percent, 3.4 percent, and 3 percent total paddy area respectively (General Statistics Office, 2022c). In a representative sample of households in the MRD, Paik et al. (2020) used expert elicitation to identify seed varieties and found that 44 percent of households grew salt-tolerant rice varieties.

Desk research indicates that from 1977 to 2022, the IRRI Genebank received 8,046 seed requests from NARS in Vietnam. There are strong indications that part of this material has been used in breeding, although the number of released varieties that have an IRRI parent is unknown[35].

[33] See also 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

[34] Marker assisted selection is a technique used in plant breeding in which selections are made based on presence/absence of specific genetic markers known to be associated in some way with specific desirable traits, rather than making selections based on observations of the traits directly.

[35] A total of 341 improved rice varieties have been certified and released in Vietnam from 2000 to 2020. Research by SPIA is ongoing to determine the precise contribution of IRRI parents to the release of certified varieties.

During a consultation workshop with breeders that SPIA organized in Can Tho in February 2023, there was a consensus that the IRRI germplasm collection has been a long-standing public source of germplasm[36]. There is also reason to believe that IRRI-related genes are likely to be found in the seeds sold by both public and private companies[37]. It is clear that agricultural extension services have played important roles in the diffusion of locally adapted varieties, and this is further confirmed by data presented in Section 3.3: Climate Change Adaptation Options.

Data from the newly integrated modules in VHLSS 2022 show that a large share of households (90 percent) reported that they grew a certified rice variety. In the MRD, 88 percent of EAs had at least one household growing certified seeds, which represents 74 percent of households in the region. Most household seed purchases occurred through seed companies or private stores/ dealers (three-quarters of purchases). It is noteworthy that 12 percent of households practiced seed recycling, with seeds stored and then reused for an average of four agricultural seasons after harvest. Nearly 60 percent of households overall (and in 84 percent of EAs at least one farmer) reported that they received recommendations about seed varieties to plant from agricultural extension services.

Rice Traits Adoption using Genetic Markers

Crop breeding research aims to develop new varieties with desirable traits. While high yield is a major trait of interest, breeding efforts have frequently targeted tolerance to environmental stress, resistance to diseases, or crop nutritional value. Rice traits are also examined during the rice seed certification process: the MARD National Center for Variety Evaluation and Seed Certification (NCVESC) classifies 70 rice traits using distinctness tests.

Recent advances in genomics allow researchers to identify molecular markers that can affect the expression of a desired trait. A large strand of research attempts at validating trait-marker associations, documenting the gene response in different environments, and at specific crop growth stages (Platten et al., 2019). Once validated (or cloned), the genetic mapping of validated markers is used to screen plants with the desired traits before developing new cultivars. This greatly improves the speed and efficiency of breeding programs. Research is at different stages for each marker, and there is evidence for some markers being major QTLs, while others are only considered promising. Indeed, genes are involved in complex regulatory networks, so the effects of a single gene mutation may not always be straightforward, instead the presence of a particular gene *contributes* to its phenotype.

The rice DNA fingerprinting exercise we conducted in 2022 allows us to use the current state-of-the-art knowledge on rice markers-traits associations to evaluate where improved rice varieties have diffused onto farmer's plots in Vietnam. The most frequent QTLs present in the crop samples from the VHLSS likely reflect which traits are in demand in Vietnam, and shed light on how Vietnam's rice production has specialized. The distribution of these QTLs in Vietnam also documents the levels of resistance to climate-related stresses, and disease tolerance in the rice varieties currently being grown. This provides important insights into the extent to which farmers' livelihoods, and Vietnam's rice sector, are protected against current and future environmental changes.

[36] Participants also noted that germplasm from Japan and South Korea has been accessed, but they stated that no known variety had been released with that parentage.

[37] For instance, CLRRI has transferred the ownership of cultivars OM5451, OM6976 to the private corporate group Loc Troi.

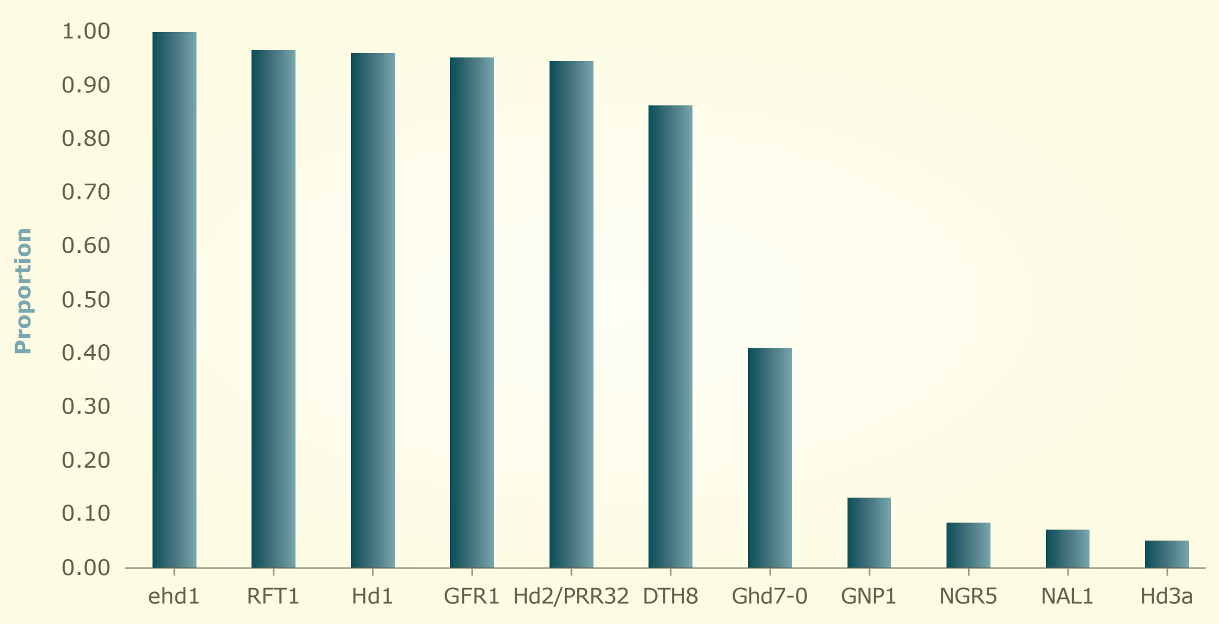
In what follows, we discuss our findings on the incidence of different QTLs among Vietnamese rice farmers. These estimates tell us the *potential* contribution of CGIAR to rice traits in Vietnam and should be understood as upper bounds. It is not possible to distinguish marker-associated traits developed through the use of the IRRI Genebank (and disseminated through the efforts described above), from those that were naturally present in Vietnam in existing landraces. The analysis presents evidence on yield-enhancing and grain quality traits, which were likely promoted during the green revolution period. In contrast, QTLs related to stress tolerance and disease resistance have been the focus of research in the past two decades.

Yield-Enhancing QTLs

Yield-enhancing traits found in the rice growing on farmers' fields could have *possibly* originated from IRRI's germplasm collection. However, for the past two decades, no major project or collaboration with CGIAR centers on yield-enhancing traits was found in the stocktake.

Among 16 QTLs identified by the RiCA v4 platform[38], we found 11 on at least 5 percent of farmers' plots in Vietnam (Figure 5). The first group encompasses markers that have proven effective at increasing the number of grains per panicle or the grain-filling rate. The *GFR1* gene was found very widely on the plots of 94 percent of the farmers in the sample. The *GNP1* and *NAL1* genes were found on the plots of 13 percent and 7 percent of farmers respectively. *GNP1* genes are found in all regions but appear more common in the MRD.

Figure 5. Proportion of rice varieties containing yield-enhancing alleles in Vietnam



Source: VHLSS 2022.
Note: Only QTLs found in at least 5% of households at the national level are plotted.

[38] RiCA stands for Rice Custom Amplicon SNP panel, which is a form of genotyping co-developed by IRRI and AgriPlex Genomics featuring 1,040 SNP markers, including 205 SNPs for QTLs, including those we use in this section.

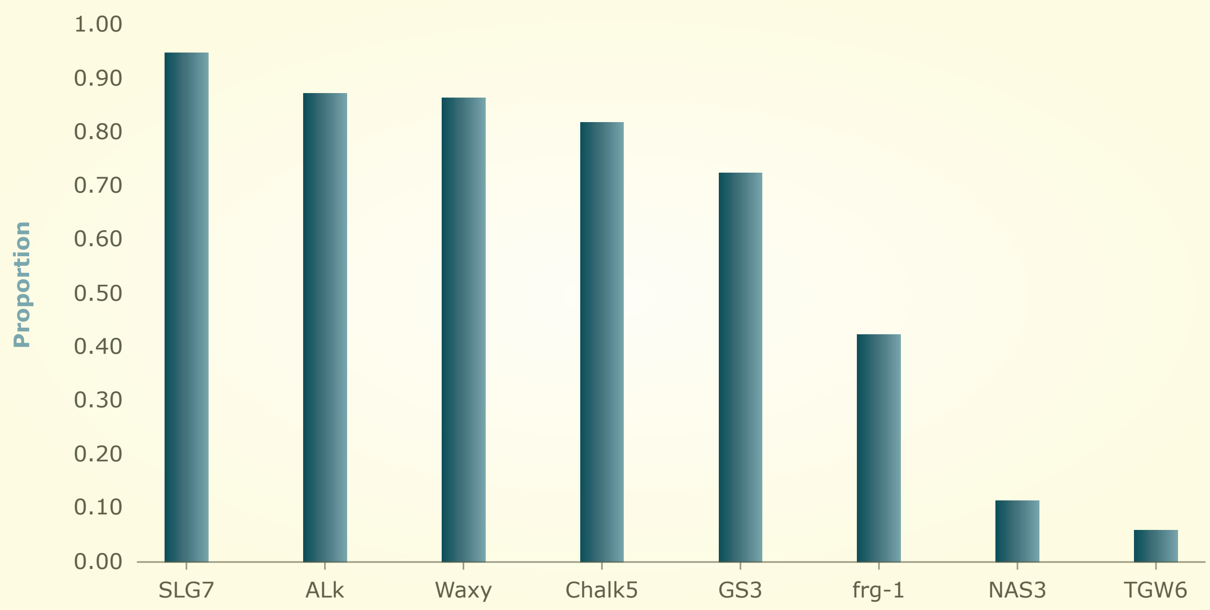
A second set of genes relate to the rice heading date and these have been used for breeding shorter-duration varieties, which can also increase yield by allowing farmers to plant rice more frequently through the year. These include genes linked to photoperiodic sensitivity (*Hd1*, 95% of households) early flowering (*Hd2*, 94%), or delayed flowering (*ehd1*, 99%, *DTH8*, 85%, and *Ghd7*, 40%). QTLs associated with flowering dates – *Hd2/PRR32, DTH8,* and *Ghd7* – are highly specific to the Vietnamese material (i.e., these QTLs are not commonly found in rice samples from other countries). These genes are likely to have played a role in the replacement of long-duration rice varieties with short-duration ones that occurred during the 1990s (Khanh et al., 2021). *NGR5*, a gene that is responsible for nitrogen efficiency, is present in 7 percent of the material grown by Vietnamese farmers.

Overall, the evidence suggests that yield-enhancing traits are found in some form or another on nearly all farmers' fields in Vietnam, suggesting a potential reach of 7.88 million households. This is consistent with a fairly comprehensive replacement of traditional rice with modern varieties.

Grain-Quality QTLs

Grain quality is an important requirement for rice exports to international markets. No major project or collaboration on grain-quality traits was found in the stocktake. However, grain quality traits found on farmers' fields could have *possibly* originated from the IRRI germplasm collection. Among 14 genes identified by the RiCA v4 platform, 8 are found on at least 5 percent of farmers' plots in Vietnam (Figure 6). These QTLs appear to be evenly distributed across Vietnam's regions.

Figure 6. Proportion of rice varieties containing grain quality alleles in Vietnam



Source: VHLSS 2022.
Note: Only QTLs found in at least 5% of households at the national level are plotted.

Four genes are linked to rice grain size/shape. *SLG7* is responsible for a slender grain shape and is found on 95 percent of plots. Among different genes, the *GS3* gene is considered to be the most important contributor to grain size/shape. The *GS3* gene was found in 72 percent of the collected samples. The other genes *NAS3* and *TGW6* were found on the plots of 11 percent and 5 percent of farmers respectively. The *NAS3* gene is more frequently found in the RRD and Central coast regions of Vietnam.

Our data show that genes related to rice gelatinization temperature (*Alk*, 87%), chalkiness (*Chalk5*, 82%) and amylose content (*Waxy*, 86%) are also highly present in farmers' fields. The *Chalk5* gene favors improved grain quality, through improved visual appearance, better milling quality, and enhanced cooking and eating quality. Different alleles of the Waxy QTL determine the level of amylose produced by rice plants, with Wx(a) producing high levels and Wx(b) producing low levels. The Wx(a) allele was identified in 62 percent of the crop samples from the VHLSS 2022[39]. Finally, the gene *frg-1*, responsible for aroma, was found on the plots of 40 percent of farmers[40].

Three alleles – *SLG7, Alk,* and *frg-1* – are noticeably abundant in the material grown by farmers. The government's strategy to move Vietnam's rice export sector progressively away from lower-grade indica rice cultivars (ex: IR50404) towards higher-valued varieties has long been in place (FAO, 2018). These differences may reflect the high-quality, export-orientation of the rice sector in Vietnam that has occurred in the last two decades.

Overall, the data suggest that 7.64 million farmers in Vietnam grow rice with high-quality traits.

Stress-Tolerant QTLs

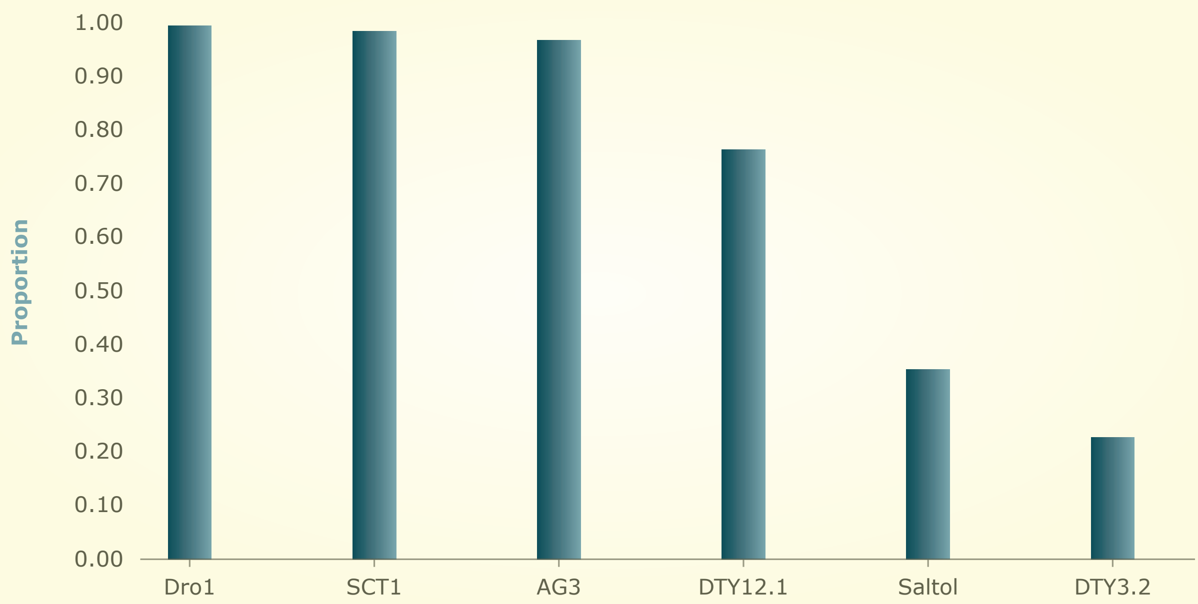
Stress-tolerant traits have received increased attention in the face of recent and projected environmental challenges. Abiotic traits include tolerance to drought, heat, and cold as well as the ability to withstand episodes of salinity (salinity tolerance). Past breeding efforts have also attempted to develop rice varieties that can withstand complete immersion of the plants during flood events - i.e., submergence tolerance.

In the 2010s, there were two collaborative efforts between IRRI and national partners in Vietnam to develop stress-tolerant varieties: 'The Consortium for Unfavorable Rice Environments' (CURE, IFAD, 2010-2018) and the 'Climate Change Affecting Land Use in the Mekong Delta: Adaptation of Rice-based Cropping Systems' (CLUES, 2011-2013).

[39] The Vietnam RiCA v4 report does not distinguish between Wx(b)-IR30, Wx(a)-Swarna and Wx(a). We assume that this allele is Wx(a) as the Swarna and IR30 alleles are very rare and specialized.

[40] This gene is one of the few that is totally absent from IRRI elite material. It is found in almost all fragrant landraces, both basmati and jasmine, from India through Thailand to the Philippines.

Figure 7. Proportion of rice varieties containing stress-tolerant alleles in Vietnam



Source: VHLSS 2022.
Note: Only QTLs found in at least 5% of households at the national level are plotted.

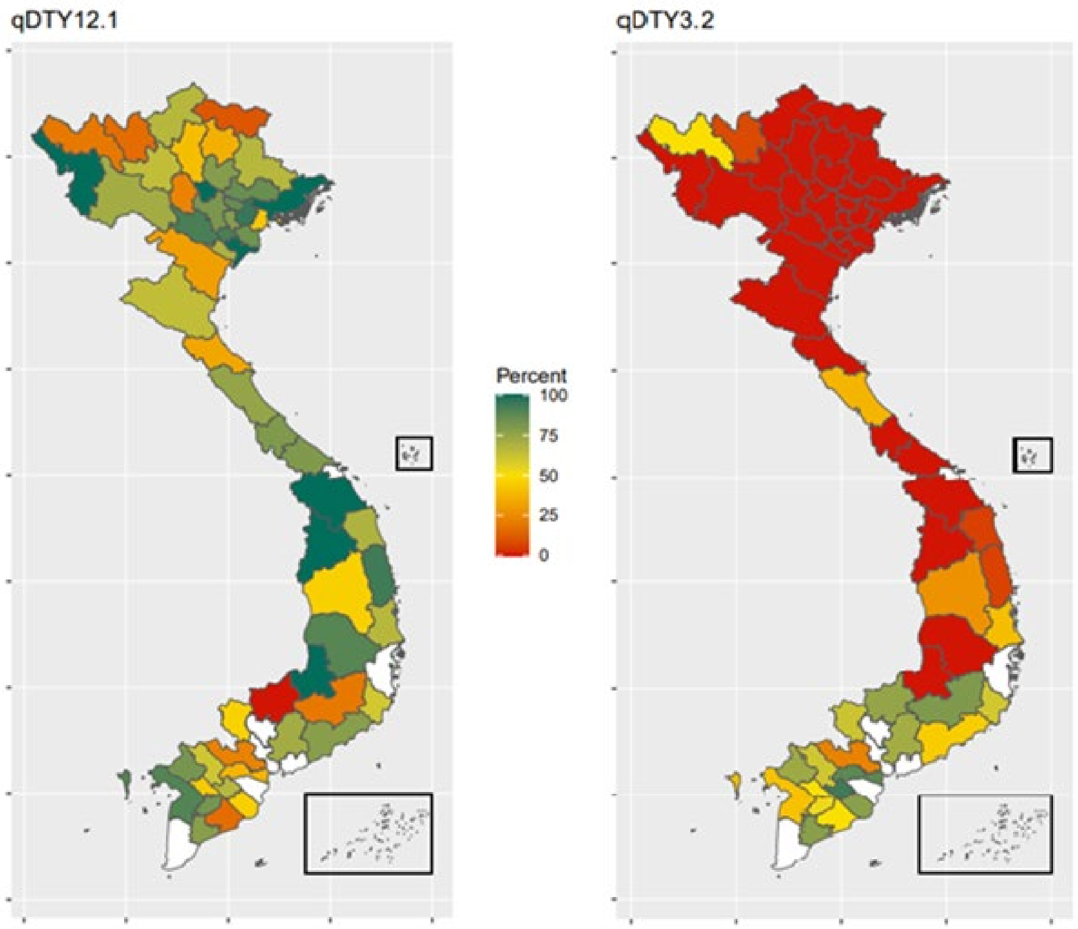
Among the 19 genes identified by the RiCA v4 platform, six were found on the plots of at least 5 percent of farmers (Figure 7). *The Dro1* and *SCT1* QTLs have respectively been linked with drought tolerance at the vegetative stage and cold tolerance at the seedling stage. However, since these are also common haplotypes[41] for indica varieties, it is difficult to know if this indicates the reach of drought and cold tolerance traits.

Drought-tolerance at the vegetative stage has been associated with seven QTLs present on the RiCA v4 platform. Among these genes, *qDTY12.1* is considered to be an important contributor to drought tolerance. *qDTY12.1* was present on three-quarters of sampled leaves. It was found on the plots of approximately 80 percent or more farmers in the RRD, Central Highlands, Southeast, and MRD (Figure 8). A second drought tolerance gene named *qDTY3.2* was present on 23 percent of the collected material overall but appeared to be limited to the southern regions, suggesting its adaptation to the Southeast and MRD agro-ecologies. Two percent of plots, all located in the MRD region, also contained the *qDTY3.1* gene which is also associated with drought tolerance.

Overall, the potential reach of drought-tolerant traits in Vietnam can be estimated at 6.16 million households.

[41] A haplotype refers to a set of alleles that tend to be inherited together from the same parent.

Figure 8. Maps showing adoption intensity of drought-tolerant markers by province in Vietnam



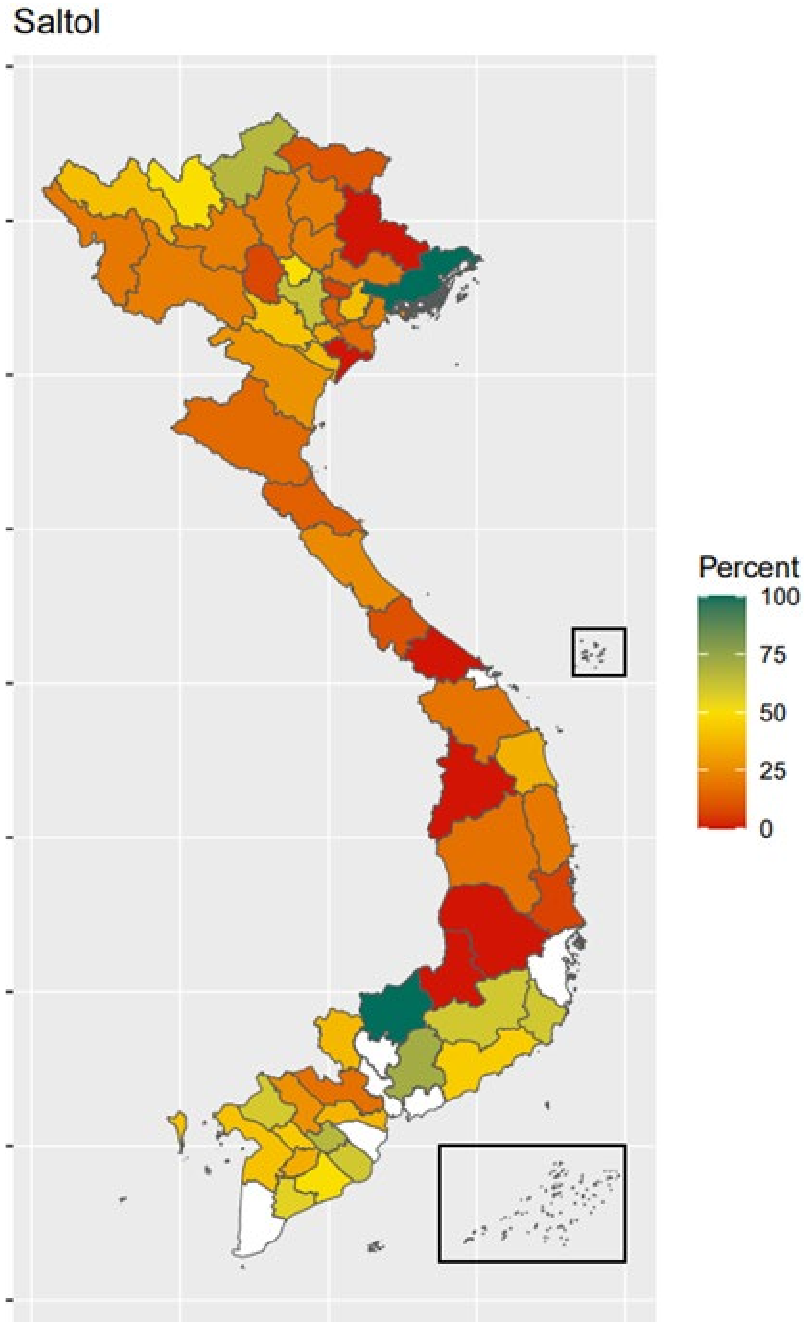
Source: VHLSS 2022

Genes that confer heat-tolerance at the vegetative stage (TT) and cold tolerance at the seedling stage (*COLD1*) were not found among the crop samples. The *qCST10* gene, associated with cold tolerance, was found in 2 percent of surveyed plots.

In the past, Vietnam has had severe salinity intrusion events (CCAFS-SEA, 2016). The risk for salinity intrusion is higher for the MRD region, but other provinces also suffer periodic intrusions in the RRD and the NC regions. Crop damage has previously occurred in Quang Nam and Binh Dinh provinces (DARD Binh Dinh, 2020; DARD Quang Nam, 2019).

An increase in the frequency and severity of salinity intrusion events is a likely consequence of climate change and rising sea levels. Starting in the early 2000s, breeders in Vietnam have consistently been working on developing varieties with salinity-tolerant traits, with a specific focus on the agroecology of the MRD. Between 2002 and 2020, at least 26 salt-tolerant varieties were released. Additionally, between 2010 and 2018, IRRI, CLRRI, and the Institute of Agricultural Science (IAS) collaborated under the umbrella Consortium for Unfavorable Rice Environments (CURE) to develop submergence-tolerant and stagnant flooding-tolerant varieties. Several cultivars were evaluated and 13 varieties were tested in four coastal provinces of the MRD in the 2012/2013 Dong Xuan season (Paik et al., 2020). Existing cultivars were also improved to include salinity tolerance traits (ex: OM4900, OM18, OM5900). The *saltol* gene, a major QTL among the three genes identified for salinity tolerance at the vegetative stage, was extensively used in this research effort[42].

Figure 9. Map showing adoption intensity of the *saltol* gene by province in Vietnam



Source: VHLSS 2022

[42] Evidence suggests that: *i)* the japonica and IR29 alleles are unfavorable; *ii)* the allele predominant in indica material has an intermediate level of activity, and *iii)* two unrelated alleles (from the aus and aromatic cultivar groups) have a high activity, producing a stronger effect on the expression of the salinity trait. Therefore, we use the aus/aro alleles to identify the presence of the *saltol* marker (Arbelaez et al., 2019).

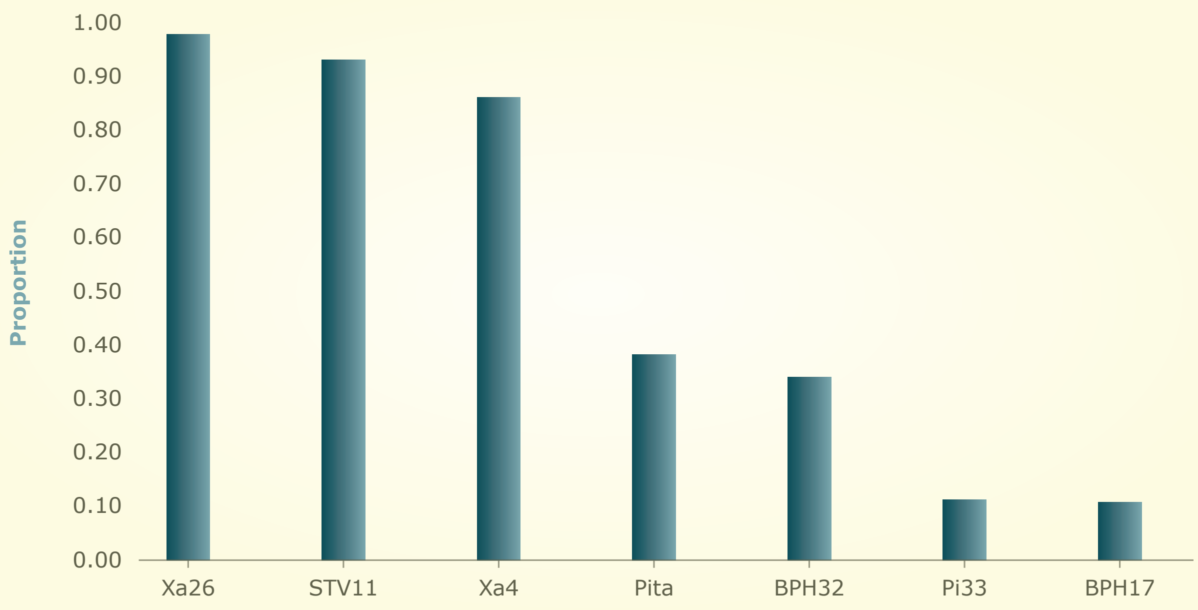
At the national level, the *saltol* gene was present on 36 percent of sampled plots, and the potential reach of the *saltol* trait for salinity tolerance is estimated at 2.39 million households. Its presence is distributed widely over the country, and following the spatial distribution of rice cultivation, it is more likely to find the *saltol* gene in rice grown in the Southeast (58%) and Mekong Delta Region (MRD) regions (43% of households). It was found less frequently in the Red River Delta (RRD) (28% of farmers) and North Central and Central Coastal Area (NC) (21% of farmers) regions (Figure 9). This would suggest a possible misallocation of the *saltol* gene, all other factors being equal: it is more likely to be present in provinces where salinity risk is low; but less prevalent in vulnerable provinces that include the RRD or are directly exposed to seawater through their coastal exposure.

Submergence tolerance – the ability to withstand complete submergence for up to 14 days – has been linked to the *gSUB1* gene. This gene has been exploited in cultivar IR64 Sub1 to obtain submergence tolerant rice variety OM1490 - Sub1 (Bui & Nguyen, 2017), and shown – in an empirical impact evaluation in India – to have a positive impact on the use of complementary inputs, thereby unlocking productivity gains as the flood tolerance acts as a kind of insurance for farmers (Emerick et al., 2016). However, in Vietnam, *gSUB1* has not been as actively targeted as other abiotic stress traits such as *saltol*. The *gSUB1* gene was found in 1.5 percent of surveyed households, equivalent to 120,000 households in Vietnam.

Pest and disease-resistant QTLs

IRRI research has placed a particular emphasis on biotic stresses (IRRI, 2018), so it is *possible* that pest and disease-resistant traits found in the rice on farmers' fields originated from the IRRI germplasm collection. No major project or collaboration on disease-resistant traits in Vietnam was found in the stocktake. The DNA fingerprinting exercise found disease-resistant genes for rice blast, the brown planthopper (BPH) pest, rice bacterial leaf blight (BLB), the Trungo virus, and the rice stripe virus. Among the 26 genes identified by the RiCA v4 platform, 7 are found on the plots of at least 5 percent of farmers (Figure 10).

Figure 10. Proportion of rice varieties containing pest and disease-resistant alleles in Vietnam

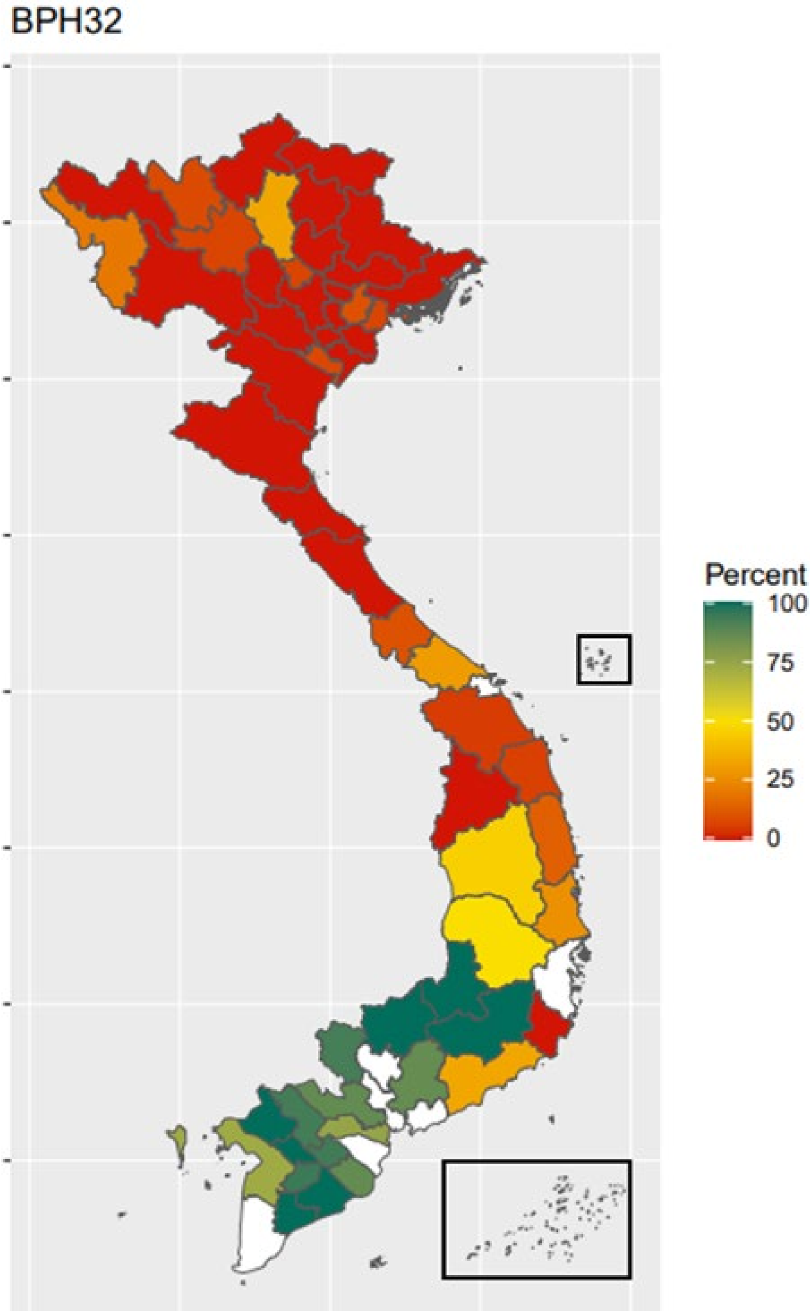


Source: VHLSS 2022.
Note: Only QTLs found in at least 5% of households at the national level are plotted.

Rice blast, a fungal disease that can affect grain quality and quantity, is widespread in Vietnam. Blast-resistant varieties have been developed using a variety of genes, including *Pita, Pii, Pi54,* and *Pi33*. *Pita* is a major blast-resistant QTL and is found on 36 percent of plots in Vietnam. It has been suggested that *Pi33* is a major contributor to blast resistance, but the gene has not yet been cloned. This gene was found on 11 percent of crop samples suggesting it is naturally occurring in Vietnam. The *Pii* and *Pi54* genes were also found but on a very limited number of plots. Five other blast-resistant genes were absent from the crop samples. The potential reach of major QTLs associated with blast resistance (*Pita, Pii, Pi54*) is 2.76 million households.

BPH is a major pest in Vietnam and can infest the plant at any rice growth stage. Severe outbreaks have occurred in the MRD region (2010-11 and 2016-17) and the Central Highlands (2016-17) in the recent past (Figure 11). Of the three genes known to provide resistance to the brown planthopper (BPH), two were found on farmer's plots. One-third of the crop samples contained the *BPH32* gene, which has proven effective against multiple BPH biotypes and has been widely used in breeding programs. *BPH17* has proven effective against some BPH biotypes only and is found on 11 percent of the grains sampled. These crop samples are primarily from households located in the MRD and Southeast regions. The potential reach of major QTLs associated with brown planthopper resistance (*BPH32* and *BPH17*) is 2.7 million households.

Figure 11. Map showing adoption intensity of the BPH32 gene by province in Vietnam



Source: VHLSS 2022

BLB affects rice plants' leaves, causing significant yield losses. Following an outbreak in MRD in 2008-2009, several BLB-resistant varieties were released. Among the several genes identified for BLB resistance, two major QTLs – *qXa26* and *qXa4* – are found on 98 percent and 86 percent of farmer's plots, respectively. The potential reach of QTLs associated with bacterial blight resistance (*qXa26* and *qXa4*) is 7.61 million households.

The Trungo virus is transmitted by an insect vector, the green leafhopper, and is prevalent in the MRD. Two virus strains are distinguished, and resistant genes have been identified for both: The

TSV1 gene has demonstrated effectiveness against the rice tungro spherical virus (RTSV); the *TBV1* gene is believed to provide resistance to the rice tungro bacilliform virus (RTBV). These resistant genes were found on the plots of only 3 percent and 2 percent of farmers respectively, primarily located in the MRD and Southeast regions.

The Rice Stripe Virus (RSV) is transmitted by the small brown planthopper and causes yellow or brownish stripes on rice leaves. A single gene, *STV11* is believed to confer resistance and was found on 93 percent of sampled material. The gene is evenly distributed across Vietnam's regions.

Rice trait misclassification

Results from the rice genotyping exercise can provide further insights into the accuracy of survey data on self-elicited traits. Such data is of significant interest for all crops for which CGIAR centers have a mandate since farmers' preferences and risk perceptions are key elements affecting the adoption decision (Asrat et al., 2009). Besides, traits are what matters most for farmers' outcomes – arguably more important than whether the farmer knows the identity of the variety they are cultivating – and traits are also what breeding efforts focus on.

There are different ways to measure crop traits. Self-reported data from farmer surveys can be a low-cost approach to returning timely data but suffers from measurement error for many reasons, including respondents' and enumerators' lack of knowledge, farmers' misperceptions, or a flawed survey process.

Since we collect both farmer self-reported data and DNA fingerprinting in the same household survey, we can shed light on the differences in measurement between these two approaches. Overall, in the VHLSS 2022 survey, more than one-half of households self-reported that they were growing a drought-tolerant variety, 14 percent of households reported they were growing a salt water tolerant variety, and 26 percent reported the rice variety they were growing could withstand complete submergence.

Since we have DNA fingerprinting data for rice samples from 758 farmers on the genetic traits of the crops they grow, we can assess whether their self-reports about their rice crop's traits match up with this objective benchmark. As we can see in Table 8, strikingly, about one-third of farmers were in fact growing a salt-tolerant variety but did not know that (or knew but did not report accurately). Similarly, despite farmers' beliefs, drought-tolerance traits were not found on 11 percent of plots. Tolerance to heat was also believed to be present in the main variety grown by 32 percent of households, but the *TT1* marker was absent from most of the genotyped seeds. Genes related to cold tolerance were present, but not acknowledged by almost two third of surveyed households.

Table 8. Summary results of household elicitation on rice salinity and drought tolerance and presence of characterized QTLs

	Salinity tolerance (*saltol*)	Drought tolerance (*qDTY12.1, qDTY3.1 or qDTY3.2*)	Heat tolerance (*TT1*)	Cold tolerance (*Cold1, qSCT1, qCST10,* and *qPSST6*)
% True Positive	5.1	41.4	0	26.8
% True Negative	55.7	10.3	68.3	4.4
% False Positive (Type I error: declared tolerant when not)	7.9	11.4	31.7	4.4
% False Negative (Type II error: declared non-tolerant when tolerant)	31.3	36.9	0	64.4

Conclusion

Overall, the number of QTLs found on farmers' plots represents more than half of the QTLs currently cloned: out of 75 QTLs, 43 are found on at least one plot in Vietnam. Variations exist between the categories – yield-enhancing QTLs, grain quality QTLs, disease resistance QTLs, and stress-tolerant QTLs. A high proportion of yield-enhancing, grain-quality QTLs can be found in Vietnam (> 70%). This share is lower for disease-resistant and stress-tolerant QTLs (46%). A combination of past breeding efforts, market demand, and possibly breeding trade-offs[43] could explain this result.

The distribution of major QTLs in Vietnam suggests the widespread adoption of high-yielding, high-quality rice cultivars. Grain quality loci (*fgr-1, Alk*) are much more common in Vietnam, compared to the IRRI elite indica material. The high level of adoption of these markers in Vietnam could reflect the high-quality, export-orientation of the rice sector in Vietnam that has occurred in the last two decades.

The geography of trait adoption also suggests the potential existence of trait misallocation. This is apparent in the case of the *saltol* gene and suggests some degree of vulnerability in the current material grown by farmers, particularly in the face of growing environmental threats.

Research is ongoing to leverage more insights from this unique dataset. Future directions include the mapping of marker-associated traits to collected breeder seeds; documenting the traits of accessions received in Vietnam from the IRRI Genebank, using available pedigree data; understanding potential geographical misallocation: documenting seed parentage of all 341 varieties certified in Vietnam since 2000, and ultimately assessing the adoption of CGIAR-related varietal cultivars.

[43] A breeding trade-off occurs when selecting for one trait may unintentionally select against another trait that is genetically linked to it.

2.2 Sustainable Intensification Practices

2.2.1 Alternate Wetting and Drying (AWD)

In Vietnam, continuously flooded rice cultivation accounts for around 41 percent of greenhouse gas emissions from agriculture (MoNRE, 2022). This is because wetlands promote the growth of methanogenic bacteria, which release methane gas – a greenhouse gas many times more powerful than carbon dioxide. Alternate Wetting and Drying (AWD) is a water management technique where the soil is irrigated and then allowed to dry down in a repeated pattern, thereby allowing the soil to reoxygenate between irrigations and reducing anaerobic bacteria that can build up in the soil. This technique enables farmers to save water and reduce methane emissions while maintaining rice yields. The origins of research on AWD in Vietnam can be traced back to initial IRRI research when AWD principles were first applied in a pilot in three provinces in 2002-03. This was followed by an evaluation in An Giang Province for three successive rice-growing seasons (Lampayan et al., 2015).

For AWD to successfully reduce greenhouse gas emissions, a minimum of two dry-down periods must occur between the transplanting and flowering stages of rice cultivation (Dong et al., 2012). AWD guidelines also 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 farmer’s plots to measure water level depth.

In 2011, the government of Vietnam supported the implementation of AWD through Decision 3119 by MARD[44]. Since 2016, it has been considered a key component of Vietnam’s climate change mitigation strategy, supporting the Nationally Determined Contributions (NDC) to the Paris agreement (Decision 819/QD-BNNK H CN)[45]. At least eight government decrees since 2011 have made AWD adoption a priority. The government’s stated objective is to ensure that 0.2 to 0.5 million hectares of rice cultivation areas are practicing AWD by 2030.

In line with this priority, IRRI research since 2016 has concentrated on AWD scaling. This includes contributing to the development of suitability maps (MapAWD)[46] that identify areas with high mitigation potential and the development of AWD training materials and technical instructions. Notable projects include the Climate Change, Agriculture and Food Security CRP (CCAFS, 2016-2021) and the Climate and Clean Air Coalition (CCAC) Phase 2: Methane mitigation from rice (UNEP, 2016-2020).

Agricultural extension training programs organized training events in 30 provinces across Vietnam. IRRI provided technical assistance to scale up AWD practices in eight provinces in

[44] MARD Decision No. 3119/QD-BNN-KHCN: https://thuvienphapluat.vn/van-ban/Tai-nguyen-Moi-truong/Quyet-dinh-3119-QD-BNN-KHCN-De-an-giam-phat-thai-khi-nha-kinh-trong-nong-nghiep-164916.aspx

[45] MARD Decision 819/QD-BNNK: 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

[46] MapAWD is an Microsoft® Excel-based tool.

the MRD via the 'Vietnam – Sustainable Agricultural Transformation' (VnSAT, WB, 2015-2022) project. It is estimated that more than 800,000 farmers received AWD training (IRRI, 2020).

To measure the adoption of AWD, we incorporated into the VHLSS 2022 questions for farmers to self-report their awareness of the term 'Alternate Wetting and Drying' (in Vietnamese: (1) Ướt khô xen kẽ; (2) Khô ngập luân phiên; and (3) Nông Lộ Phơi), as well as their own practice of AWD in the previous Winter-Spring season. This was measured generally in answer to the question "Did you practice AWD?", as well as specifically, by the number of days they left the plot dry between transplanting and flowering, and the average number of days the plot was left dry before it was irrigated again. While this measurement method is subject to caveats (see Section 2: Methods and data)[47], this is useful as a first attempt to investigate awareness of AWD and to construct a proxy of AWD adoption.

In the VHLSS 2022, 7 percent of households reported they were aware of AWD and 5 percent declared practicing AWD in the previous Winter-Spring season. However, the practice of drying-down the field was more common: 14 percent of households said they had dried-down their rice plots at least twice during the season, for an average of 10 days each time. Farmers in nearly one-third of EAs reported they had done this (Table 9).

Depending on the measurement used, estimates of the reach of AWD range between 400,000 (farmer self-reported data, by name) and 1.16 million households (self-reported data on whether used a dry-down practice). It is plausible that the true adoption is likely to be within that range. Restricting our estimate to only those farmers who know the term would lead to under-reporting by those farmers who practice a form of AWD having learned about the principles from others, without learning the correct terminology. The upper bound, using data on dry-downs, includes farmers that settled on this way of producing rice via their own experimentation and with no attribution to IRRI.

Table 9. AWD adoption estimates in the VHLSS 2022 in %

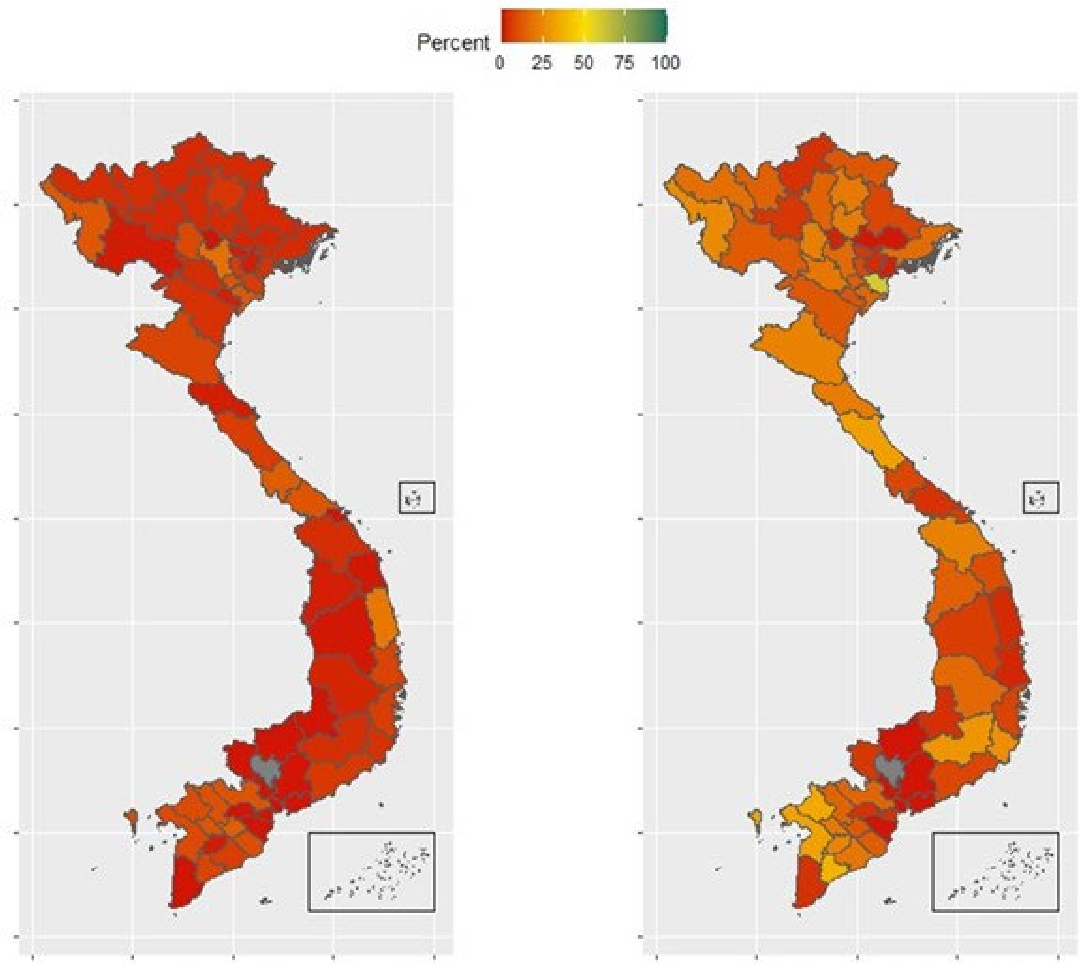
	EAs	Households
Measurement A		
Self-reported data by name	13.7	5.4
Measurement B		
Self-reported data – At least two dry-downs	72.5	46.4
Self-reported data – At least two dry-downs of 7 days on average	46	22.7
Self-reported data – At least two dry-downs of 10 days on average	32.4	14.6

[47] Notably, no survey-based variable could possibly capture below-ground plot water levels. As explained above, the AWD guidelines require that the water level be allowed to fall 15 cm below the ground before the field is re-irrigated. Takayoshi et al. (2016) shows that after 10 days of dry-off the water is likely to reach that level, but several parameters (soil percolation rate, temperature, plot location) influence this outcome.

Both statistics are displayed at the province-level in Figure 12. On the left map, as measured by self-reported data by name, adoption rates are higher in the Mekong River Delta, with at least one adopter in 69 percent of EAs. By the same metric, there is adoption in 25 percent of EAs in the Southeast region, 18 percent in the North Central and Central Coastal Areas, 10 percent in the Red River Delta, 8 percent in Central Highlands, and 4 percent in the Northern Midlands and Mountain areas. These results are in line with what we know about the dissemination of AWD practices which were first introduced in An Giang province (in the MRD). Since then, there have been major dissemination efforts focused primarily on the MRD region.

The right map displays results from the questions about specific actions the farmers took in the previous Winter-Spring season. In particular, a farmer is considered an adopter if they report that they dried-down their rice plots at least twice during the cultivation period, for ten or more days on average. Once again, adoption is higher in the MRD where at least one farmer in 46 percent of EAs in the MRD was an adopter. In the NC, the RRD, and the Central Highlands (CH), between 26 percent to 36 percent of EAs have at least one farmer following this practice.

Figure 12. Maps comparing two measurement methods for AWD



Source: CGIAR-SPIA

Note: Self-elicited AWD adoption relying on terminology (left) and self-elicited plot-level changes on at least two dry-down periods of 10 days on average in the last Winter-Spring season (right).

Both metrics integrated into VHLSS 2022 suggest that AWD adoption is the highest in the MRD but is likely to have occurred in other regions too. However, the metrics deliver different adoption rates: self-reported data using the term suggests only 5 percent of farmers have adopted AWD, whereas when measured through self-reported practice of dry-downs the adoption rate is considerably higher at 14 percent. The geographical patterns of adoption are also somewhat different across the two measurement methods.

Since all farmers answered both questions, we can also examine how often their answers overlap. In particular, one can consider households that report that they have practiced AWD (identifying it by name) and also report that they dried down their rice plots at least twice for at least ten days each time in the previous Winter-Spring season. There is no systematic pattern of overlap between the two answers. Among the 14 percent of households who satisfied the dry-down criterion, only 1 percent reported they had practiced AWD (Table 10).

Table 10. Contingency table of the two measurements used to assess AWD adoption A and B

		Self-reported data – At least two dry-downs of 10 days on average	
		True	**False**
Self-reported data by name	**True**	1.2	4.0
	False	13.3	81.4

These results suggest that some farmers may be adopting AWD practices without necessarily being able to identify the name of the practice, while some other farmers may claim they are practicing AWD without in fact making the irrigation choices that AWD involves. Thus, a more sophisticated measurement method that can identify what farmers actually do is likely to deliver more accurate estimates of the adoption rate.

AWD is also an important element of the ‘One Must Do, Five Reductions’ (1M5R) innovation package, discussed in the next subsection.

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

‘Three Reductions, Three Gains’ (3R3G, *Ba Giảm Ba Tăng*) and ‘One Must Do, Five Reductions’ (1M5R, *Một Phải Năm Giảm*) are each a package of input-saving principles for rice production. The recommendations in both packages involve reducing the use of seeds, nitrogen, and pesticides, allowing farmers to lower production costs while maintaining yield. The 1M5R package was introduced in Vietnam in 2012 and is considered a successor to 3R3G. It also has two additional recommendations on water management (AWD) and harvest processes to reduce post-harvest losses.

The specific requirements in the two packages are detailed in Table 11.

Table 11. Overview of 3R3G and 1M5R criteria and requirements in MRD

Criteria	3R3G Requirements	1M5R Requirements	
Seed type		Certified seed	
Seed rate	< 120 kg ha	< 120 kg ha	
Nitrogen	< 100 kg ha, at least 3 splits	< 100 kg ha, at least 3 splits	
Insecticides	Max 1 application	Max 1 application	No application within 40 days after sowing (IPM)
Fungicides	Max 2 applications	Max 2 applications	No application after flowering
Water management		Alternate Wetting and Drying (AWD)	At least one dry down period between transplanting and flowering
Harvesting		Using combine harvester	Harvest when 80-85% of panicles grains are yellow-colored

Source: Adapted from Flor et al. (2021) and Le & Singleton (2018)

The origins of 3R3G date back to the mid-1990s when there were efforts to encourage farmers to avoid pesticide application during the first 40 days after sowing. IRRI designed the integrated pest management (IPM) framework, which was popularized through the ‘No Early Spraying’ (NES) mass media campaign 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 amount by which seed and fertilizer use could reasonably be reduced. Subsequently, research sites were set up in 11 provinces in the MRD. It showed that reducing seeds, fertilizers, and insecticides had little effect on yield, and allowed farmers to earn about USD 35/ha more in the Summer-Autumn season and USD 58/ha more in the Winter-Spring season. This increase in profit margin from rice production was mainly attributed to the reduced use 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 a higher profit was certainly in conflict with their beliefs, so it was considered important to spread awareness. The dissemination of 3R3G began in Can Tho province in March 2003. Following a 2005 technical document by MARD[48], 3R3G dissemination was scaled up and funds were allocated for all provinces. Dissemination occurred through extension activities and campaigns, multiple forms of mass media, such as TV and radio soap operas, posters (Figure 13), public demonstrations, farmer field days, and public announcements via loudspeaker.

1M5R was developed during Phase IV of the International Rice Research Consortium (IRRC, 2008-2012). It has benefited from several IRRI research projects, including Closing Rice Yield Gaps in Asia with Reduced Environmental Footprints (CORIGAP, SDC, 2013-16 and 2017-20).

To follow the 1M5R recommendations, farmers must use certified seeds (1 Must Do) and reduce seed rates, nitrogen fertilizer inputs, pesticide use, water use, and post-harvest losses (5 Reductions). The innovation optimizes rice productivity while reducing the negative environmental impact of rice production.

[48] QĐ 1579 QĐ/BNN-KHCN issued on 30/6/2005

Initially introduced in An Giang province, the 1M5R program was recognized by MARD as technical progress through Presidential Decree 532-QD-TT-CLT in 2012. This helped to ensure that future national policies for lowland rice cultivation included the promotion of the 1M5R package as an objective. MARD coordinated the policy direction at the national level, while at the province-level, departments of agriculture and rural development (DARDs) were responsible for implementing 1M5R extension and governance.

Figure 13. Poster used for the launch of the 'One Must Do, Five Reductions' program in An Giang province, 2010

Source: DARD An Giang

1M5R was also scaled up in seven provinces in the MRD through the World Bank Agriculture Competitiveness Project (ACP, WB, 2009-2014), later extended to encompass eight provinces during the Vietnam – Sustainable Agricultural Transformation Project (VnSAT, WB, 2015-2022).

MARD's policy orientation includes an emphasis on promoting sustainable farming practices in Vietnam. This is manifest in the Rice Sector Restructuring strategy[49], which aims for 75 percent of rice-growing areas to be implementing sustainable farming practices by 2030. The practices that the government promotes through this strategy include 1M5R and AWD, which were developed through the research efforts of CGIAR and Sustainable Rice Intensification (SRI), and Vietnamese Good Agricultural Practices (VietGAP), which were not. In addition, the Vietnamese climate change mitigation strategy which supports Vietnam's Nationally Determined Contributions (NDC) to the Paris agreement (Decision 819/QD-BNNKHCN)[50] also aims to increase areas under integrated pest management (IPM), 3R3G and 1M5R. All of these sustainable intensification (SI) packages have been promoted in Vietnam for a considerable while: IPM was first introduced in the 1990s; initial research on 3R3G, SRI, and AWD was carried out in Vietnam in the early 2000s; the promotion of 1M5R started in 2008, and VietGAP was introduced in 2010.

According to the Rural, Agricultural, and Fishery Census in 2016 by the General Statistics Office (GSO), the average amount of fertilizer used was 0.58 tonnes/ha for the Winter-Spring season, 0.6 tonnes/ha for the Mua season, 0.47 tonnes/ha during the Autumn-Winter season, and 0.49 tonnes/ha for the Summer-Autumn season. These average amounts exceed MARD recommendations. Consistent with the attempts to reduce input uses and implement sustainable intensification packages, data from the Mid-Term Rural and Agricultural 2020 Survey by GSO shows that 53 percent of rice-growing households follow the recommendations given by agricultural extension officers; 25.8 percent apply fertilizers in amounts that are suitable with the needs of rice plant at each stage of growth; 51.2 percent state that they consider soil types and local climate when determining the amounts and schedule of fertilizer application, and lastly, 10.6 percent use organic fertilizer entirely or partly for rice production (General Statistics Office, 2022b).

In the VHLSS 2022, we integrated a module to measure rice farmers' awareness and application of these SI packages by asking them close-ended questions referring to the packages by name[51]. Each package was named individually, and the farmer was asked if they knew of it and if yes, whether they had applied it during their rice cultivation in the previous Winter-Spring season.

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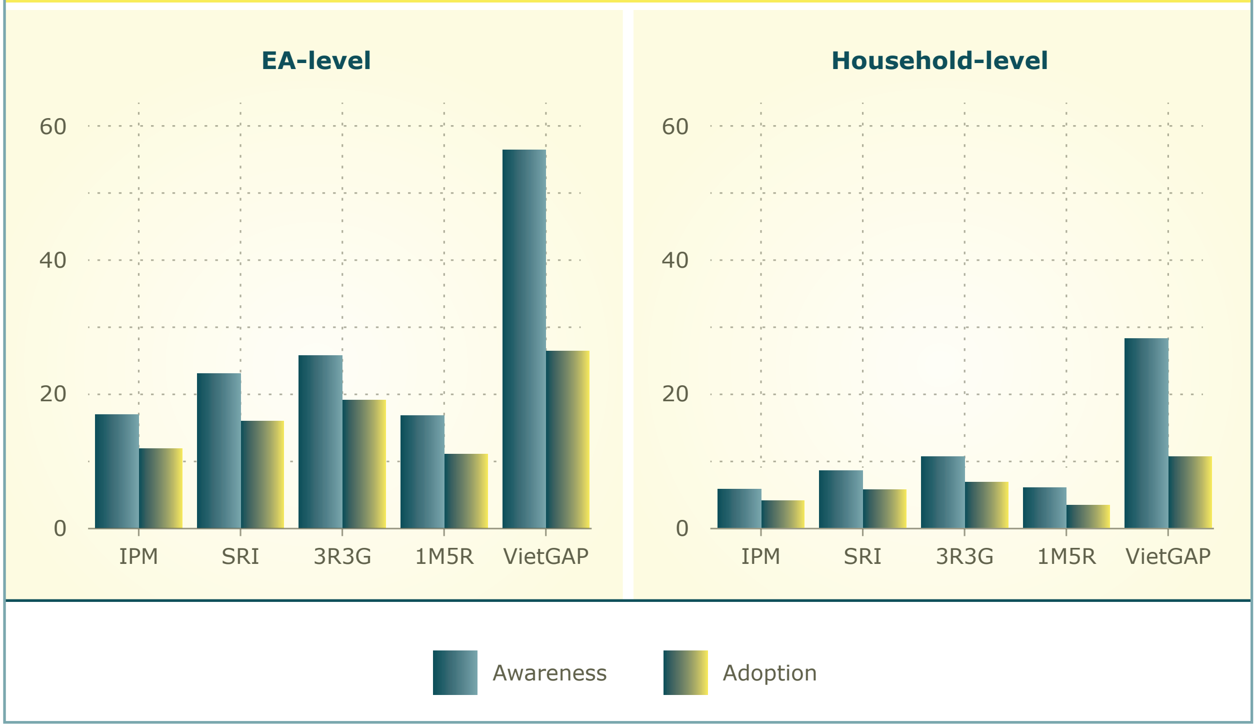
[49] MARD Decision No. 1898/QD-BNN-TT Rice Restructuring Plan (2016): https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-1898-QD-BNN-TT-de-an-tai-co-cau-nganh-lua-gao-Viet-Nam-2020-tam-nhin-2030-2016-313302.aspx

[50] MARD Decision 819/QD-BNNKHCN: 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

[51] We used the exact Vietnamese terminology used by the agricultural extension services. See Appendix C, module 4B1.1.2

Figure 14. Awareness and adoption estimates for Sustainable Intensification packages promoted in Vietnam (y axis in %)



Source: VHLSS 2022

Note: IPM = Integrated Pest Management; SRI = Sustainable Rice Intensification; 3R3G = '3 Reductions, 3 Gains'; 1M5R = 'One Must Do, Five Reductions'; VietGAP = Vietnamese Good Agricultural Practices.

As the graph on the right in Figure 14 shows, data suggest that among the three CGIAR-related SI packages (IPM, 3R3G, and 1M5R), awareness of 3R3G is the highest (11 percent of farmers reported they knew of it). The awareness of IPM and 1M5R awareness was lower at about 6 percent. When we ask whether farmers had adopted the practice, we see that 7 percent of farmers said they had applied 3R3G, 4 percent said they had applied Integrated Pest Management (IPM) practices, and 3 percent said they had applied 1M5R. About 5 percent said they had applied Sustainable Rice Intensification (SRI) practices.

The geographical patterns of adoption measured through self-reported data differ between the 3R3G and 1M5R packages. 17 percent of households in the MRD said they had adopted 3R3G, but less than 3 percent said they had in the other regions. In contrast, a similar share of households (between 6-8 percent) declared adoption in MRD, RRD, and Northern and coastal central areas.

VietGAP, a package of 'good agricultural (production) practices' stands out in Figure 14. This certification scheme promotes, manages, and certifies Vietnamese rice exports (Decision No. 2998/QD-BNN-TT, 2010)[52]. In more than half of the EAs, at least one farmer reported they were aware of VietGAP. Overall, 27 percent of households said they were familiar with the term and 10 percent reported they were implementing these practices.

[52] MARD Decision No. 2998/QD-BNN-TT Promotion of good agricultural production practices (VietGap) for rice (2010): https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-so-2998-QD-BNN-TT-quy-trinh-thuc-hanh-san-xuat-nong-nghiep-tot-VietGAP-cho-lua-2010-172687.aspx

Among those households that said they knew of a package/practice, some reported they were not using it. However, the correlation between awareness and adoption is similar across SI packages: 59-75 percent of households who declared being familiar with the package also said they were adopters.

One can only speculate on why VietGAP is the most well-known, and the most widely adopted package. Some possible explanations are as follows. First, VietGAP-certified products generally command a price premium and so can help increase farmers' revenue. Second, of all the SI packages we asked farmers about, VietGAP was introduced most recently (in 2010). Third, the VietGAP certification scheme applies to several crops, vegetables, and fruits – thus broadening the scope considerably compared to rice-oriented packages. Fourth, in our questionnaire module, VietGAP was listed as the first SI package that enumerators asked about and this ordering may have created a survey-based, positive bias. And fifth, the fact that the VietGAP package's name includes the word "Viet" (and is short and punchy), may have resulted in some combination of greater social desirability bias and/or greater salience or ease of recall.

Given the challenging nature of SI measurements, these numbers are suggestive at best and should not be taken as definitive assessments of current adoption levels.

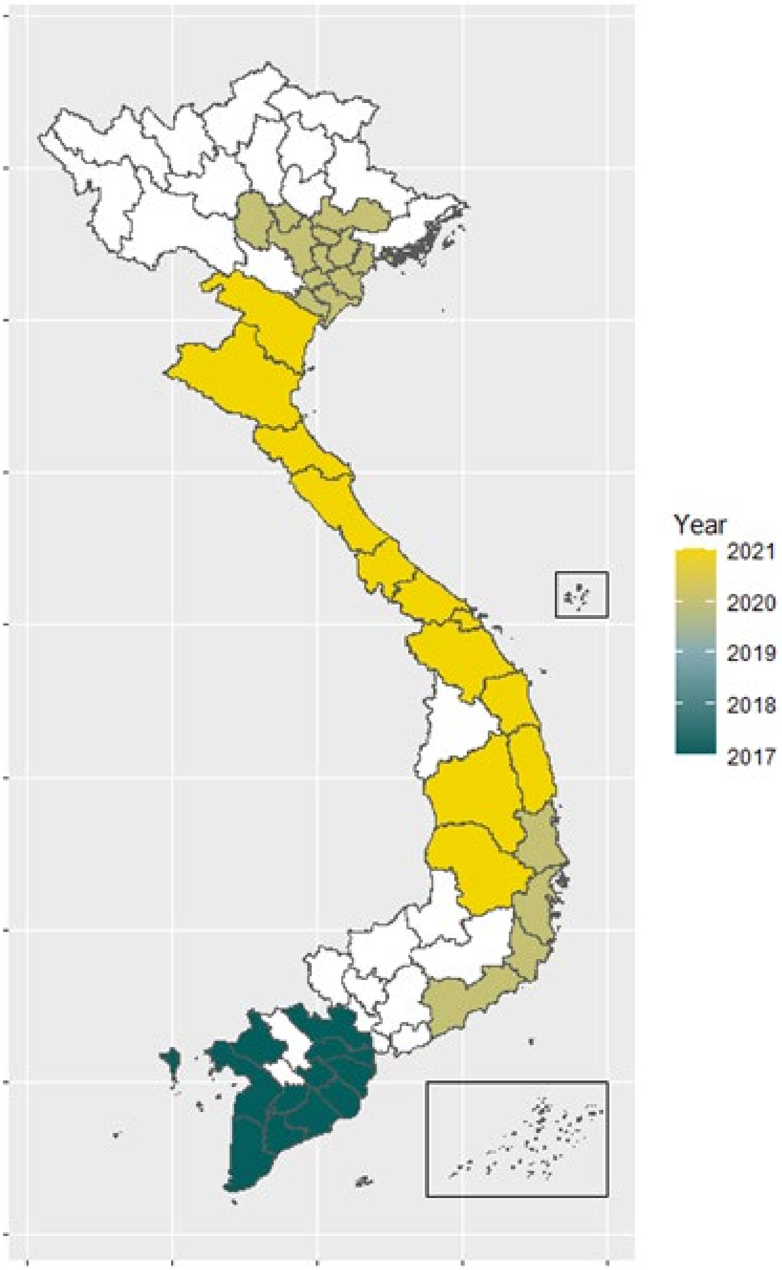
2.3 Climate Change Adaptation Options

In the CGIAR Research Program 'Climate Change, Agriculture and Food Security' (CCAFS, 2016-2021), the development of Climate-Smart Maps and Adaptation Plans (CS-MAPs) was a collaboration with MARD Department of Crop Production (DCP). A participatory approach for mapping climate risks and adaptive interventions was first tested in 2017 and then further developed (Yen et al., 2019). In particular provinces, policymakers identified the major climate risks that farmers faced and proposed adaptation solutions. In addition to adaptation plans, this participatory approach has generated maps that integrate stakeholders' local knowledge of topography, infrastructure, hydrological management schemes, and land use plans.

The process of developing CS-MAPs began in the MRD region in 2017. The exercise considered two types of risk – drought/salinity risk and flood risk – for each of the three cropping seasons (Winter-Spring, Summer-Autumn, and Autumn-Winter). In 2020, further CS-MAPs workshops were conducted in the four South Central Coast provinces and the twelve Northern Midlands and Red River Delta provinces. This regional widening of the scope of the CS-MAP project was supported through the project 'Applying seasonal climate forecasting and innovative insurance solutions to climate risk management in the agriculture sector in SE Asia' (DeRisk, 2018-2022). In these regions outside MRD, the primary risk considered for rice production is drought. The CS-MAP project develops adaptation plans appropriate to the available irrigation system. For example, in the Red River Delta (RRD) and nearby Northern Midlands (NM) provinces, government officials could rely on CS-MAP maps and derived plans to determine their water discharge schedule, whereas, in the coastal regions, the tool could support production directives and land use planning[53]. Between 2017 and 2022 the participatory mapping exercise was progressively implemented in 41 provinces, as shown in Figure 15.

[53] Two examples of CS-MAPs are available in Appendix B.

Figure 15. Roll-out of CS-Maps related to drought risk by year of delivery



Source: CGIAR SPIA
Note: Can Tho and Dong Thap provinces have CS-Maps related to flooding risk, but not to drought risk.

MARD recognized CS-MAPs and adaptation plans as an important part of Vietnam's climate change adaptation strategy through Decision No. 1438/ BC-TT-VPPN[54] (2020). In 2020, provinces in the MRD updated the CS-MAPs and adaptation plans to integrate new knowledge (T. Le et al., 2021). The government's MARD Official Document No. 8278 instructed the twelve Red River Delta and Northern Midlands (RRD-MN) provinces to follow the water discharge schedules and cropping calendars recommended by the CS-MAP adaptation plans during the Winter-Spring season 2020-2021.

For farmers to change their cropping calendars in line with the CS-MAPs-derived adaptation plans, they must receive risk-, season- and location-specific agricultural recommendations. In each cropping season, authorities use El Niño–Southern Oscillation (ENSO)-based rainfall predictions to predict available quantity from reservoirs in RRD, Coast, and Highland areas (No risk, moderate risk, and high risk). In the Mekong River Delta, the effect on rice yield is predicted (No risk, low risk, moderate risk, and high risk of drought). This then triggers the relevant CS-MAP and adaptation plans, and DARD issues annual and seasonal production directives and diffuses information through local officials, cooperatives, extension services, loudspeakers, social media, and meetings with relevant organizations.

In Table 12, we see households' reports in the VHLSS 2022 on whether in the past 12 months they had received and applied recommendations about the six common climate change adaptations. A very high proportion, 63.3 percent of households, reported that they had received a recommendation to change their rice varieties. Twenty-seven percent said they had received recommendations to change their rice sowing/planting dates. These two options appear in most CS-MAP adaptation plans. Based on these reports, we estimate the potential reach of these recommendations at 3.25 and 1.37 million households in Vietnam, respectively.

Table 12. Recommendations received and applied by households in the last 12 months in %

	Received advice		Applied advice on at least one plot		Applied advice on at least one season	
	EAs	Households	EAs	Households	EAs	Households
Not cultivating rice	30.6	13.6	25.1	10.7	24.4	10.4
Shifting from rice to another crop	13.9	3.9	3.8	0.8	3.8	0.8
Change in rice sowing/planting dates	56.2	27.6	50.3	22.6	49.8	22.2
Change in rice varieties to sow	86.2	63.3	79.4	53.1	79.0	52.4
Shifting to shorter-duration rice varieties	36.3	14.6	26.0	10.5	25.4	10.2
Changes in plot irrigation schedule	42.7	19.1	36.7	15.2	36.2	14.9

[54] MARD Decision No. 1438/ BC-TT-VPPN regarding the recognition of the scope of influence and effect at national and ministerial levels of initiatives, and scientific research projects: https://drive.google.com/file/d/1qCpQ6u4eY-mfS-DLyGVNsSTUTk4AFUYh/view. English translation: https://drive.google.com/file/d/1i-w1dhNFtxTwKfCBo1_6J64nCipYA3Ud/view

Figure 16. Maps displaying the percentage of households who heard, households who applied conditional on hearing, and households who applied by province

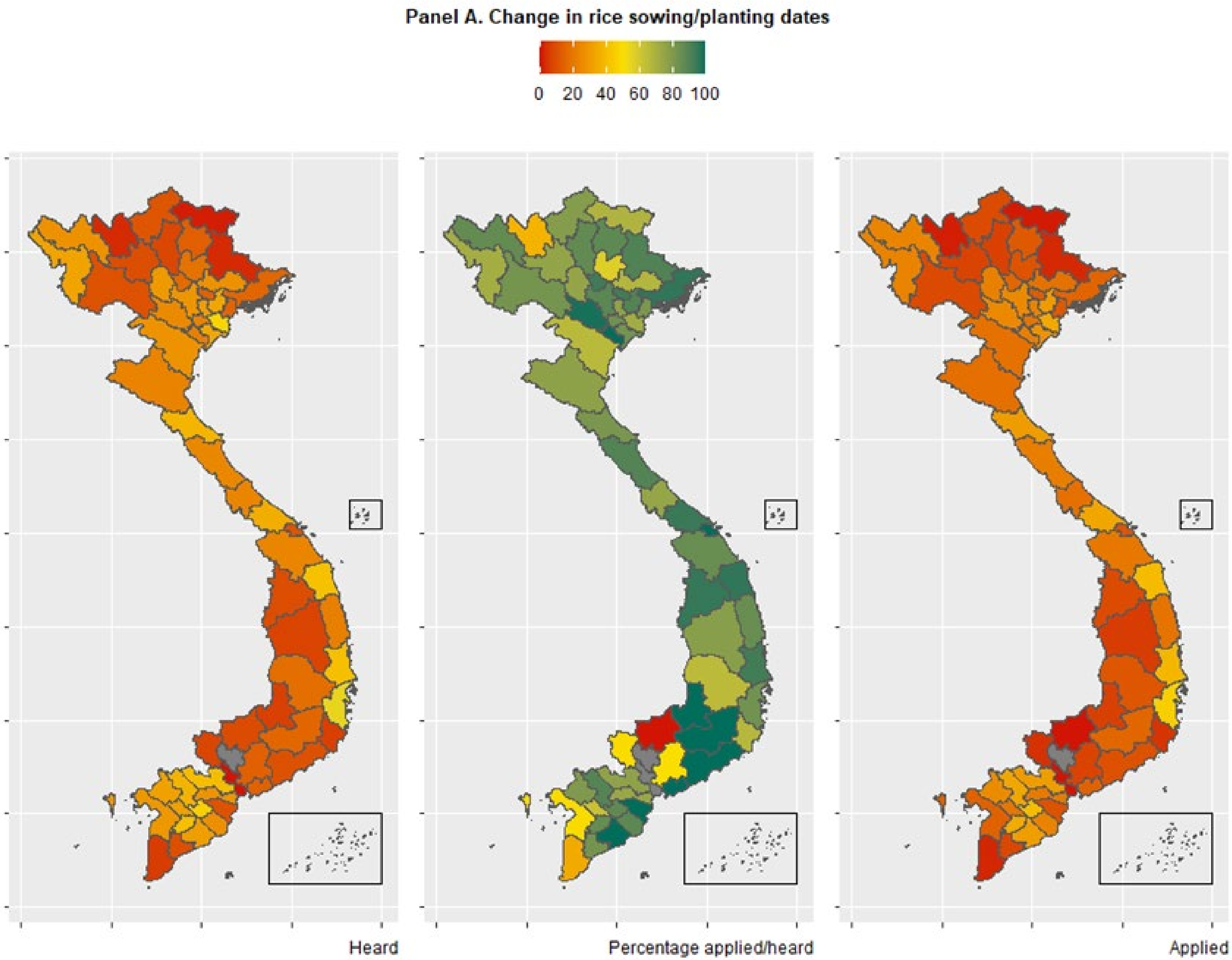


Figure 16. Maps displaying the percentage of households who heard, households who applied conditional on hearing, and households who applied by province

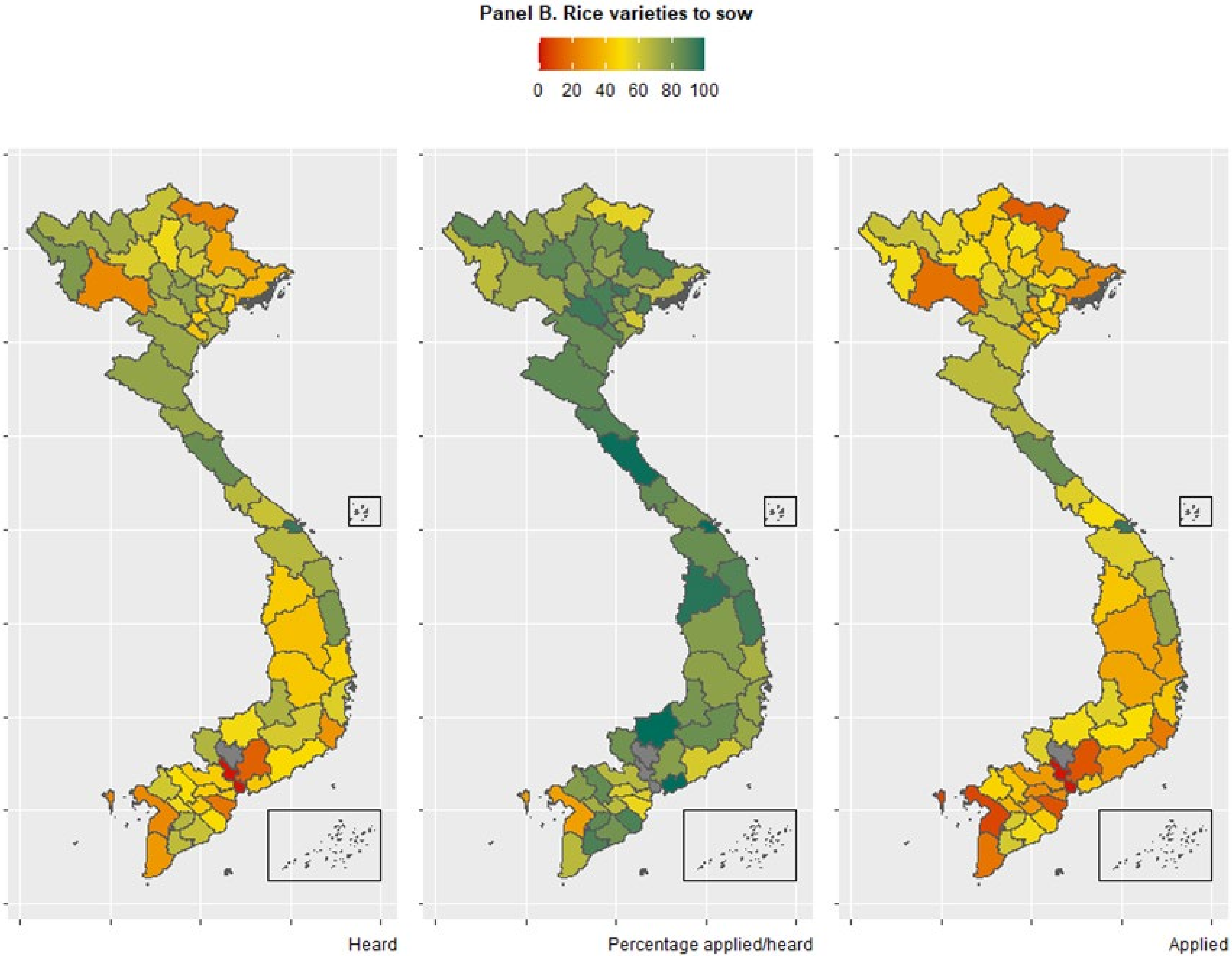
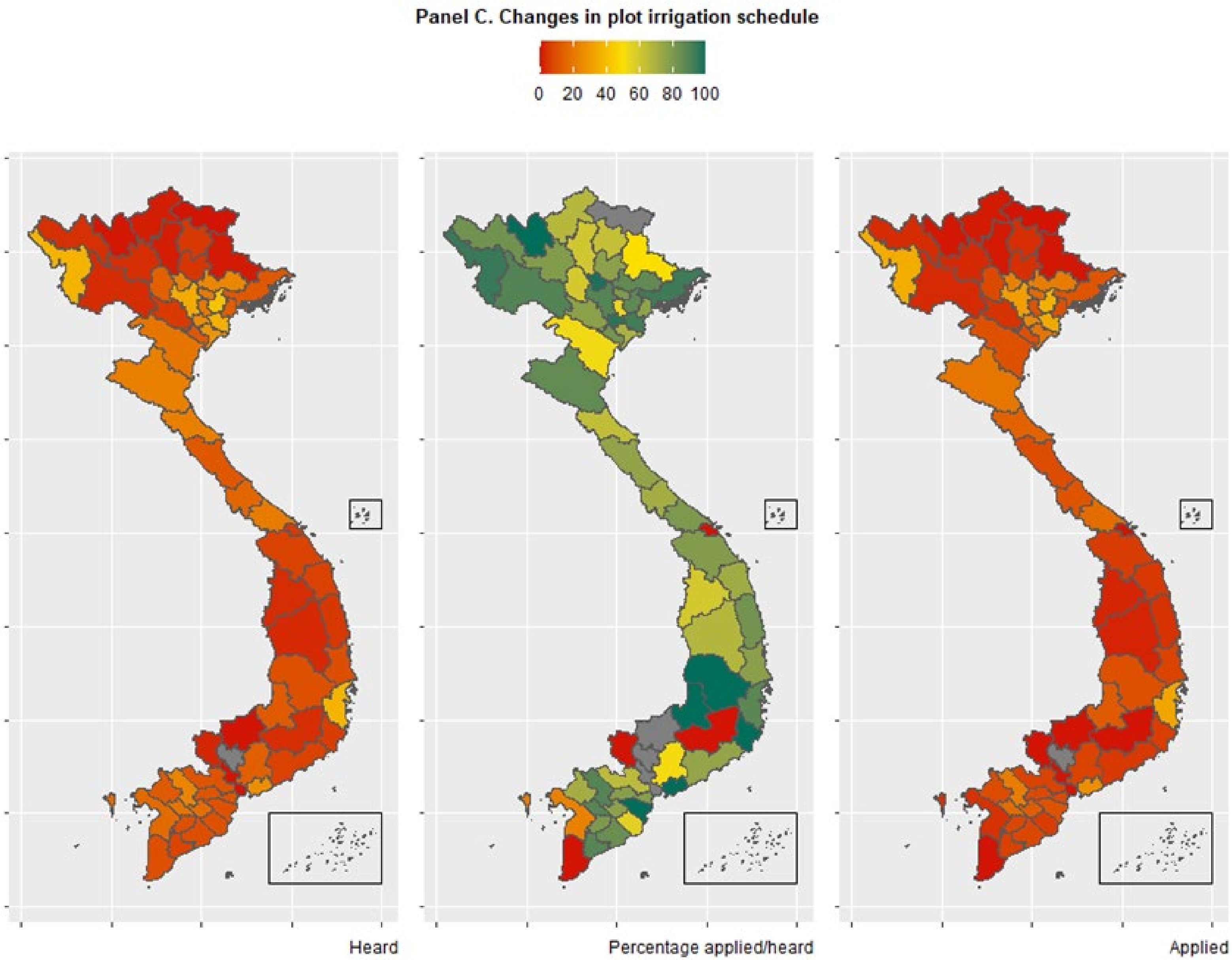


Figure 16. Maps displaying the percentage of households who heard, households who applied conditional on hearing, and households who applied by province



The three panels in Figure 16 show how the percentage of rice-growing households in the VHLSS 2022 that reported receiving the recommendation and those that reported following it varies across the country. Panel A refers to the recommendation to change rice sowing dates, Panel B to change rice varieties, and Panel C to change the plot irrigation schedule.

The left map plots the percentage of households that reported having heard of the recommendation. the middle map plots the (unconditional) percentage of farmers who said they had followed the recommendation when cultivating rice in the previous 12 months. The right map plots the households that followed the recommendation as a percentage of those who had heard of it (i.e. adoption conditional on awareness).

As we see in the left map in Panel A, farmers were more likely to report that they had heard of recommendations to change rice sowing/planting dates in the three main rice-growing regions: Red River Delta, North Central and Central Coast, and Mekong River Delta. The map looks very similar to the middle map where we plot the percentage of farmers who reported changing their rice sowing/planting dates. This is because, as we see in the right map, among those who said they had heard of the recommendation, compliance was very high: in most regions, more than 75 percent of farmers who had heard of the recommendation said they had in fact changed their sowing/planting dates. An exception is the Southeast Region, where the number of rice households is substantially smaller (only 1.7 percent of households in VHLSS 2022 claimed to plant rice in the last 12 months), and the planted area of rice is relatively small (General Statistics Office, 2021b). This likely means that rice cultivation is not a policy priority for DARDs there.

In contrast to changing sowing/planting dates, as we see in Panel B, the MRD households were less likely to say that they had heard advice to change the rice variety they grow. In the Red River Delta and along the coast, the percentage continues to be high. Conditional on hearing about the recommendation, self-reported adoption is high in most parts of the country, except for the MRD. One explanation could be the distinctive nature of rice farming in the Mekong: farmers there are larger landowners and more likely to sell fresh (or unmilled) rice on the market immediately after harvest[55]. Accordingly, they may choose to plant varieties that are in high demand even if they are not recommended by the government.

In contrast, as shown in Panel C, farmers in the Red River Delta were more likely to say they had received advice to change their plot irrigation schedule, reflecting the significant effort and long commitment of the local government to build, maintain, and manage the complex irrigation’s infrastructure for rice, which is jointly operated by multiple agencies in MARD, Vietnam Electricity, and MoNRE (World Bank, 2019). Once again, conditional on hearing about it, compliance with the recommendation is extremely high, with 75-100 percent of households that are aware also saying that they had adopted it. This high compliance rate could reflect trust in the local government, social desirability bias in responding, or both.

Overall, the potential reach of climate change adaptation options in Vietnam is estimated to be 4.46 million households. This number corresponds to households who have followed at least

[55] In the RRD and the central coastal provinces, more than 90% of rice-farming households own less than 0.5 ha. In contrast, in the Mekong two third of rice-growing households own more than 0.5 ha (General Statistics Office, 2016).

one recommendation for agricultural extension services. The two most common practices – changing the rice varieties they sow and changing rice planting/sowing dates – seem to have been applied by 3.25 and 1.37 million households respectively.

We also explore the association between the roll-out of the CSMAP project and the probability that farmers said they received and applied two key recommendations: to change their sowing/planting schedule and to change the varieties they sow.

Table 13. Ordinary Least Squares regression of farmer's received and applied recommendations by province status in Vietnam

	(A) Received recommendations				(B) Applied recommendations			
	Sowing/Planting dates		Varieties to sow		Sowing/Planting dates		Varieties to sow	
	Beta[1]	SE[2]	Beta[1]	SE[2]	Beta[1]	SE[2]	Beta[1]	SE[2]
Province has CSMAP	0.15***	0.028	0.08	0.054	0.12***	0.025	0.09*	0.049
(Intercept)	0.13***	0.024	0.54***	0.049	0.11***	0.021	0.43***	0.041
R^2	0.027		0.006		0.021		0.006	
Adjusted R^2	0.027		0.006		0.021		0.006	

[1] *p<0.1; **p<0.05; ***p<0.01

[2] SE = Standard Error

Note: Standard-Errors are clustered at the province level.

As we see in the results of a simple regression in Table 13 farmers in provinces where CS-MAPs were designed are more likely to state that they had received and applied a climate change adaptation recommendation during the past 12 months. The correlation is especially high for the recommendation to change sowing/planting schedules. This provides suggestive evidence that the CS-MAP project may have influenced the advice that farmers received, and their adoption of the practices that the CS-MAP project promotes. However, the low R-squared in all columns also makes it clear that the likelihood that farmers reported hearing or applying such advice in the main depends on factors other than the CS-MAP project roll-out. A more in-depth analysis of the adoption of specific CS-MAP recommendations will be attempted in next year's report.

3. Workplan for 2023

The SPIA-GSO collaboration is continuing in 2023. The VHLSS 2023, which is in the field at the time this report is going to press, includes several new data integrations. These include more detailed and comprehensive questions to measure the adoption of certain innovations, as well as include some innovations that our stocktake has indicated are likely disseminated at scale but that were not included in the 2022 integration. In addition, some modules that had been integrated into the VHLSS 2022 have been included again.

3.1 Modules Integrated into VHLSS 2023

The VHLSS 2023 data collection will be conducted on a quarterly schedule, with interviews in February, May, August, and November. Approximately 12,000 households will be interviewed each quarter. One-half of the EAs surveyed in VHLSS 2022 will be interviewed again in 2023. This will allow us to build a panel dataset for approximately 16,000 rural households.

Based on the results from the stocktaking exercise, data from previous integrations, and the consultation meeting in June 2022, we identified six measurement priorities for the VHLSS 2023. These are 1) DNA fingerprinting to measure adoption of improved cassava varieties; 2) self-reported (name-based elicitation) adoption of improved potato varieties 3) DNA fingerprinting to measure adoption of improved tilapia strains; 4) improved survey-based measurements of 3R3G and 1M5R adoption; 5) self-reported adoption of water-saving methods in coffee production; and 6) self-reported adoption of climate change adaptation recommendations. In what follows, we explain the rationale for integrating these innovations into the VHLSS 2023.

3.1.1 Improved Cassava Varieties (DNA Fingerprinting)

Vietnam is currently among the largest exporters of cassava and the second-largest exporter of processed cassava starch in the world. Cassava has become an important cash crop for smallholder farmers. It is believed that this growth in the production of cassava and cassava starch has been facilitated by high-starch cultivars originating from CGIAR genebanks (Labarta et al., 2017; D. P. Le et al., 2019).

The cassava sector is highly relevant to Vietnam's agricultural strategy. Decision 37/2018/TT-BNNPTNT[56] lists cassava as one of the 13 main agricultural products of the country. A recent national conference held by MARD advocates maintaining the current cassava planting area and focusing on improving the yield and value-added of cassava and cassava products (MARD, 2022). In Vietnam, cassava is planted across more than 32 provinces. A 2015 CIAT-led DNA fingerprinting exercise estimated that more than 85 percent of cassava farmers were growing

[56] MARD Decision 37/2018/TT-BNNPTNT: https://datafiles.chinhphu.vn/cpp/files/vbpq/2019/01/37-bnnptnt.signed.pdf

improved cassava varieties. The two most popular varieties were KM94 and KM419, found on 39 percent and 23 percent of the cassava area planted respectively (D. P. Le et al., 2019).

SPIA's decision to include a cassava DNA fingerprinting module was motivated by the need to document all CGIAR-related innovations using a similar sampling frame – to make estimates across innovations broadly comparable – and within the 2022-23 timeframe. New data integrations consist of 1) a survey module for all cassava-growing households to investigate cassava value chains and 2) a plot selection procedure and tissue sampling of cassava leaves for DNA fingerprinting.

3.1.2 Improved Potato Varieties (Self-Reported via Name-Based Elicitation)

Eighty-five percent of Vietnam's potato cultivation is concentrated in the lowlands of the RRD, with some cultivation also occurring in the Northern and Central Provinces (Gatto et al., 2018). Since 2000, a total of 13 new potato varieties have been released by NARS. Five of these (KT3, VC38-6, KT1, PO3, and Eben) are believed to be derived from germplasms developed by the International Potato Center (CIP).

In a new module integrated into the VHLSS 2023 questionnaire, enumerators will ask the household the name of the main potato variety that they have planted, where they sourced the seed, and how long they have been recycling tubers from previous harvests. The data will provide a better understanding of potato varietal turnover and could inform future data collection efforts with methods superior to farmer self-reporting. It is estimated that approximately 100 potato-growing households will be interviewed through this module.

3.1.3 3R3G and 1M5R (Improved Survey-Based Measurements and Use of Visual Aids)

As we discussed in Section 2.2.2: Sustainable Intensification Packages, the 3R3G and 1M5R sustainable intensification packages include input use and agricultural practice recommendations related to seeds, fertilizer, pesticides, water, and harvesting. As the data presented in this report suggest, measurements that rely on farmers' awareness of the names of these packages are inappropriate to accurately measure the adoption of a complex package.

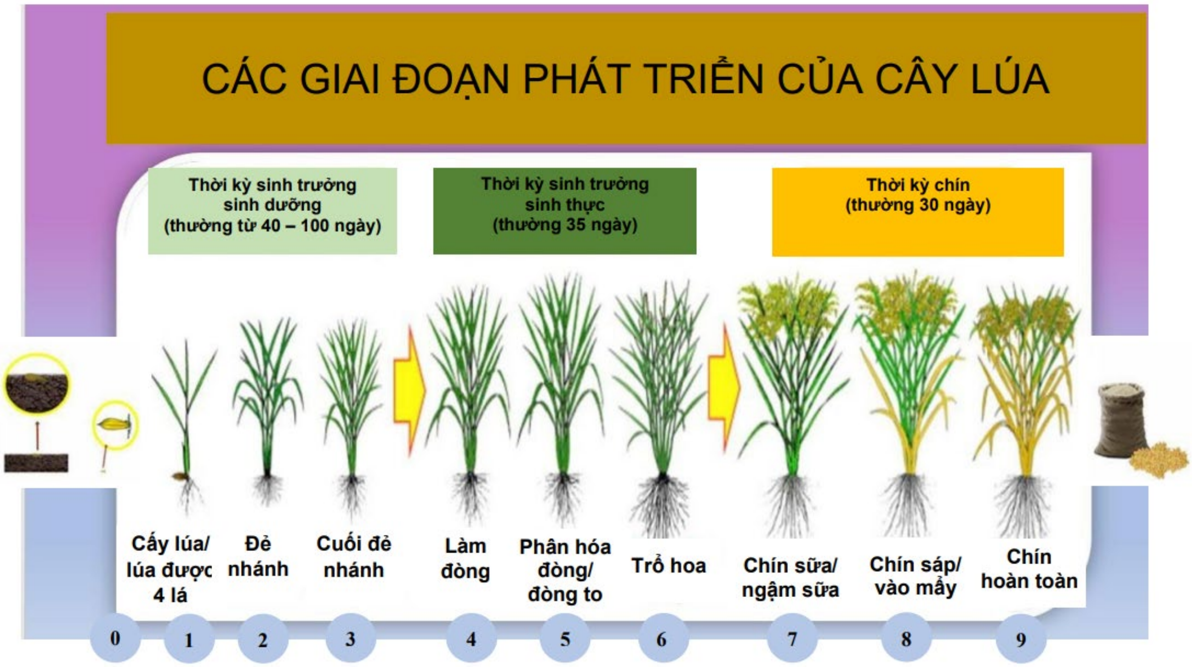
In 2022, SPIA conducted a qualitative study aimed at developing a new comprehensive survey module that would more accurately capture the 1M5R practices that farmers do adopt. To begin with, 45 open-ended semi-structured interviews were conducted with rice farmers in the upstream area of the Mekong Delta. These included both male and female farmers, and both those who had received training in 1M5R (as per the information delivered by local extension agents) and those who had not. These qualitative data were analyzed and the findings informed the development of new close-ended survey questions that would capture the actual agricultural choices that farmers made. This in turn would allow researchers to identify if they had complied with the recommendations of the 1M5R package. These include separate questions regarding each of the six components of 1M5R: use of certified seeds, seed rates, pesticide use, fertilizer inputs, water use, and reducing postharvest losses. The questions were made sufficiently comprehensive to allow for seasonal variation in agricultural circumstances, and variation due to different institutional structures, particularly in relation to the irrigation system.

These newly developed questions were then field-tested across four sites: the Mekong Delta, Red River Delta, North Central Coast, and South-Central Coast. This was accompanied by open-ended conversations with farmers who had answered the questionnaire. This helped to understand how the questions fared in the field in terms of accurately measuring the important elements of interest, and to understand why some questions were ineffective, and how to redesign them. This also led to the development of a visual aid in Vietnamese to ensure that meaning was preserved across the researchers, enumerators, and respondents and to avoid distortions introduced through verbal communication.

Finally, a team of enumerators tested this new module with 150 rice farmers in 6 provinces across 3 regions of the country. The SPIA Vietnam team assessed the effectiveness of the module by examining the distribution of each variable and how it correlated across farmers[57].

SPIA then proposed that the GSO include these questions in the VHLSS 2023 survey questionnaire, along with visual aids on rice growing stages, pest images, water measuring tubes, and sowing and harvesting machines. After reviewing for feasibility, the GSO integrated these into the VHLSS CAPI application. In addition, enumerators also carry a laminated A4 color page with a visual aid of different stages of growth of a rice plant, to be shown to the respondent while administering the questionnaire, upon prompting by the CAPI application (Figure 17). It is estimated that 14,000 rice–growing households will be interviewed through this module.

Figure 17. Visual aid used by enumerators



Source: CGIAR SPIA

Note: The visual aid helps to pinpoint the specific crop stage at which fertilizer and pesticides were applied and the stage when the plot dried down (AWD). Enumerators enter into the CAPI application the relevant growth stage number (as shown below the image of the relevant plant) or report the two stages the plant was in between.

[57] These descriptive statistics are available in supplementary material here. The file will appear as a txt file on github, and needs to be saved as an .html file.

3.1.4 Water Saving for Coffee Production (Self-Reported)

Nearly 90 percent of Vietnam's coffee-growing areas, equivalent to around 640,000 ha, are in the Central Highlands region. Scientists have warned that current cultivation practices overuse water in the dry season (January-April) and that water usage could be cut by 50-60 percent. If farmers do not reduce their water usage practices, their water demand will only increase as climate change induces temperature increases, and they will likely face water shortages. In collaboration with partners, CGIAR centers have implemented projects to test water-saving techniques for coffee production in five provinces of the region.

In the VHLSS 2023, we integrated a survey module to ask coffee farmers about the number of times they have irrigated their coffee plants, the quantity of water they used each time, and the method used to estimate that quantity. We expect to receive data from approximately 1,200 coffee-growing households in the Central Highlands provinces.

3.1.5 GIFT-Derived Improved Tilapia Strains (DNA Fingerprinting)

In Vietnam, tilapia is a fish that is both consumed locally and processed for exportation, and the tilapia sector benefits from strong policy support. As per the recent Decision 1639/QD-BNN-TCTS (2016), the government intends for Vietnam to be producing 400,000 tonnes of tilapia annually by 2030, and it is hoped that 45-50 percent of these will be exported. It also aims to be producing 100 percent of tilapia fingerlings – seed fish that serve as the starting point for raising tilapia to marketable sizes – for domestic commercial production.

Selective breeding programs conducted by the Research Institute for Aquaculture (RIA1) have bred the GIFT strain — a faster-growing strain of the Nile tilapia (*Oreochromis niloticus*) strain that WorldFish made available in 1988. Several GIFT-derived strains have been released and distributed to hatcheries over the past 20 years in Vietnam (Ninh et al., 2014).

Following desk reviews, interviews with RIA1 and RIA2, a visit to a hatchery in the Thai Binh province, and a phone survey of hatcheries, we have strong reason to believe that Vietnam has maintained a breeding population of GIFT and that GIFT-derived tilapia strains are available for purchase in hatcheries. Households also purchase from hatcheries (although not exclusively), so GIFT-derived strains may have been adopted at scale.

To document the adoption of GIFT-derived strains in Vietnam, a unique approach is being implemented in 2023. A simple question introduced into the VHLSS 2023 questionnaire first identifies tilapia-growing households. This then triggers a new module (Modules 4B5.1.A, see Appendix D) that collects data on the self-reported name of the tilapia strain, the source of the fingerlings, the cost, and the current stock in the farmer's pond. In addition, we include a question about integrated aquaculture management practices[58]. The households identified through this method and their information will then provide a sampling frame to deploy another data collection team that will visit the household and a separate data collection exercise with hatcheries from where the fingerlings were sourced.

[58] Integrated farming systems combine aquaculture with other agricultural practices, typically rice in the context of Vietnam. The waste products aquaculture can serve as inputs for crop growth.

At the household level, we will use the data that the GSO will share with us in quarterly batches (in April, June, September, and December 2023), soon after each of their four survey rounds. A team of enumerators to re-visit the tilapia-growing households and sample fin clips from the tilapia in their ponds. Three individual fish per strain will be sampled, if the fish are all the same sex, and five fish will be sampled if the pond has a mixed-sex population. The sample size we ultimately obtain will depend on the number of tilapia growers that the VHLSS 2023 identifies and the availability of their fish for sampling at the time of the enumerator visit. However, our power calculations indicate that GIFT-derived strains can be detected at a 95 percent confidence level with a sample size of 270 households.

In addition, enumerators will visit the hatcheries where these tilapia-growing households purchased their fingerlings and obtain fin clip samples from them. These include government and private hatcheries. This sample will be complemented by fin clips from tilapia fingerling-producing hatcheries from an official list, in each visited district. Three fish will be sampled from each tilapia strain that has been available for sale in the last five years will be sampled (GIFT, GIFT-derived and non-GIFT). Fin-clipping will follow a strict protocol for which enumerators will receive training.

Tilapia strains from collected samples will be identified using the genomic markers presented in Hamilton et al. (2020) and Lind et al. (2017). Approximately 1,300 Single Nucleotide Polymorphisms (SNP) variants have been identified that could determine strain identity with an accuracy ranging from good (83%) to excellent (100%). The classification of strains into GIFT, GIFT-derived and non-GIFT strains can be done with a higher level of accuracy[59]. These references will be completed by the GIFT-derived strains bred by RIA1 in Vietnam.

Given the innovative nature of this exercise, the cost-effectiveness of a variety of survey design choices will also be compared to inform future survey designs. This study will additionally include methods experiments on the reliability of alternative methods to collect fish DNA, including fish swabbing (Tilley et al., 2020) and bulk sampling (Zou et al., 2016). Both could represent cost-effective alternatives but need to be validated under fieldwork conditions.

[59] The DaRT tilapia platform includes data from 10 key nucleus populations (712 individuals), including GIFT (Malaysia), GIFT-ff (Philippines), GET-ExCEL, BEST, Molobicus, Nile x Moss, Abbassa, FaST, Chitralada, and *O.mossambicus*

3.1.6 Climate Change Adaptation Options (Using Farmer Self-Reporting)

Similar to the VHLSS 2022, the module on farmers' received and applied recommendations has been re-integrated into the VHLSS 2023. The new data will enable us to build a 2022-23 panel of households at the province level and measure changes in adoption rates and how they correlated with dissemination efforts.

In collaboration with MARD, we also plan to examine the history of recommendations on cropping decisions since 2017, and the actors involved. This will allow us to link the province-level adaptation plans designed (CS-MAPs) with the changes in practices implemented by households and observed in the VHLSS household surveys. The end-goal is to refine current estimates of the reach of climate change adaptation options in Vietnam.

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Rice paddy landscape
Credit: Jacquelyn Turner/CCAFS

Appendices

Appendix A. List of Marker-Associated Traits Characterized in the AgriPlex RiCA v4 Panel

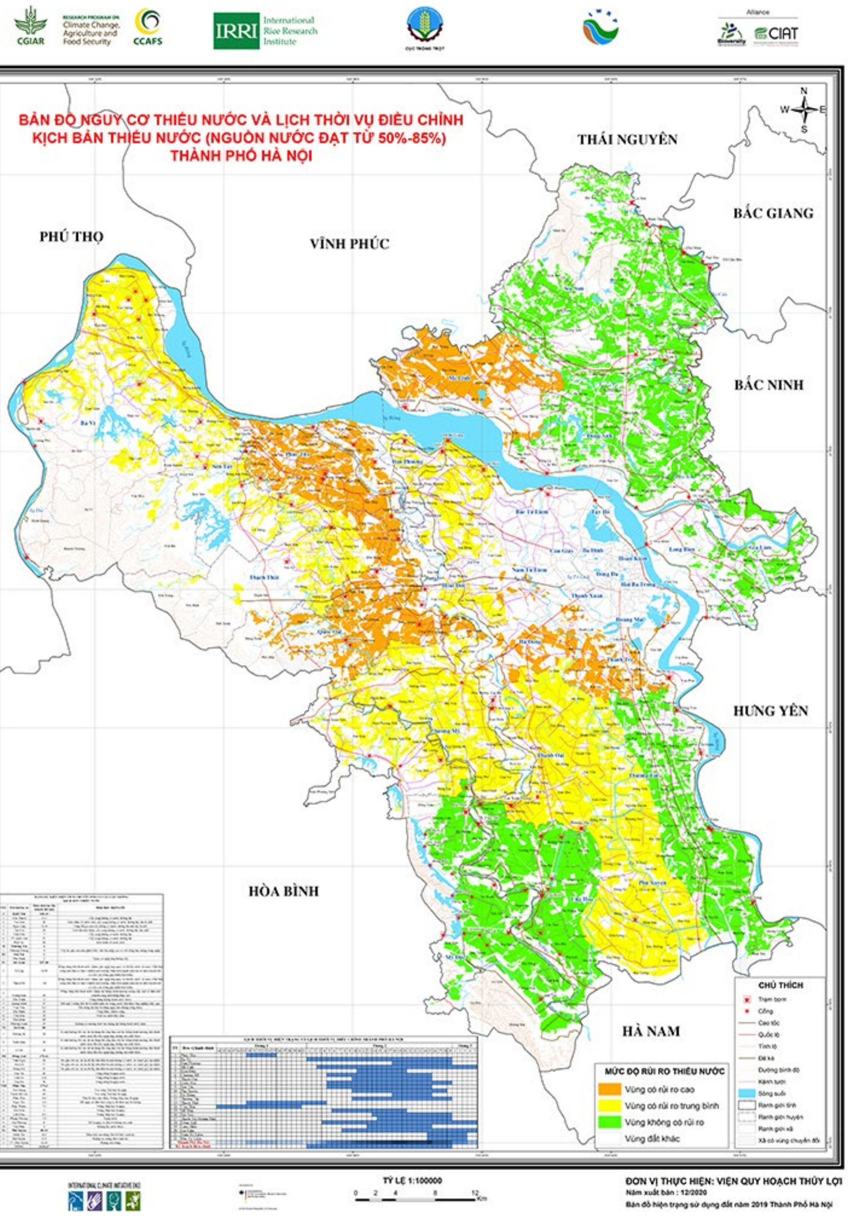
Trait category	Trait	Gene targets
Disease	Blast	Pi9 (3 alleles), Pik (11 alleles), Pii, Pita, Ptr, pi21, Pi35, Pi54, qPi33
	Bacterial blight	qXa4, xa5, qXa7, xa13, Xa21, Xa23, qXa26, Sweet14
	Brown planthopper	Bph9, Bph17, Bph32
	Other insects	qGm4
	Virus	TSV1, TBV1, rymv1-2, rymv1-4, rymv1-5, rymv2, RYMV3, STV11
Grain quality	Amylose	Waxy (6 different alleles distinguished)
	Chalkiness	PGC8.2, GW5
	Aroma	fgr-1
	Gelatinisation temp.	Alk (3b and 4)
	Other grain quality	NAS3 (grain zinc), LOX3 (spoilage), SBE-I, SBE-IIb, SBE-III, GPT1
	Grain size/shape	GS3, TGW6, SLG7
Abiotic stress	Drought	qDTY1.1, qDTY2.2, qDTY3.1, qDTY3.2, qDTY 4.1, qDTY12.1, Dro1
	Cold	Cold1, qSCT1, qCST10, qPSST6
	Heat	TT1
	Salinity	qSIS1.2, *Saltol*, qSOR1
	Anaerobic germination	qAG1, qAG3
	Submergence	Sub1
	Other abiotic stresses	BET1 (boron toxicity)
Yield components	Heading date	Ghd7, DTH8, Hd2/PRR37, Hd1, Hd6a, RFT1, Hd3a, ehd1
	Miscellaneous	DEP1, NAL1, WFP1, HIS1, GNP1, GFR1, FZP1, NGR5, SCM2
Hybrid		Rf3, Rf4, ms-IR36, WA-CMS, tms5

Source: Agriplex, 2023

Note: These markers were identified on collected rice samples in the VHLSS 2022.

Appendix B. Climate-Smart Mapping and Adaptation Planning (CS-MAP) for the provinces of Hanoi (RRD) and Dong Thap (MRD).

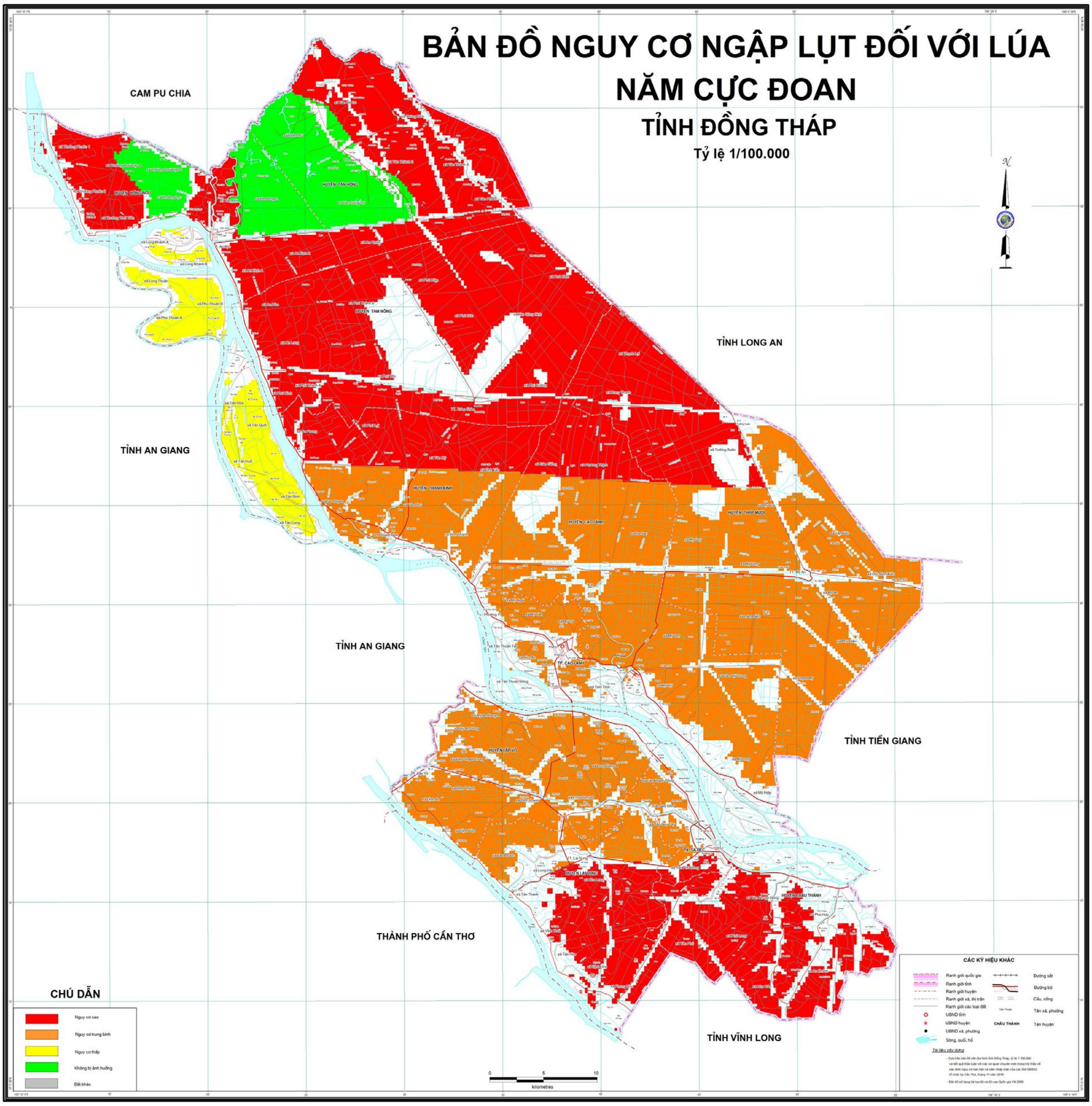
Figure 18. Drought-risk map for rice cultivation in an extreme year (water supply at 50-80% of total supply) during the Winter-Spring crop in the province of Hanoi (RRD)



Source: DARD Hanoi

Note: Drought risk is divided into three levels: green = no risk (sufficient water, rice cultivation as normal), yellow = low risk (difficulty in taking water, delay sowing/ transplanting), and orange = high risk (severe difficulty in taking water, stop rice cultivation and/or switch to other crops). The second table in the bottom left of the figure presents the suggestive sowing/ transplanting schedule of the Spring rice for all districts in Ha Noi.

Figure 19. Flooding risk map for the Dong Thap province (MRD) during the Autumn-Winter cropping season



Source: DARD Dong Thap

Note: Risk is divided into four levels. Green = no risk, yellow = low risk (30% of the yield could be damaged), orange = average risk (50% of the yield could be damaged), and red = high risk (70% of the yield could be damaged).

Appendix C. Modules Integrated into VHLSS 2022 (English version)

4B1. Cultivation

4B1.1a. Have you harvested any products from planting activities for the last 12 months? (Including by-products and collected products from cultivation)?

1 - Yes
2 - No

4B1.1b. Was the damage caused by natural disasters, pest diseases, or environmental pollution...?

1 - Yes
2 - No

4B1.1. Rice

Note: The below roster is part of the VHLSS original design. It is used to direct rice-growing households to the newly integrated modules.

	2		3	3a			3b	4	5
	Which types of rice have your household harvested in the last 12 months?		What is the cultivated area of [...] in the last 12 months?	When did you sow / transplant seeds for [...]? Use starting date ENUMERATOR: IF RICE WAS PLANTED SEVERAL TIMES IN A GIVEN SEASON, WRITE THE LAST SUCCESSFUL SOWING/PLANTING DATES			Is the date in the Lunar or Gregorian calendar? 1. Lunar calendar 2. Gregorian calendar	What is the output of [...] harvested in the last 12 months?	Value of product harvested in the last 12 months?
	Mark X if YES	**X**	**M2**	**DAY**	**MONTH**	**YEAR**	**CODE**	**KG**	**THOUSAND VND**
1	Year-round ordinary rice?								
2	Winter-Spring ordinary rice?								
3	Summer-autumn ordinary rice?								
4	Tenth-month or autumn-winter rice?								
5	Ordinary rice planted in terraced fields?								
6	Year-round glutinous rice?								
7	Year-round specialty rice?								

4B1.1.1. Adaptive rice-based systems

1. Has the household harvested at least one plot of rice in the last 12 months?
   1 - Yes (>>> Q2)
   2 - No (>>> Next module)

	2		**3**	**4**				**5**
	In the last 12 months, have you received advice from authorities regarding the following: [ENUMERATOR: AUTHORITIES REFER TO DISTRICT AGRICULTURE OFFICE, DISTRICT PEOPLE'S COMMITTEE, COOPERATIVES, EXTENSION SERVICES, AND COMMUNE/VILLAGE LEADERS] 1. Yes 2. No		Have you applied this advice on at least one plot? 1. Yes 2. No	In which cropping season have you applied this advice?				Following this advice, which product did you plant instead of rice? 1. Shrimp 2. Fruit crops 3. Lotus or buffalo nut crop 4. Growing fish in cages 5. Vegetable 6. Other [ENUMERATOR: IF MORE THAN ONE SEASON, CHOOSE THE DONG-XUAN CROP SHIFT]
				Winter-Spring (Dong-Xuan)	Summer -Autumn (He-Thu)	Autumn - Winter (Thu Đông)	Wet season (Mua)	
1	Not cultivating rice in a particular season.	IF 1 >>>	IF 1 >>>					
2	Shifting from rice to another crop	IF 1 >>>	IF 1 >>>	>>>	>>>	>>>	>>>	
3	Change in rice sowing/planting dates	IF 1 >>>	IF 1 >>>					
4	Rice varieties to sow	IF 1 >>>	IF 1 >>>					
5	Shifting to shorter-duration rice varieties	IF 1 >>>	IF 1 >>>					
6	Changes in plot irrigation schedule	IF 1 >>>	IF 1 >>>					

4B1.1.2. Rice management practices

	5b		5c	5d
	Are you familiar with [...]? 1. Yes 2. No (>> NEXT LINE) IF ALL LINES == 2 (>> QUESTION 6) ENUMERATOR: CITE EVERY RICE MANAGEMENT PRACTICE		Have you ever applied [...]? 1. Yes 2. No IF ALL LINES == 2 (>> QUESTION 6)	Have you applied [...] during the last Winter-Spring (Dong-Xuan) season? 1. Yes 2. No
1	VietGAP [Tiêu chuẩn thực hành sản xuất nông nghiệp tốt của Việt Nam]	IF 1 >>	>>	
2	One Must Do, Five Reduction (1M5R) [Một Phải, Năm Giảm (1P5G)]	IF 1 >>	>>	
3	Alternate Wetting and Drying (AWD) [Ướt khô xen kẽ ; (2) Khô ngập luân phiên; (3) Nông Lộ Phơi]	IF 1 >>	>>	
4	Integrated Crop Management (ICM) [Quản lý tổng hợp dinh dưỡng và dịch hại cây trồng]	IF 1 >>	>>	
5	Three Reductions, Three gains (3R3G) [Ba Giảm Ba Tăng]	IF 1 >>	>>	
6	System of Rice Intensification (SRI) [1) Hệ thống thâm canh lúa cải tiến; (2) Hệ thống thâm canh lúa tổng hợp]	IF 1 >>	>>	
7	Other: (Specify…………………….…)	IF 1 >>	>>	

ENUMERATOR: ASK THE FOLLOWING QUESTIONS FOR THE LAST COMPLETED DONG-XUAN SEASON, 2021 OR 2022, DEPENDING ON THE TIME OF DATA COLLECTION

6	7	8	9
During the last Winter-Spring season, which method did you use for seedlings? ENUMERATOR: A ROW SEEDER/SEED DRU HAS SIX TO EIGHT DRUMS (16 MM IN DIAMETER), EACH WITH A PAIR OF ROWS OF HOLES (8–9 MM IN DIAMETER) ON EACH SIDE OF THE DRUM) 1. Hand seedling 2. Row seeder 3. Seed blower 4. Transplanting (Manual/Machine) 5. Other	Between transplanting and flowering, how many times was the plot left dry? ENUMERATOR: A PLOT IS CONSIDERED DRY WHEN THE SOIL IS CRACKED. A PLOT CAN BE DRY FOR MANY REASONS, I.E. DROUGHT, COOPERATIVE/ FARMER'S DELAY IN PUMPING WATER, ETC	How many days, on average, was the plot left dry before irrigation was applied?	Are you able to determine the timing of the irrigation in your plot? 1. Yes 2. No, determined by the farmer cooperative/ commune 3. No, determined by a private company
CODE	**TIMES (IF 0 >>>> Q9)**	**DAYS**	**CODE**

10	11	12	13	14
Did you use certified seeds? ENUMERATOR: ON AT LEAST ONE PLOT 1. Yes 2. No	How many times did you apply pesticides, fungicides, or insecticides?	Which method did you use for harvesting? ENUMERATOR: MULTIPLE ANSWERS POSSIBLE 1. Manual labor 2. Using a mini-combine harvester / 2WT 3. Using a combine harvester 4. Using a straw baler 5. Other	After harvest, what did you mostly do with rice straws? 1. Burn on the plot (>> MODULE 4B1.1.2) 2. Left on the plot for mulching (>> MODULE 4B1.1.2) 3. Incorporated to the soil plot (>>PHẦN 4B1.1.2) 4. Removed partially from the plot (>>Q14) 5. Removed completely from the plot (>>Q14) 6. Other (>> MODULE 4B1.1.2)	What did you mostly do with the straws removed from the plot? 1. Feed for livestock 2. Use for cooking 3. Used for mushroom cultivation 4. Use for compost 5. Sold 6. Other
CODE	**TIMES**	**CODE**	**CODE**	**CODE**

4B1.1.3. Plot roster

1. Is this household selected for rice crop sampling?
   1 – Yes (>> Q2)
   2 – No (>> MODULE 4B1.1.3)

ENUMERATOR: PLEASE GIVE ME THE LIST OF ALL RICE PLOTS CULTIVATED THIS SEASON

	2	**3**	**4**
PLOT CODE	Plot Description	At which growth stage is the rice planted on [...]? 1. Less than 20 days since sowing 2. More than 20 days since sowing IF 2 >>> Q4 IF 1 >>> NEXT PLOT	Plot selection RANDOM SELECTION BY CAPI
1			
2			
3			
4			
5			
6			

4B1.1.4 Rice crop sampling

ENUMERATOR: CONTINUE WITH THE PLOT SELECTED FOR CROP SAMPLING IN MODULE 4B1.1.2

1	2	3	4	5
What is the ID code of the plot selected for crop sampling? [Note: Automatic filling]	Plot Description [ENUMERATOR: USE THIS NAME IN THE FOLLOWING QUESTIONS] [Note: Automatic filling]	What is the cultivated area of the plot, in sq. meters?	How many varieties of rice were planted on this plot?	What is the name of the main variety planted in this plot? ENUMERATOR: CONTINUE WITH THE MAIN VARIETY ONLY
ID	**NAME OF PLOT**	**M2**	**NUMBER**	**NAME**

6	7	8	9
What type of rice is the main variety planted in this plot? 1. Traditional 2. Improved/certified 99. Don't know	Is the main variety used on this plot a certified seed? 1. Yes 2. No ENUMERATOR: CERTIFIED SEEDS ARE PRODUCED BY COMPANIES AND COME IN A LABELLED BAG WITH THE VARIETY NAME	What is the source of the main seeds planted on this plot? 1. Self-produced 2. Farmer Group/Seed Club 3. Seed Company 4. Research Institutes/Universities 5. Extension services 6. Cooperative 7. Private stores/dealers 8. Other If 1 >>> Q9 If NOT 1 >>> NEXT MODULE	For how many seasons have you re-used the main variety planted on this plot? ENUMERATOR: IF SEEDS ARE NEWLY PURCHASED, ENTER 0
CODE	**CODE**	**CODE**	**NUMBER**

ORDER	10. Is this main variety: ENUMERATOR: CITE EVERY STRAIT. TICK THE BOX IF YES	MARK X IF THE ANSWER IS YES
1	Salt-tolerant	
2	Submergence-tolerant	
3	Drought-tolerant	
4	High-temperature tolerant	
5	Cold-tolerant	
6	Acid-sulfate tolerant	

ORDER	11. Have you applied [...] on this plot? ENUMERATOR: CITE EVERY METHOD. TICK THE BOX IF YES	MARK X IF THE ANSWER IS YES
1	VietGAP [Tiêu chuẩn thực hành sản xuất nông nghiệp tốt của Việt Nam]	
2	One Must Do, Five Reduction (1M5R) [Một Phải, Năm Giảm (1P5G)]	
3	Alternate Wetting and Drying (AWD) [Ướt khô xen kẽ; (2) Khô ngập luân phiên; (3) Nông Lộ Phơi]	
4	Integrated Crop Management (ICM) [Quản lý tổng hợp dinh dưỡng và dịch hại cây trồng]	
5	Three Reductions, Three gains (3R3G) [Ba Giảm Ba Tăng]	
6	System of Rice Intensification (SRI) [1) Hệ thống thâm canh lúa cải tiến; (2) Hệ thống thâm canh lúa tổng hợp]	
7	Other: (SPECIFY……………………)	

ORDER	12 In this Dong-Xuan season, have you received advice from authorities regarding: ENUMERATOR: AUTHORITIES REFER TO DISTRICT AGRICULTURE OFFICE, DISTRICT PEOPLE'S COMMITTEE, COOPERATIVES, EXTENSION SERVICES, COMMUNE/VILLAGE LEADERS 1. Yes 2. No (>> NEXT LINE)		13 Have you applied this advice? 1. Yes 2. No
			CODE
1	Shifting from rice to another crop	IF 1 >>>	
2	Change in rice sowing/planting dates	IF 1 >>>	
3	Rice varieties to sow	IF 1 >>>	
4	Shifting to shorter-duration rice varieties	IF 1 >>>	
5	Changes in plot irrigation schedule	IF 1 >>>	

14 DATE OF CROP SAMPLING		15 TAKE A PICTURE OF THE LOCATION OF THE SAMPLE TAKEN ON THE PLOT	16 CROP SAMPLE BARCODE [Enumerator: Scan the tube barcode]	17 GPS Coordinates Corner of the plot [Enumerator: Record the GPS coordinates	
DAY	MONTH	PICTURE	BARCODE	LONGITUDE	LATITUDE

Appendix D. New modules Integrated into VHLSS 2023 (English Version)

4B. Agricultural, Forestry and Aquacultural Production Activities

4B1. Cultivation

4B1.1a. Have you harvested any products from planting activities for the last 12 months? (Including by-products and collected products from cultivation)?

1 - Yes

2 - No

4B1.1b. Was the damage caused by natural disasters, pest diseases, or environmental pollution...?

1 - Yes

2 - No

4B1.1. Rice

Note: The below roster is part of the VHLSS original design. It is used to direct rice-growing households to the newly integrated modules.

	2		3	3a			3b	4	5
	Which types of rice have your household harvested in the last 12 months?		What is the cultivated area of […] in the last 12 months?	When did you sow / transplant seeds for […]? USE STARTING DATE			Is the date in the Lunar or Gregorian calendar? 1. Lunar calendar 2. Gregorian calendar	What is the output of […] harvested in the last 12 months?	Value of product harvested in the last 12 months?
	Mark X if YES	**X**	**M2**	**DAY**	**MONTH**	**YEAR**	**CODE**	**KG**	**THOUSAND VND**
1	Year-round ordinary rice?								
2	Winter-Spring ordinary rice?								
3	Summer-autumn ordinary rice?								
4	Tenth-month or autumn-winter rice?								
5	Ordinary rice planted in terraced fields?								
6	Year-round glutinous rice?								
7	Year-round specialty rice?								

4B1.1.A. Rice-based Innovations

4B1.1.A.1. Adaptive Rice-based Systems

2. Has the household harvested at least one plot of rice in the last 12 months?
   1 – Yes (>>> Q2)
   2 – No (>>> NEXT MODULE)

	2		**3**	**4**				**5**
	In the last 12 months, have you received advice from authorities regarding the following: [ENUMERATOR: AUTHORITIES REFER TO DISTRICT AGRICULTURE OFFICE, DISTRICT PEOPLE'S COMMITTEE, COOPERATIVES, EXTENSION SERVICES, AND COMMUNE/VILLAGE LEADERS] 1. Yes 2. No		Have you applied this advice on at least one plot? 1. Yes 2. No	In which cropping season have you applied this advice?				Following this advice, which product did you plant instead of rice? 1. Shrimp 2. Fruit crops 3. Lotus or buffalo nut crop 4. Growing fish in cages 5. Vegetable 6. Other [ENUMERATOR: IF MORE THAN ONE SEASON, CHOOSE THE DONG-XUAN CROP SHIFT]
				Winter-Spring (Dong-Xuan)	Summer -Autumn (He-Thu)	Autumn - Winter (Thu Đông)	Wet season (Mua)	
1	Not cultivating rice in a particular season.	IF 1 >>>	IF 1 >>>					
2	Shifting from rice to another crop	IF 1 >>>	IF 1 >>>	>>>	>>>	>>>	>>>	
3	Change in rice sowing/planting dates	IF 1 >>>	IF 1 >>>					
4	Rice varieties to sow	IF 1 >>>	IF 1 >>>					
5	Shifting to shorter-duration rice varieties	IF 1 >>>	IF 1 >>>					
6	Changes in plot irrigation schedule	IF 1 >>>	IF 1 >>>					

MODULES A2 TO A6 BELOW ARE ASKED FOR THE HARVESTED WINTER-SPRING SEASON IN THE PAST 12 MONTHS.
IF FARMERS DID NOT CULTIVATE IN THE WINTER-SPRING SEASON, THESE QUESTIONS ARE APPLIED TO THE LAST HARVESTED SEASON

4B1.1.A.2. Seeds

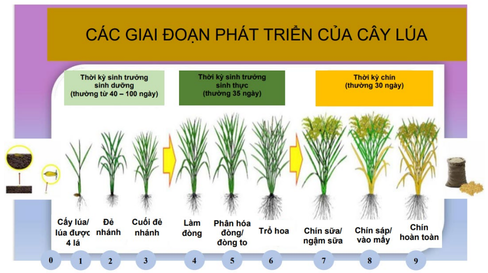
1		2		3
During the last Winter-Spring season, which method did you use for seeding in your largest plot? 1. Hand seeding 2. Row seeder/ drum seeder 3. Seed blower 4. Transplanting by hand using hard plating 5. Transplanting by hand using soft plating 6. Transplanting by machine 7. Other 99. Don't know		During the last Winter-Spring season, which seed rate did you use on your largest plot? 1. In m2 2. Sào Bắc Bộ (360m2) 3. Sào Trung Bộ (500m2) 4. Sào Nam Bộ or Công Nhà nước (1000m2) 5. Công Tầm Cắt or Công Lớn (~ 1300m2) 99. Don't know >> Q5		How long have you been using this seed rate for the last winter-spring season?
CODE		**NUMBER**	**CODE**	**NUMBER (YEARS)**

4		5	6
What was your seed rate before this time? 1. In m2 2. Sào Bắc Bộ (360m2) 3. Sào Trung Bộ (500m2) 4. Sào Nam Bộ or Công Nhà nước (1000m2) 5. Công Tầm Cắt or Công Lớn (~ 1300m2) 99. Don't know		During the last Winter-Spring season, did you use certified seeds? [ENUMERATOR: READ ALL OPTIONS, AND SELECT ONE] 1. Only certified seeds 2. Combination of certified seeds and your own seeds 3. Only self-produced seeds or seeds from other farmers 99. Don't know	What was the name of the main rice variety that you used last Winter-Spring season?
NUMBER	**CODE**	**CODE**	**TEXT**

4B1.1.A.3. Pesticides

1	2a	2b
In the last WS season, how many times did you apply plant protection drugs on your main plot, including herbicides, molluscicides, insecticides, fungicides, and rodenticides?	Of these, how many times did you apply insecticides and fungicides?	If 0 application, do you normally experience bugs, diseases, or fungus on your main plot? 1. Yes 2. No
NUMBER OF TIMES	**NUMBER OF TIMES**	**CODE**

ID	3	4	5			6
	For application [ID], for which object(s) are you using this plant protection drug? LIST OF OBJECTS [ENUMERATOR: CAN CHOOSE MULTIPLE CHOICES]	What was the purpose of this application [ID]? 1. Prevention 2. Treatment 3. Nutrient 99. Don't know	At which rice stage did you apply this chemical? **[ENUMERATOR: USE VISUAL AID AND LET THE FARMER INDICATE TO YOU THE RICE GROWTH STAGE]** 0. Stage 0 1. Between 0 and 1 2. Stage 1 3. Between 1 and 2 4. Stage 2 5. Between 2 and 3 6. Stage 3 7. Between 3 and 4 8. Stage 4 9. Between 4 and 5	10. Stage 5 11. Between 5 and 6 12. Stage 6 13. Between 6 and 7 14. Stage 7 15. Between 7 and 8 16. Stage 8 17. Between 8 and 9 18. Stage 9		How many drugs did you use in application [ID]?
	CODE	**CODE**	**CODE**			**NUMBER**
1						
2						
3						
…						



LIST OF OBJECTS TO BE FILLED IN A3.Q3

Note: The CAPI design allows for automatic filling when enumerator type in the disease/pest name in Vietnamese. Only relevant options are displayed, along with the visual. The visual is used to request the interviewee' confirmation about the disease/pest he intended to treat with this pesticide application.

ID	Name in Vietnamese	Visual	Name in English
1	Sâu cắn gié; Sâu keo; Sâu cắn chẽn; Sâu đàn.	 	Paddy armyworm, Rice ear-cutting caterpillar, Paddy swarming caterpillar
2	Sâu phao; Sâu phao bướm trắng; Sâu phao đục bẹ.	 	Rice caseworm; Leaf-sheath borer
3	Sâu sừng xanh	 	Rice horn caterpillar, Rice butterfly

ID	Name in Vietnamese	Visual	Name in English
4	Sâu cuốn lá (nhỏ)	 	Rice leafroller, Rice leaf folder
5	Sâu gai (lúa); Bọ gai;		Rice hispa
6	Châu chấu lúa; Cào cào xanh;		Rice grasshoppers
7	Sâu đục thân		Stem borer-related

ID	Name in Vietnamese	Visual	Name in English
8	Rầy nâu; Muội nâu;		Brown planthopper
9	Rầy xanh;		Rice green leafhopper
10	Rầy lưng trắng;		White-backed planthopper
11	Muỗi hành; Sâu năn; Muỗi năn; Lúa năn;		(Asian) Rice (stem) gall midge
12	Rầy phấn trắng; Rầy cánh trắng, Bọ phấn trắng; Rầy phấn.		Rice whitefly

ID	Name in Vietnamese	Visual	Name in English
13	Ruồi đục lá lúa; Giòi đục lá; Ruồi/ giòi đục nõn/ ngọn.		Rice leaf miner; Rice whorl maggot
14	Bọ xít	 	Rice seed bug-related
15	Bọ trĩ, bù lạch, mò lửa, mò;		Rice thrips
16	Nhện gié; Bệnh cạo gió; Bệnh nấm bẹ;		Panicle rice mite
17	Cháy bìa lá lúa; Cháy lá; Bạc lá lúa;		Rice leaf blight; Bacterial leaf blight (BLB)
18	Đốm sọc lá lúa; Đốm sọc vi khuẩn hại lúa; Bệnh sọc trong;		Bacterial leaf streak (of rice); Bacterial grain rot

ID	Name in Vietnamese	Visual	Name in English
19	Lem lép hạt, Lép vàng; Thối hạt;		Bacterial panicle blight
20	Đạo ôn;		Rice blast; rice blast fungus On leaf: Leaf rice blast On rachis: Rachis rice blast
21	Đốm nâu; Tiêm lửa;		Brown spot disease; Rice brown leaf spot
22	Vàng lá chín sớm; Vàng lá;		Red stripe disease (yellow leaf disease)

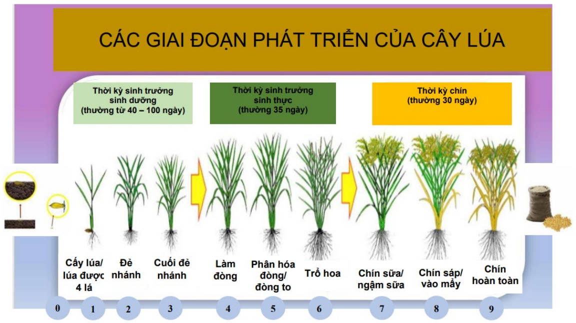
ID	Name in Vietnamese	Visual	Name in English
23	Đốm vằn, khô vằn		Rice sheath blight
24	Thối bẹ (lúa);		Stem rot; Rice sheath rot
25	Bệnh lúa von; Bệnh bakanae; Bệnh thối gốc; Bệnh vươn lóng; Bệnh mạ đực;		Bakanae disease of rice
26	Bệnh lan truyền bởi rầy/ rầy nâu		Plant hoppers-related virus
27	Bệnh tuyến trùng hại rễ lúa; Bệnh bướu rễ lúa		Rice root nematodes

4B1.1.A.4. Fertilizer

1. In the last WS season, how many times did you apply chemical fertilizer on your plots? | NUMBER OF TIMES |

ENUMERATOR: ONLY CONSIDER CHEMICALS. PUT EACH APPLICATION IN ORDER, FROM LAND PREPARATION TO HARVEST

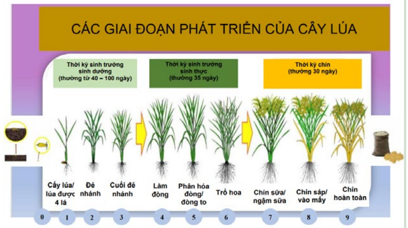
ID	2	3			4		5
	During the last Winter-Spring season, what type of fertilizers did you apply? 1. Nitrogen 2. Phosphate >>Q4 3. Kali >>Q4 4. NPK 5. DAP >>Q4 6. Other >>Q4 (Specify)	Do you know the chemical formula of this fertilizer? e.g, NPK 20-20-15, NPK 8-10-3, Urea (46-0-0), Armoni (21-0-0)			How many kg did you apply per unit of land? 1. In m2 2. Sào Bắc Bộ (360m2) 3. Sào Trung Bộ (500m2) 4. Sào Nam Bộ or Công Nhà nước (1000m2) 5. Công Tầm Cắt or Công Lớn (~1300m2) 99. Don't know		At which rice stage did you apply this fertilizer? **[ENUMERATOR: USE VISUAL AID AND LET THE FARMER INDICATE TO YOU THE RICE GROWTH STAGE]** 0. Stage 0 1. Between 0 and 1 2. Stage 1 3. Between 1 and 2 4. Stage 2 5. Between 2 and 3 6. Stage 3 7. Between 3 and 4 8. Stage 4 9. Between 4 and 5 10. Stage 5 11. Between 5 and 6 12. Stage 6 13. Between 6 and 7 14. Stage 7 15. Between 7 and 8 16. Stage 8 17. Between 8 and 9 18. Stage 9
	CODE	**N**	**P**	**K**	**NUMBER**	**CODE**	**CODE**
1							
2							
…							



4B1.1.A.5. Water

1	2	3	4
During the last Winter-Spring season, which water source did you use to irrigate your fields? 1. Cooperative, irrigation service center 2. Agent Level II 3. Only own pump 4. Own pump and others 5. Other (Specify)	Has your largest plot been leveled with a laser leveling machine? 1. Yes 2. No 99. Don't know	Are you using a water pipe/tube to measure the water level? 1. Yes 2. No 99. Don't know 	In the last Winter-Spring season, how many times did your largest plot dry? [ENUMERATOR: DRY PLOT MEANS NO WATER ON THE SURFACE OF THE LAND]
CODE	**CODE**	**CODE**	**NUMBER**

4B1.1.A.5. Water (cont)

ID	5			6	7	8
	For dry event [Drydown ID], at what stage/between stages were the rice plants? **[ENUMERATOR: USE VISUAL AID AND LET THE FARMER INDICATE TO YOU THE RICE GROWTH STAGE]**			For dry event [Drydown ID], how many days was the plot dry?	On dry event [Drydown ID], what reason below caused the soil to dry? [ENUMERATOR TO READ ALL OPTIONS. SELECT ONLY ONE ANSWER] 1. I actively drained the water out 2. Cooperative/irrigation company drained out the water 3. Cooperative/irrigation company stopped pumping the water 4. Cooperative pumped but I did not receive enough water 5. Mound land 6. Sunny, hot weather 7. Other 99. Don't know	On dry event [Drydown ID], how much did your feet sink when you stepped on the soil (in cm) at the driest time of your plot? [ENUMERATOR: 99 IF DO NOT KNOW]
	0. Stage 0 1. Between 0 and 1 2. Stage 1 3. Between 1 and 2 4. Stage 2 5. Between 2 and 3 6. Stage 3 7. Between 3 and 4 8. Stage 4 9. Between 4 and 5	10. Stage 5 11. Between 5 and 6 12. Stage 6 13. Between 6 and 7 14. Stage 7 15. Between 7 and 8 16. Stage 8 17. Between 8 and 9 18. Stage 9	 			
	CODE			**DAYS**	**CODE**	**NUMBER (CM)**
1						
2						
3						
...						

4B1.1.A.6. Post-harvest

1	2	3	4
When did you start harvesting rice? 1. When 70-80% of the grains per panicle were straw-yellow colored. 2. When 80-90% of the grains per panicle were straw-yellow colored 3. When 90-100% of the grains per panicle were straw-yellow colored	Which method did you mostly use for harvesting? 1. Using a combine harvester 2. Using a straw baler 3. Manual labor >> Q4 4. Other methods (Specify) >> Q4	For how long have you been using this harvesting method?	Which method did you use to dry your rice? 1. Field drying >> Q6 2. Sun drying on the road or home ground >> Q6 3. Sun drying using a mat or pavement >> Q6 4. Heated air drying (batch dryer) 5. Low-temperature drying (In-store dryer) 6. Solar drying or Solar bubble dryer 7. I dry by machine, but I don't know the technology 8. No drying sold fresh rice >> Q6 9. Other (Specify) >> Q6
CODE	**CODE**	**YEARS**	**CODE**

5	6	7
How long have you been using this drying method?	How did you store your rice? 1. No storage, sold fresh rice 2. Storage shed in bags; 3. In storage shed loose (bulk); 4. Hermetic storage (Cocoon or Super Bag) 5. Other (Specify)	How did you check the moisture content of your rice? 1. I don’t check the moisture content 2. I checked by hand 3. I used a machine 4. The buyer checks the moisture content
YEARS	**CODE**	**CODE**

4B1.1.A.7. NRM Methods

	Have you applied [...] during the last Winter-Spring (Dong-Xuan) season? [ENUMERATOR: CITE EVERY RICE MANAGEMENT PRACTICE] 1. Yes 2. No 99. Don’t know	
		CODE
1	One Must Do, Five Reduction (1M5R) [Một Phải, Năm Giảm (1P5G)]	
2	Alternate Wetting and Drying (AWD) [(1) Ướt khô xen kẽ; (2) Khô ngập luân phiên; (3) Nông Lộ Phơi; (4) Tưới lộ ruộng]	
3	Three Reductions, Three gains (3R3G) [Ba Giảm Ba Tăng]	
4	System of Rice Intensification (SRI) [1) Hệ thống thâm canh lúa cải tiến; (2) Hệ thống thâm canh lúa tổng hợp]	

4B1.2. Other Starchy, Vegetable, and Annual Plants

Note: The below roster is part of the VHLSS original design. It is used to direct cassava-growing and potato-growing households to the newly integrated modules.

	2		3	4	5	6	7	8
	Which of the following products have you harvested in the last 12 months? ENUMERATOR: ASK QUESTION 2 FOR ALL KINDS OF PLANTS BEFORE STARTING QUESTION 3		What was the area in which you grew […]?	What was the output of […] that you harvested in the last 12 months?	What was the amount of […] that you did sell or barter in the total harvested output in the last 12 months?	How much did you earn from the sale/barter of […] in the last 12 months?	Value of the product harvested in the last 12 months?	Do you currently have […] planted on at least one plot? 1. Yes 2. No
	Mark X if YES	**X**	**M2**	**KG**	**KG**	**THOUSAND VND**	**THOUSAND VND**	**CODE**
1	Maize (corn)							
2	Sweet potato							
3	Cassava/manioc							>>> Module 4B1.2. A
4	Other staple food crops							
5	Potato							>>> Module 4B1.2. B
6	Morning glory vegetable							
7	Kohlrabi							
8	Cabbage, cauliflower							
9	Cruciferous vegetables							
10	Edible beans							
11	Tomato							
12	Seasoning herb							
13	Other edible vegetables, fruits, and roots							
14	Other annual crops (green, black, and red bean, flowers, decorative plants, plants for animal feed and manure, etc.)							

4B1.2.A. Cassava

4B1.2.A.1. Cassava Use and Marketing

c	1	2	3	4	5	6
Types of cassava products sold	To whom did you mainly sell this [Cassava product]? 1. Local traders at the cassava plot 2. Local traders at the market (i.e., weighing points) 3. Starch/Ethanol processing factory 4. Directly to consumers >> Q5 5. Other (Specify)	Do you know the name of the factory that received your [Cassava product]? [ENUMERATOR: 99 IF DO NOT KNOW]	Do you know the commune in which the factory that received your [Cassava product] is located? [ENUMERATOR: SEARCH AND SELECT COMMUNE NAME AND CODE, 99 IF DO NOT KNOW]	For how many years have you been selling to this buyer?	In total, how much did you pay for processing this [Cassava product] (in thousand VND)?	In total, how much did you receive from selling this [Cassava product]?
	CODE	**CODE**	**CODE**	**YEARS**	**THOUSAND VND**	**THOUSAND VND**
a. Fresh root						
b. Flour						
c. Dried chips						
d. Do not sell						

4B1.2.A.2. Cassava Plot Roster

1. Is this household selected for cassava crop sampling?

1. Yes (>>> Q2)
2. No (>>>Q1a)

1a. Why is this household not selected for crop sampling?

1. This EA has collected samples from 5 households already.
2. Cassava was harvested already and not planted for the new season.
3. Other (specify)…........................

NUMERATOR: PLEASE GIVE ME THE LIST OF ALL CASSAVA PLOTS CULTIVATED THIS SEASON

	2	3	4	5
PLOT CODE	Plot Name	What is the cultivated area of the plot, in sq. meters?	Was cassava in this plot planted more than 1 month? 1. Yes 2. No	*[Note: Automatic filling]* RANDOM SELECTION REPORTS THE PLOT ID IN THE NEXT SECTION
	NAME	**AREA**	**CODE**	**NUMBER**
1				
2				
…				

4B1.2.A.3. Cassava Crop Sampling

ENUMERATOR: CONTINUE WITH THE PLOT SELECTED FOR CROP SAMPLING

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Household ID *[Note: Automatic filling]*	What is the ID code of the plot selected for crop sampling? *[Note: Automatic filling]*	How many varieties of cassava were planted on [Plot name]?	What is the name of the main variety planted on [Plot name]? [Enumerator: continue with the main variety only]	What type of cassava is the main variety planted on [Plot name]? 1. Traditional 2. Improved 99. Don't know	What is the source of the main seeds planted on [Plot name]? 1. Research Institutes/ Universities 2. Agricultural Extension services 3. Processing factories/traders 4. Farmer Group/Seed Club/Cooperatives 5. Private stores/dealers 6. Obtained from a relative/friend 7. Other	For how many years have you been reusing the planting material for this variety? [ENUMERATOR: If tubers are newly purchased, enter 0]	Is [Plot name] irrigated? 1. Yes 2. No
ID	**ID**	**NUMBER**	**NAME**	**CODE**	**CODE**	**NUMBER**	**CODE**

ORDER	**9. Is this main variety:**	
		Mark X if the answer is Yes
1	High-yielding (roots)	
2	Resistant to cassava mosaic disease (CMD)	
3	High starch content	
5	Early maturity	
6	Resistant to drought	

10		**11**
DATE OF CROP SAMPLING		CROP SAMPLE BARCODE [Enumerator: Scan the tube barcode]
DAY	**MONTH**	**BARCODE**

4B1.2.B. Potato

1	2	3
What is the name of the main variety planted? [ENUMERATOR: CONTINUE WITH THE MAIN VARIETY ONLY]	What is the source of the main variety planted? 1. Research Institutes/ Universities 2. Agricultural Extension services 3. Processing factories/traders 4. Farmer Group/Seed Club/Cooperatives 5. Private stores/dealers 6. Obtained from a relative/friend 7. Other (Specify)	For how many years have you been reusing the planting material for this variety?? [ENUMERATOR: IF TUBERS ARE NEWLY PURCHASED, ENTER 0]
NAME	**CODE**	**NUMBER**

4B1.3. Annual and Perennial Industrial crops

Note: The below roster is part of the VHLSS original design. It is used to direct cofee-growing to the newly integrated modules.

	2		3	4	
	Which of the following products has your household harvested in the last 12 months? [ENUMERATOR: Ask question 2 for all kinds of plants before starting question 3]		What was the output of […] your household harvested in the last 12 months?	Value of the product harvested in the last 12 months?	
	Mark X if YES	**X**	**KG**	**`000 VND**	
1	Soya bean/soybean				
2	Peanut/groundnut				
3	Sesame				
4	Sugarcane				
5	Tobacco, rustic tobacco				
6	Cotton				
7	Jute, ramie				
8	Sedge				
9	Other industrial annual plants				
10	Tea				
11	Coffee				>>>> Module 4B13A
12	Rubber				
13	Pepper				
14	Coconut				
15	Mulberry				
16	Cashew				
17	Other industrial perennials				

4B1.3.A. Coffee Irrigation

ENUMERATOR: We would like to know about your irrigation practices in the last dry season

1	2	3	4
In the last dry season, which irrigation method did you use to irrigate your coffee? 1. Root Irrigation 2. Sprinkler Irrigation 3. Sprinkler Irrigation at Root 4. Drip Irrigation 5. Other 99. Don't know	In the last dry season, how many rounds of irrigation did you use? [ENUMERATOR: 99 IF DO NOT KNOW]	In each irrigation round, how many liters did you use per plant? [ENUMERATOR: 999 IF DO NOT KNOW]	How do you know that the water volume allocated to each plant is [Q3 answer] liters? 1. I use a flow meter in the water pipeline 2. I use a sink dug around coffee roots 3. I know the time it takes to reach this amount 4. Do not know with precision 5. Other
CODE	**NUMERIC**	**LITERS**	**CODE**

4B5. Aquaculture/Fishery

1a. For the past 12 months, has anyone in your household bred and reared fish, shrimps, and other aquatic products or caught aquatic products from lakes, ponds, rivers, streams, and sea; or had income from aquaculture service activities?

1. Yes (>>> Q2)
2. No (Next module)

1b. Was the damage to production caused by natural disasters and epidemics?

1. Yes (>>> Q4B5T2)
2. No (Module 4C)

Note: The below roster is part of the VHLSS original design, and was modified to additionally include tilapia production (1.1b). It is used to select tilapia-growing households to the newly integrated modules.

ORDER	2			3	4
	Which of the following products has your household gotten revenues from?			Total output in the past 12 months?	TOTAL VALUE OF PRODUCTS GAINED for the last 12 months?
		Mark X if YES	**X**	**KG**	**IN THOUSAND VND**
1	**Aquaculture production**				
1.1	Fish				
	If Fish was produced, ask below:				
1.1b	Fish (tilapia)				
1.2	Shrimp				
1.3	Fish and shrimp seeds				
1.4	Other aquatic products (specify_____________)				
2	**Catching**				
2.1	Fish				
2.2	Shrimp				
2.3	Other aquatic products (specify______________)				

4B5T2. What is the total amount of money your household has been compensated/assisted for damages to aquaculture/fishery caught for the last 12 months? (Excluding compensation for live loss, fixed assets such as boats/vessels….)

THOUSAND VND

4B5T. Sum of question 5 + 4B5T2 (Revenues from fishery)

4B5.1.A. Tilapia

1	2	3	4	5
In what year did you start producing tilapia for the first time?	Has your household been involved in fish farming every year since? 1. Yes >> Q4 2. No	How many years has your household NOT been involved in fish farming since then?	Did you purchase tilapia fingerlings in the last 12 months? 1. Yes 2. No	How many pond facilities did your household stock in the last 12 months?
YEAR (4 DIGITS)	**CODE**	**NUMBER**	**CODE**	**NUMBER**

[ENUMERATOR: IF MORE THAN ONE POND, START WITH THE LARGEST]

POND FACILITIES AND EXPERIENCE

6	7	8	9	10	11
Pond Facility Type 1. Pond 2. Cage 3. Channel/Field 4. Other	What is the size of the facility?	What is the average water depth for this facility (in meters)?	What is the source of pond water? 1. Surface (river, lake, creek, stream) 2. Groundwater (tube well, well, ...) 3. Irrigation canal 4. Dam 5. Other (specify)	Which species do you currently stock in the facility? 1. No fish species currently stocked 2. Tilapia and other species 3. Tilapia only 4. Other species only	Do you practice integrated agriculture/ aquaculture, such as tilapia-rice, on this pond? [ENUMERATOR: Integrated Agriculture-Aquaculture is the simultaneous or sequential culture of fish and rice] 1. Yes 2. No
CODE	**M2**	**NUMBER**	**CODE**	**CODE**	**CODE**

ORIGIN

12	13	14	15	16	17
What month and year did you purchase fingerlings?	What was the source of the fingerlings? [ENUMERATOR: MULTIPLE ANSWERS POSSIBLE] 1. Your own farm >> Q18 2. Neighbor or relative 3. Farmers' Group 4. Government hatchery 5. Private hatchery 6. Local dealer (commission agent) 7. NGO 8. Other (specify)	Do you know the name of the hatchery that sold these fingerlings? [ENUMERATOR: NAME OF THE HATCHERY, 99 IF DO NOT KNOW]	Do you know the commune in which this hatchery is located? [ENUMERATOR: SEARCH AND SELECT COMMUNE NAME AND CODE, 99 IF DO NOT KNOW]	Approximately how far is the distance between your household and the hatchery (in Km) [ENUMERATOR: 99 IF DO NOT KNOW	For how many years have you purchased tilapia fingerlings from this provider?
MONTH/YEAR	**CODE**	**TEXT**	**CODE**	**NUMBER**	**YEAR**

STRAIN						OUTPUT		
18	**19**	**20**	**21**	**22**	**23a**	**23**	**24**	**25**
What is the name of the tilapia strain that you purchased?	How many fingerlings (fish) were stocked?	How many fingerlings were monosex male tilapia?	How many cm was the average length per fingerling at stocking?	What was the total price paid for these fingerlings?	Have you completely harvested the fish? 1. Yes (>>>Q23) 2. Have been gradually harvesting (Q24) 3. Not harvested yet (Next module)	When did you completely harvest the fish?	In what form was the tilapia sold? 1. Fresh 2. Dried 3. Processed 4. Other (Specify)	To whom did you mainly sell to? 1. Traders 2. Rural consumers 3. Urban consumers 4. Processing factory 5. Other (Specify)
TEXT	**NUMBER**	**CODE**	**CM**	**VND**		**MONTH/YEAR**	**CODE**	**CODE**

Standing
Panel on
Impact
Assessment

CGIAR Independent Advisory and Evaluation Services (IAES)

Standing Panel on Impact Assessment (SPIA)

Alliance of Bioversity International and CIAT

Via di San Domenico,1

00153 Rome, Italy

email: spia@cgiar.org

url: https://cas.cgiar.org/spia