Standing Panel on Impact Assessment

CGIAR

SPIA Bangladesh Study 2025: Updating the Green Revolution

Saumya Singla, Tanjim Ul Islam, Fuad Hassan, Isabella Monteiro, James Stevenson, Kyle Emerick

December 2025

The Standing Panel on Impact Assessment

The Standing Panel on Impact Assessment (SPIA) is an external, impartial panel of experts in impact assessment appointed by the CGIAR System Council and accountable to it. SPIA is responsible for providing rigorous, evidence-based, and independent strategic advice to the broader CGIAR System on efficient and effective impact assessment methods and practices, including those measuring impacts beyond contributions to science and economic performance, and innovative ways to improve knowledge and capacity on how research contributes to development outcomes.

https://iaes.cgiar.org/spia

Recommended Citation

Singla, S., Ul Islam, T., Hassan, F., Monteiro, I., Stevenson, J.,Emerick, K. (2025). SPIA Bangladesh Study 2025: Updating the Green Revolution. Rome. Standing Panel on Impact Assessment (SPIA)

Full replication code and data are available at:
https://github.com/CGIAR-SPIA/SPIA-Bangladesh-Study-2025

Authors

Saumya Singla, Tanjim Ul Islam, Fuad Hassan, Isabella Monteiro, James Stevenson, Kyle Emerick

Editor

Samantha Collins

Design and layout

Luca Pierotti

Countries and Territories Disclaimer

Boundaries used in the maps do not imply the expression of any opinion whatsoever on the part of CGIAR concerning the legal status of any country, territory, city, or area, or its authorities, or concerning the delimitation of its frontiers or boundaries. Border lines are approximate and cover some areas for which there may not yet be full agreement. The term country also refers, as appropriate, to territories or areas.

Cover Photo: Women farmers growing rice.
Credit: b.a.sujan/Map PhotoAgency/IRRI

SPIA Bangladesh Study 2025: Updating the Green Revolution

Saumya Singla, Tanjim Ul Islam, Fuad Hassan, Isabella Monteiro, James Stevenson, Kyle Emerick

Contents

List of Figures

List of Tables

Abbreviations

AFP	Axial Flow Pump
AWD	Alternate Wetting and Drying
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BFRI	Bangladesh Fisheries Research Institute
BIHS	Bangladesh Integrated Household Survey
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
CIAT	International Center for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Center
CIP	International Potato Center
CRP	CGIAR Research Program
CSISA	Cereal Systems Initiative in South Asia
DATA	Data Analysis and Technical Assistance
FAO	Food and Agriculture Organization of the United Nations
GIFT	Genetically Improved Farmed Tilapia
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
ILRI	International Livestock Research Institute
NARES	National Agricultural Research and Extension Systems
NARS	National Agricultural Research Systems
NRM	Natural Resource Management
PANI	Program for Advanced Numerical Irriagtion
SIS	Small Indigenous Species

Acknowledgments

We are grateful to the many people who have contributed to this report. Dr Humnath Bhandari, IRRI Country Representative for Bangladesh has been unceasingly supportive in hosting SPIA's team in the country and providing advice on how we should approach this work. We are grateful to Dr Akhter Ahmed, Dr Mehrab Bakhtiar, and Julie Ghostlaw in allowing us to add an additional survey wave to the Bangladesh Integrated Household Survey and thank them for the work they have done to curate and protect this international public good over the past fifteen years. Professor Sattar Mandal did a wonderful job of facilitating our consultation workshop in 2023, which fed directly into the design of the study. We are similarly grateful to all participants in that workshop, but particularly the members of the Steering Committee, namely Professor Karen Macours (former SPIA Chair), Dr Tim Krupnik (CIMMYT Country Representative) and Temina Lalani-Shariff (CGIAR Regional Director, South Asia). We thank the directors and staff of Data Assistance and Technical Assistance (DATA) for their flexibility in adapting the BIHS survey to meet the specific needs and unusual features that SPIA introduced. Finally, we thank all the Bangladeshi citizens who graciously gave their time to participate in responding to the survey questions.

Executive Summary

This report presents the results of a comprehensive study on the adoption and diffusion of CGIAR-related agricultural innovations in Bangladesh. We focus on innovations across diverse CGIAR research avenues: crop germplasm, aquaculture and fisheries, climate change adaptation, digital apps, natural resource management innovations, and mechanization.

This is the fifth country report, following Ethiopia (2018-19 data), Ethiopia (2021-22 data), Uganda (2021-22 data) and Vietnam (2022-24 data). To produce this report, SPIA commissioned a new survey wave of the Bangladesh Integrated Household Survey (BIHS), focused primarily on the country's agriculture. The BIHS is a nationally representative panel dataset with previous survey waves implemented in 2011-12, 2015, and in 2018-19. It was originally designed by the Bangladesh Office of the International Food Policy Research Institute (IFPRI) and implemented by the survey firm Data Analysis and Technical Assistance (DATA). In late 2023, SPIA reached an agreement with the International Food Policy Research Institute (IFPRI) to manage BIHS Wave 4 independently. SPIA led the survey design and analysis, in consultation with IFPRI. This wave followed the same sample of households surveyed in Wave 3.

The 1960s and 1970s marked the establishment of the first global agricultural research centers that now form the CGIAR network. Centers like the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT) quickly made significant contributions to crop development in Bangladesh, particularly in rice and wheat. Fifty years after the Green Revolution, farmers in Bangladesh can now access a wide range of new agricultural technologies developed by both domestic and international sources. IRRI began working in Bangladesh in the early 1970s to boost rice production, which was essential for the nation's food security. Since then, this initial narrow focus on rice has diversified significantly. Today, five CGIAR centers – CIMMYT, IFPRI, the International Potato Research Center (CIP), WorldFish, and IRRI – are embedded within Bangladesh's agricultural research landscape, working in close coordination with local institutions. In addition, Bangladesh's national agricultural research system has also collaborated with other CGIAR centers, including the Alliance of Bioversity International and CIAT, the International Water Management Institute (IWMI), and the International Livestock Research Institute (ILRI).

Prior to data collection, we conducted an extensive stocktaking exercise to map CGIAR activity in Bangladesh. This exercise delineated the scope of CGIAR research initiatives in the country from 1970 to 2022 and identified key areas to guide the prioritization of data collection on CGIAR-related developments. The stocktaking process involved three interrelated phases: desk-based research, interviews with stakeholders, and review/consultation. The resulting stocktake includes 64 CGIAR-related innovations and 57 instances where CGIAR research is reported to have influenced government or development institution policies. A common pathway for such policy influence is the scaling up of government pilot programs following CGIAR-led impact evaluations. In other cases, CGIAR expertise has helped shape policy frameworks at both regional and national levels.

From the initial list of 64 CGIAR-related innovations, we identified several that we considered high priority and presented these for discussion during a consultation workshop in Dhaka in

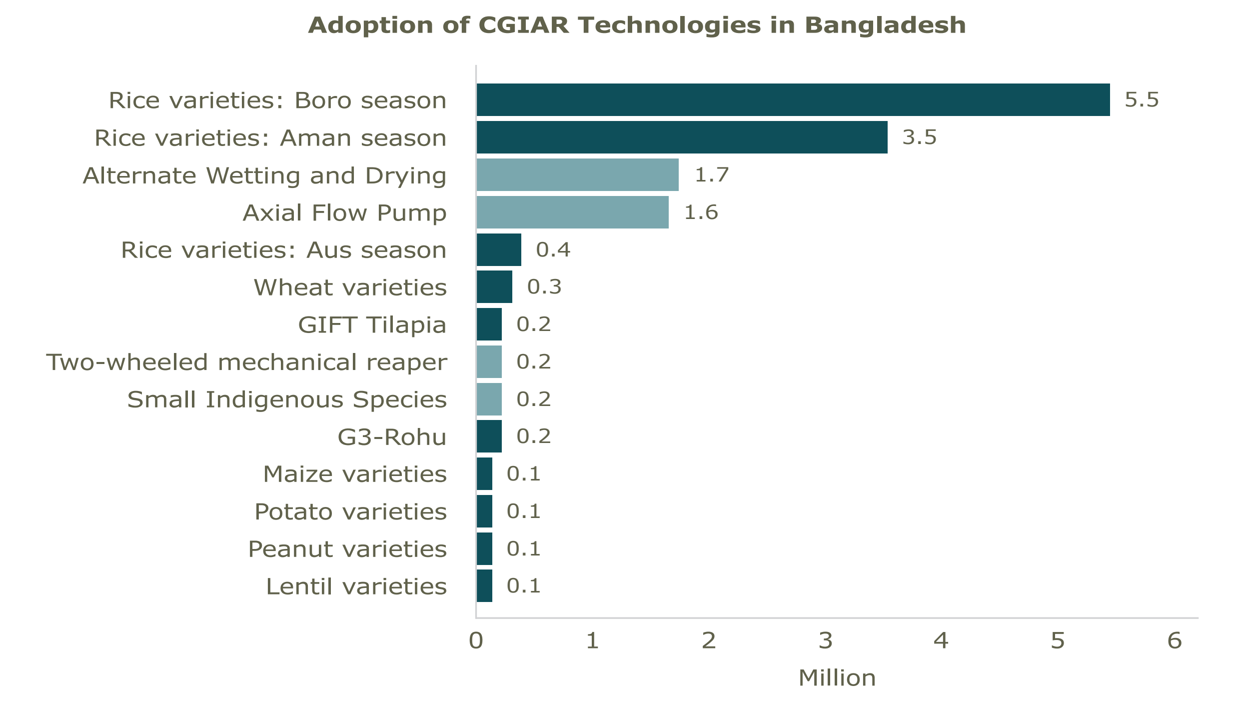
July 2023. Based on the consultation feedback, the list was refined to 46 innovations that were believed to be widely adopted and could be measured. These became the focus of data collection in the BIHS. While some were already a part of the BIHS, others necessitated the development of specialized measurement protocols. A novel feature of this wave was the collection of paddy leaf samples during the Boro season for DNA fingerprinting. Several potential DNA fingerprinting candidates – such as lentil and wheat – were omitted because relevant data had already been collected in recent CGIAR surveys. These included lentil (Yigezu et al. 2022), wheat (Gade et al. 2021), and Aman rice (Kretzschmar et al 2018). Given that previous BIHS rounds had already collected rich panel data across a broad range of topics, Wave 4 deliberately prioritized agriculture-related modules to generate more detailed information for studying innovation adoption. As a result, a shorter version of the main BIHS questionnaire was administered.

Drawing on our data collection, we estimated the potential reach of these innovations among Bangladeshi agricultural households. **The total reach across all innovations is estimated to range from 8.05 to 9.37 million.**

We present a range of reach estimates to reflect varying levels of confidence in attributing adoption to CGIAR involvement. This approach allows us to distinguish innovations with clear, direct CGIAR contributions from those involving broader dissemination efforts. For example, in the case of germplasm, sophisticated DNA fingerprinting techniques enabled us to confidently assess CGIAR’s role. Similarly, for aquaculture, we could identify strains with a direct CGIAR contribution. We have considered these in the lower bound. In contrast, attribution is more challenging for innovations such as agronomic practices or digital tools, where multiple actors are involved and diffusion pathways are less easily traced, and hence they are considered in the upper bound of CGIAR’s reach.

In Figure 1, the large reach observed for rice is owed to rice being the staple crop in Bangladesh, cultivated by around 80% of the agricultural households. Notably, the success of rice germplasm dissemination remains a cornerstone of CGIAR’s impact, as validated through the DNA fingerprinting exercise conducted during the Boro season. Other crops, by contrast, have a reach of under a million households, covering about 1-5% of agricultural households in the BIHS. Around 24% of agricultural households are engaged in aquaculture, with a noticeable trend toward consolidation in commercially viable species such as rohu, tilapia, and carp. As for CGIAR’s reach, G3 rohu has already reached over 200,000 households despite its recent release.

Figure 1: Number of rural households adopting each CGIAR-related innovation in Bangladesh in 2024, in millions



Note: Dark blue bars reflect lower-bound reach numbers, light blue bars reflect upper-bound reach numbers.

Insights from the DNA fingerprinting exercise, combined with self-reported data, reveal important patterns in varietal turnover. Newer stress-tolerant and micronutrient-enriched rice varieties have yet to fully replace the older varieties. The weighted year of release shows that varieties are on average 20 years old. This suggests that while CGIAR-developed varieties are widely adopted, older releases – particularly BRRI Dhan 28 and 29 – continue to dominate. Interestingly, those who are indeed cultivating newer varieties often report them as BRRI Dhan 28 and 29. Investigations of seed bag images collected during the survey revealed that these newer varieties are often marketed as older varieties. This may reflect a strategy by seed companies to leverage the stronger brand recognition of legacy varieties, like BRRI Dhan 28, thereby making it easier to sell newer ones. It could also reflect quality issues during the seed multiplication process. While varietal replacement has been slow, some recent varieties have spread fast, including BRRI Dhan 74, 89, and 100. These results show why there have been efforts by numerous stakeholders to replace BRRI Dhan 28 and 29 with newer varieties (Lojo, n.d.)There is considerable heterogeneity in household and plot-level characteristics among adopters of CGIAR-related innovations, with different factors driving adoption across innovation types. For crop germplasm, adoption seems to be concentrated among less wealthy households. In the case of Boro rice, these include households with lower savings, and in the case of non-rice crops like wheat, maize, lentil, groundnut, and potato, those with a smaller farm size and no outside employment. CGIAR-related aquaculture innovations, like G3 rohu and Genetically Improved Farmed Tilapia (GIFT), are broadly accessible to households engaged in aquaculture, without strong differentiation. In the case of Alternate Wetting and Drying (AWD[1]), the physical characteristics of the plots suggest that farmers practice AWD for those that have higher irrigation demands and pumping costs. Similarly, larger plots located further from the main pump or canal are more likely to be irrigated using an axial flow pump (AFP).

The geographic distribution of adopters for different innovations is concentrated in different parts of the country, showing that CGIAR reach is spread across the whole country. For instance, the Boro rice adopters are predominantly concentrated in central areas, i.e., Dhaka and Sylhet divisions, largely driven by the continued dominance of older varieties, BRRI Dhan 28 and 29. In contrast, newer varieties released after 2005 have higher levels of dispersion across the country, possibly reflecting a successful shift in targeting efforts towards more diverse and peripheral regions. In aquaculture, the distribution of GIFT tilapia and G3 rohu adopters is relatively geographically balanced. Households reporting GIFT tilapia fingerling purchases are concentrated in regions such as Sylhet, Dhaka, and parts of Chittagong. Despite its recent release, G3 rohu has already gained traction in Rangpur and Sylhet, where 11-15% of all reported fingerling purchases were G3. AWD of Boro plots has proliferated at a higher rate in Barisal and Mymensingh than in other districts. Similarly, AFPs, which were primarily tested and disseminated by CIMMYT in Barisal and Chittagong, also show a higher adoption in these divisions.

This report underscores the importance of continued efforts in the country to unpack the impact of CGIAR-related innovations. To build on these initial findings, upcoming efforts, such as the use of DNA fingerprinting in aquaculture, will enable more precise measurement. Looking ahead, SPIA will continue to leverage the panel structure of the BIHS through 2030 to further deepen the understanding of the reach and impact of CGIAR innovations in Bangladesh.

[1] It is important to clarify that by AWD, we refer to farmers who reported drying their fields at least once for a period of five days. This differs from the IRRI-defined AWD method, which involves using a 'field water tube' or plastic pipe to monitor water depth. Farmers who use the pipe represent a small subset of those who report drying their plots.

A middleman offers maize and wheat grain and seed for sale at a market in Nur Islam, Dinajpur, Bangladesh. Credit: S. Mojumder/Drik/CIMMYT

Regeneration of wheat wild relatives under screenhouse conditions in CIMMYT, to have enough healthy and viable seed for distribution when necessary.
Credit: Rocio Quiroz/CIMMYT

1. Introduction

Bangladesh has long been a high-priority country for CGIAR. This is reflected in numerous active research programs in the country, involving most CGIAR centers. Having identified Bangladesh as suitable for a SPIA country-level study, we began work on the stocktaking exercise for this report in June 2022, carrying out desk research and interviewing CGIAR researchers and external stakeholders. In July 2023, in Dhaka, we held a consultation workshop with CGIAR research colleagues and representatives from government ministries and the Bangladesh Agricultural Research Council (BARC). We then laid the plans for the survey fieldwork that was carried out between January and June 2024 and reported on here.

This report is the fifth in a series following Ethiopia (2018-19 data), Ethiopia (2021-22 data), Uganda (2021-22 data) and Vietnam (2022-24 data). Data collection concluded in early 2024, just before the onset of widespread political unrest in Bangladesh. Beginning in June, student-led protests escalated into a nationwide movement that culminated in a change of government in August 2024. The findings in this report, therefore, reflect conditions immediately prior to this major political and economic disruption.

In this report, we aim to estimate the reach of CGIAR-related agricultural innovations in Bangladesh and to understand the geographic distribution and socioeconomic correlates of their adoption by households nationwide. It is organized as follows. Section 2 introduces the Bangladeshi context, focusing on agriculture in the context of structural transformation of the economy, and the ongoing vulnerabilities the country faces from natural hazards, exacerbated by climate change. Section 3 presents the methods used to identify and measure the adoption of CGIAR-related innovations among households in the Bangladesh Integrated Household Survey (BIHS) sample, via a special stand-alone survey round administered by SPIA in 2024. Section 4 provides details of the stocktaking process we undertook to identify agricultural innovations believed to be operating at scale in Bangladesh, and which helped us set data collection priorities. In Section 5, we use earlier waves of the BIHS to examine secular trends in the country's agricultural development prior to our main fieldwork. Section 6 provides our adoption estimates for CGIAR-related innovations using the BIHS (2024). For some innovations, we also examine changes in adoption from earlier waves of the BIHS, going back to 2012. In Section 7, we ask, "Who are the adopters?". This is to determine whether innovations reach subpopulations that are of particular interest to CGIAR. Section 8 documents where these adopters are located. In Section 9, we discuss our results and suggest priorities for future data collection efforts, prior to our conclusion, set out in Section 10.

2. Context

2.1 Geographic Overview

Bangladesh is relatively young as a nation state, gaining independence from post-colonial Pakistan in the liberation war of 1971. It is surrounded by neighboring India, apart from a small border with Myanmar's mountainous and forested regions to the south-east. Many rivers - principally the Padma, the Jamuna, and the Meghna - bring Himalayan glacial snowmelt as well as rain deposited by the monsoon down from the north of Bangladesh and out into the Bay of Bengal. Much of the land in this riverine country is in the Ganges Delta - the largest delta system in the world, and one of the most densely populated regions anywhere on Earth. The nation's capital, Dhaka, is situated within the Ganges River Floodplain. Its greater metropolitan area is home to over 22 million people.

Figure 2: Map of Bangladesh showing eight administrative divisions[2]

[2] Armanaziz, Peter Fitzgerald, Cacahuate, JamesA, CC BY-SA 4.0.

Bangladesh is divided into eight major administrative divisions, each with its own unique landscape that influences agricultural practices, crop varieties, fish species prevalence and overall productivity. The Dhaka Division has fertile alluvial soils that are formed by the deposition of sediments carried by rivers and streams. These are ideal to support rice paddy production, as well as fruits and vegetables, with the added advantage of proximity to urban markets. Chittagong is a low-lying coastal area categorized as a Coastal Saline Zone. It is home to the country's busiest seaport and the Chittagong Hill Tracts, which is a hilly and forested region. Saline intrusion influences agricultural selections in both coastal regions. Barisal is often called 'the Land of Rivers' due to its dense network of waterways, while Khulna has the largest mangrove forest in the world. The northeastern region of Sylhet is renowned for its tea plantations and picturesque landscapes, while the northern regions of Rajshahi and Rangpur are prone to drought conditions. In 2015, Mymensingh was constituted as the newest division, having been segregated from Dhaka.

Each division is further administratively subdivided into districts (or zilas). Bangladesh currently consists of 64 districts. There are 400 sub-districts (upazilas) which are the administrative entities within districts. Unions, or union councils, constitute the most basic rural administrative entities that further segment each upazila, with over 4,500 nationwide.

2.2 Agriculture in Bangladesh's Structural Transformation

The 1960s and 1970s saw the founding of the first of the global agricultural research centers that now make up CGIAR. The International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CIMMYT) quickly made significant advances in crop development in relation to rice and wheat that have relevance for Bangladesh. Fast forward fifty years from the days of the Green Revolution, and Bangladeshi farmers now have access to a wide range of new agricultural technologies from several different domestic and international sources. IRRI started working with Bangladesh in the early 1970s to increase rice production, which was essential for the nation's food security. This initially narrow focus on rice has diversified over the decades since with five CGIAR centers – CIMMYT, the International Food Policy Research Institute (IFPRI), the International Potato Research Center (CIP), WorldFish, and IRRI – having offices in the country, and through close collaboration with regional organizations. Bangladesh's national agricultural research system has also collaborated with other CGIAR centers such as the Alliance of Bioversity International and CIAT[3], the International Water Management Institute (IWMI), and the International Livestock Research Institute (ILRI).

In the 1970s, Bangladesh faced widespread famine due to its rapidly growing population and limited food grain availability per person. In recent decades, pressures on its food system have eased as the country has seen sustained growth in rice production. Average yields have risen from approximately one tonne per hectare in the early 1970s to three tonnes per hectare by 2013 (Gautam and Faruqee, 2016) while the population increased 2.3-fold over this same

[3] Bioversity International and the International Center for Tropical Agriculture (CIAT) merged in 2020 to become the Alliance of Bioversity International and CIAT.

period, from 67.5 million in 1970 to 154.0 million in 2013[4]. This is lower than the yield increase, thus avoiding the Malthusian trap, where population growth outpaces the growth of food production and resources. While this is no mean achievement, challenges remain.

The Food and Agriculture Organization of the UN (FAO) listed Bangladesh as one of 36 member states classified as "protracted food crisis countries" (FAO, 2024). The prevalence of undernourishment in the population in 2021-23 was estimated at 11.9%, only modestly lower than the 13.7% estimated for 2004-06 (FAO, 2024). Progress on food security appears similarly challenging. 30.5% of the population in 2021-23 were considered either moderately or severely food insecure, modestly lower than the 32.2% estimate for 2014-16. However, for context, the South Asian nations of Afghanistan, Nepal, Pakistan, and Sri Lanka all saw substantial increases in these measures over the same period. The Government of Bangladesh updated their policy guiding government action in these areas from the National Food Policy (2006) to the National Nutrition Policy (2015) through to the National Food and Nutrition Security Policy (NFNSP, 2020). The plan of action for the NFNSP recognizes a greater role for the private sector in shaping food security and nutrition outcomes, and aims for nutrition-sensitive food systems.

Since independence in 1971, economic growth rates have steadily risen. The estimated rate of economic growth of 4% year-on-year average for 1990 to 2020 puts the country comfortably in the top 10% of performers globally. The country's "recovery from financial turmoil, increasing trade openness, and more foreign direct investment" (Beyer and Wacker, 2022, p.24) are governance factors associated with its strong performance, led by its extensive ready-made garment industry.

In terms of the contribution of agricultural progress to underpinning structural transformation and dynamic economic growth in recent decades, Emran and Shilpi (2018) highlight some descriptive statistics using three rounds of the Household Income and Expenditure Survey (HIES) from 2000, 2005, and 2010. During the period 2000-2010, rice yields grew by 3.8% annually, accompanied by both an increase in agricultural wages and a reduction in the amount of hired labor. Sen et al (2021) examine the phenomenon of agricultural exits, or more accurately, the de-prioritization of agriculture in the economic life of rural Bangladesh. They find that non-farm orientation increased over 2000-2013, and that household members are increasingly engaged in salaried work. The implication is that structural transformation is not entirely driven by mass permanent migration to cities, but rather that rural areas, particularly peri-urban rural areas, are changing rapidly.

Aquaculture has boomed in Asia, and Bangladesh in particular, since 2000. This growth is driven by strong domestic demand and underwritten by technological innovations and a major deepening in the capitalization of the value chain at all levels (Hernandez et al, 2018). The sector's importance is reflected in policy instruments such as the National Aquaculture Development Strategy and Action Plan of Bangladesh (2013 – 2020). In Bangladesh, most aquaculture production is destined for domestic consumption, particularly by urban dwellers who consume aquaculture products at higher rates per capita than those in rural areas (Toufique and Belton, 2014). Commercial aquaculture – operations where produce is sold – now dwarfs subsistence fish farming. Hernandez et al (2018) find a 207% growth in hatcheries over ten years, far outstripping the growth in the number of fish farmers (63% increase) or total output (117% increase). As the

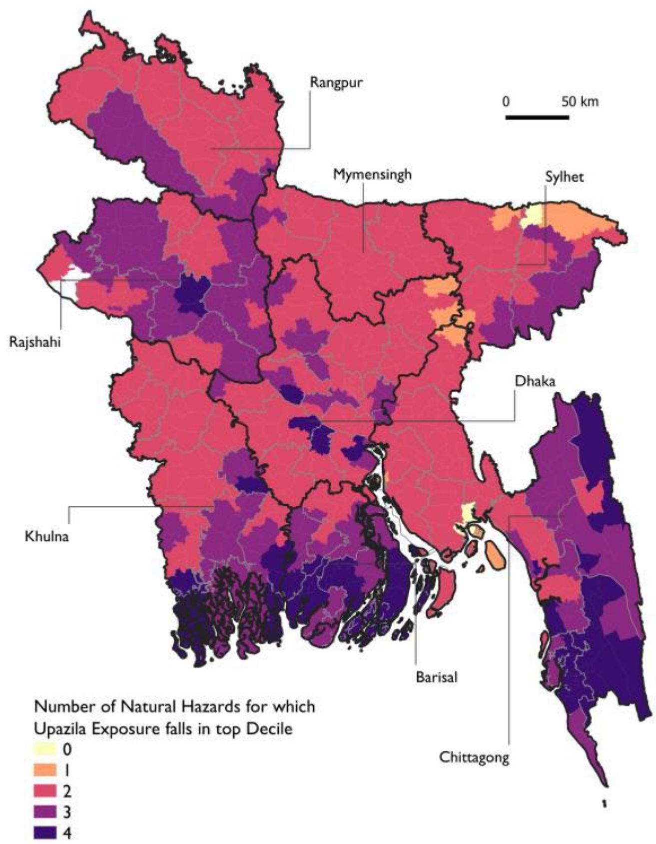
[4] https://data.worldbank.org/.

authors note, this trend strongly suggests a major "shift to purchased seed" (p.461), providing opportunities for technological change through new, improved fish strains. Over the same period, the number of feed mills jumped from around 8 in 2004 to approximately 100 by 2014, and the number of feed dealers approximately doubled.

2.3 Existing Hazards and Vulnerability to Climate Change

Agricultural development in Bangladesh faces multiple, compounded climate-related hazards. These include river floods, coastal floods, tropical cyclones, drought, heat stress, landslides, and air pollution. Figure 3 shows the extent to which any given upazila (subdistrict) is exposed varies across the country, but from a global perspective, Bangladesh is high on every list in terms of vulnerability to the projected temperature and sea level rises over the coming decades. Climate change adaptation has thus been an important framing concept for agricultural research in Bangladesh since at least 2011.

Figure 3: Natural hazard co-occurrence by upazila



Note: The color-coding indicates how many out of seven natural hazards – riverine floods, coastal floods, heat stress, drought, tropical cyclones, landslides, and air pollution – each upazila ranks in the highest decile for exposure to.

Source: United Nations Office for Coordination of Humanitarian Affairs (2020), in World Bank Country Climate and Development Report (2022).

3. Methods and Data

3.1 Identifying CGIAR-Related Innovations

Before collecting data, we produced an extensive stocktake of CGIAR activity in Bangladesh. This exercise delineated the scope of CGIAR Research Initiatives in the country from 1970-2022 and documented pertinent information to aid in prioritizing data collection for CGIAR-related developments. Stocktaking involves three interrelated phases: desk-based research, interviews with stakeholders, and review/consultation. We retrieved information from the CGIAR Results Dashboard for 2017-2021[5], and from the updated 2022 version, which aims to track real-time progress to 2030[6]. We reviewed reports from the CGIAR Research Programs (CRPs) that ran from 2011 to 2021, Annual Reports from the Challenge Programs, as well as bilateral/center-specific project reports. The goal was to construct the universe of CGIAR-related innovations from the past two decades, as well as record claims of policy influence. In addition, 15 interviews were conducted with impact assessment focal points, country representatives, CGIAR, and National Agricultural Research System (NARS) scientists.

Following the completion of an initial draft, we conducted a consultation workshop in Dhaka on 10-11 July 2023, with stakeholders from ministries, National Agricultural Research System (NARS) scientists and CGIAR researchers, and management. The primary objectives were to gather feedback about the stocktake, to identify the priority innovations therein, and to discuss possible data sources for supporting our understanding of technology dissemination and adoption. This resulted in a longlist of 64 innovations, from which we prioritized 46 innovations for data collection in the BIHS. These form the basis of this report. We also collect 61 examples of possible policy influence that we include in the stocktake for future investigation, but that are not suited for interrogation through a household survey. The full stocktake table is posted here, and we include some example entries in Section 4.

3.2 Bangladesh Integrated Household Survey

Following the 2023 consultation workshop, SPIA determined that the best course of action for data collection was to commission a new survey wave of the Bangladesh Integrated Household Survey (BIHS). The BIHS is a nationally representative panel dataset. Three previous survey waves were implemented in 2011-12, 2015, and in 2018-19, designed by the Bangladesh Office of the International Food Policy Research Institute (IFPRI) and implemented by a contracted survey company, Data Analysis and Technical Assistance (DATA). SPIA approached IFPRI about the possibility of carrying out an independently managed wave of the BIHS, and an agreement was reached in late 2023. For BIHS Wave 4, SPIA would be responsible for all aspects of the design and analysis, but would consult with IFPRI on design issues. DATA would remain the survey company, allowing for continuity for the surveyed households.

[5] https://www.cgiar.org/food-security-impact/results-dashboard-2017-2021/.

[6] https://www.cgiar.org/food-security-impact/results-dashboard/.

3.2.1 Sampling Villages and Households

The survey follows a stratified sample design selected in two stages using the sampling frame developed from the community series of the population census 2001. As there were seven divisions in Bangladesh when the first round took place, each of them formed a separate stratum[7]. At the first stage, 275 villages (our Primary Sampling Units - PSUs) were selected with probability proportional to the number of households in the village. The distribution of villages per division is listed in Table 1.

Table 1: BIHS sample villages per division

Division	Number of sample villages
Barisal	21
Chittagong	48
Dhaka	87
Khulna	27
Rajshahi	29
Rangpur	27
Sylhet	36
Total	**275**

In the second sampling stage, IFPRI researchers used a linear systematic sampling[8] scheme to select 20 households from each cluster with an equal probability. Thus, the total sample size for the first BIHS round in 2011/12 was 5,500 households. In subsequent rounds, the original households may have split (and some have attrited). The BIHS follows both the original and the split households. The measure of village size that was originally used for selecting the PSUs is the total number of households as of the 2001 population census. The current value of this size measure could have changed significantly; therefore, we updated the number of households at the selected PSU level. For the SPIA BIHS 2024 round, we use the population census of 2022.

Survey weights should not vary widely within a division/stratum, as a wide variation of weights within a division/stratum could unnecessarily increase the variances of the estimates. Base weight is the inverse of the selection probability of an ultimate sampling unit (household). To ensure similar or uniform weight within a division/stratum, Table 2 illustrates the procedure of computing sampling weights for the national survey. The final weight is calculated by dividing the predicted number of households in 2024 by the number of observations in 2024 for each division.

[7] The Mymensingh division was only officially formed as being distinct from the Dhaka division in 2015, so the BIHS surveys are not statistically representative of this division. Households in the territory of the current Mymensingh division are included in the sample but form part of the Dhaka division sample.

[8] Linear systematic sampling is a method where samples aren't repeated at the end, and 'n' units are selected to be a part of a sample having 'N' population units. Here, a skip pattern is created following a linear path. The selection process follows a predetermined sequence, such as selecting every 5th member, then every 7th member, then every 9th member, and so on.

Table 2: Household weight calculation for SPIA-BIHS 2024

Division	Total households in 2001	Total households in 2022 (per 2022 census)	Growth rate	Predicted household number in 2024	Number of observations in 2024	Adjusted final weight of SPIA-BIHS round
Barisal	1,410,100	1,663,967	0.79%	1,677,136	419	4,002.71
Chittagong	3,326,980	4,922,971	1.88%	5,015,693	991	5,061.24
Dhaka	5,357,120	8,408,048	2.17%	8,590,477	1670	5,144
Khulna	2,468,280	3,383,245	1.51%	3,434,428	551	6,233.08
Rajshahi	2,972,460	4,127,351	1.58%	4,192,371	613	6,839.11
Rangpur	2,690,360	3,530,386	1.30%	3,576,365	555	6,443.9
Sylhet	1,209,260	1,783,477	1.87%	1,816,783	755	2,406.34

Notes: The figures in Columns 2 and 3 are taken from the census data of the Bangladesh Bureau of Statistics. The total number of households in 2001 and 2022 is the village-level population for each division. The growth rate is the yearly growth rate calculated from the figures in Columns 2 and 3. The predicted household number is calculated by multiplying the total number of households in 2022 by the growth rate. The adjusted final weight is calculated by dividing the predicted household number by the number of observations in 2024.

3.2.2 Attrition

The 5,503 original households from the 2011/12 Wave are considered for attrition calculations. For split households (those in which members have left since the prior wave), if at least one of the newly created split households consented and completed a survey, the original household is considered not to have been subject to attrition. For the period 2015-2018, there was an anomaly: 92 original households (of which five had split, thus 97 households in total) were not surveyed successfully in 2015 but were surveyed successfully in 2018. We have not considered these 92 households as having been subject to attrition. The attrition for each wave is calculated based on the number of original panel households in the previous round, and the percentages are as follows: BIHS 2015 =2.74, BIHS 2018-19= 4.37, and SPIA-BIHS 2024 = 5.43.

3.2.3 Overall Data Collection Approach

BIHS Wave 4 followed the same sample households from Wave 3. A novel feature of Wave 4 was the collection of leaf samples from rice paddy during the Boro season[9]. To accommodate the additional survey burden of SPIA's specific interests in agricultural innovations, we administered a shorter version of the main BIHS questionnaire compared to prior rounds. For example, the sub-module pertaining to land preparation, fertilizer and pesticide use, and the sub-module on input costs and returns were only asked for one randomly selected plot for all agricultural households. We added necessary questions for assessing the adoption of the relevant CGIAR innovations from the stocktake as outlined in the following sections.

All Boro-cultivating households were visited, and leaf samples were taken for DNA fingerprinting to identify the varieties farmers are cultivating. We employed probability proportional to size (PPS) sampling to randomly select a plot from all Boro plots cultivated by the household, and questions were asked for that plot. This was done to ensure that there was no bias in selecting

9 The Boro season is one of the main rice-growing seasons in Bangladesh and parts of South Asia. It refers to the period when Boro rice is cultivated, typically from January to April/May.

the plot based on enumerator preference, owing to the distance of different plots under operation by the household. For households cultivating Boro paddy, the sub-modules on DNA fingerprinting, on land preparation, fertilizer and pesticide use, and one on input costs and returns were asked for the same randomly selected plot. If an agricultural household had no rice plots in Boro, then we took the total agricultural land area in the past four seasons and randomly selected a plot based on PPS to be used as the focal plot for our sub-modules on land preparation, fertilizer, pesticide use, and input costs and returns. We then took the plot boundaries using GPS for the selected Boro paddy fields to obtain an accurate estimate of the plot area.

SPIA was an active partner during survey implementation. SPIA instituted a process of high-frequency checks and audited data quality using random audio audits of segments of the interviews. Resurveys were carried out when data collection was found to be insufficiently rigorous. Further details can be found in Appendix A.

3.3 Measurement Approaches

3.3.1 Varietal Adoption

During the July 2023 stakeholder consultation, we discussed measurement priorities, identifying groups of CGIAR-related innovations with the potential for large-scale adoption. Within the crop germplasm improvement group, rice varieties were identified as the top priority for DNA fingerprinting. In Bangladesh, rice is the principal crop and is grown during three distinct seasons: Boro (January to April/May - also known as the Rabi season); Aus (March- June); and Aman (JuneJuly to October/November). Most Aus and Aman rice is rainfed or uses limited supplemental irrigation, whereas Boro rice requires consistent irrigation due to minimal rainfall during the Rabi period.

An earlier study by Kretzschmar et al (2018) applied DNA fingerprinting to varietal identification in the Aman rice season. To complement this study, we decided instead to focus our DNA fingerprinting efforts on the Boro season. This meant that for Aman varietal adoption (and the relatively minor Aus rice season), and varietal adoption in wheat, lentil, maize, potato, and sweetpotato, we would rely on farmer self-reported data. The lack of a nationally representative DNA fingerprinting effort on estimating the adoption of these other non-rice crops reflects their much less widespread cultivation compared to rice. Rice is cultivated by around 80% of agricultural households in our survey, whereas the value for the non-rice crops ranges from 1-5%. There is also evidence to suggest that farmer self-reported data for lentil is quite accurate, given the small number of varieties used by farmers (Yigezu et al., 2022) obviating the need for the more expensive and complicated DNA fingerprinting data collection.

Details of the rice varietal releases for all seasons, including the complete set of reference materials used for DNA fingerprinting in the Boro season, are detailed in Appendix B. The Bangladesh Rice Research Institute (BRRI) has released 115 rice varieties in total, while the Bangladesh Institute of Nuclear Agriculture (BINA) has released 27. The relationship between the International Rice Research Institute (IRRI) and BRRI has been strong for several decades (IRRI, n.d.), so we have 115 varieties that are CGIAR-related. Most of these varieties exhibit one or more of three key traits: higher yield, stress tolerance (drought, flood, salt), and higher levels of micronutrients due to biofortification. The prior BIHS survey wave (Wave 3, 2018) has self-reported data from farmers on rice varieties up to the BRRI Hybrid 4 and BRRI Dhan 69 series. We expanded the varietal adoption options to include varieties released since 2018, up to BRRI Hybrid Dhan 8 and BRRI Dhan 106.

3.3.1.1 Field Protocol for Rice Leaf Collection

To allow for consistent interpretation, we designed the protocol for leaf collection using the approach developed for Vietnam (Kosmowski et al., 2024). SPIA procured all necessary supplies for collecting leaf samples, including rolls of adhesive barcode labels, 50 ml plastic pots, silica gel, leaf punches, alcohol-based wipes, and sample-holding bags. To assemble the kit for enumerators, we developed 3,000 unique barcodes for labeling the plastic containers into which the leaf samples would be deposited. Each 50 ml plastic pot was filled with 21 grams of dried silica gel in packets. The silica gel ensures the correct drying of the punched leaves. SPIA conducted two on-farm pilots of the plant tissue collection modules in January 2024 to help ensure smooth fieldwork operations.

Enumerators identified the plot for sample collection based on the random sampling protocol programmed into SurveyCTO – a comprehensive data collection platform used for designing, deploying, and managing surveys. Enumerators were instructed to take leaf samples from healthy plants within the plot, meaning that there were no obvious signs of disease on the leaves. This was to ensure that the tissue had a high DNA concentration. Enumerators were instructed that sampled plants should be away from the edge of the plot, preferably taken by walking three steps into the interior of the field. The next step was to excise a young, growing leaf and fold it three times to create four layers of leaf tissue. The enumerator then placed the front side of the leaf punch and the leaf within the plastic pot for the sample and punched through all four layers, thereby creating four leaf discs and ensuring that all the leaf discs fall inside the pot. After punching, the enumerators sealed the pot tightly and immediately scanned the barcode when prompted by the SurveyCTO CAPI application.

The enumerators then used alcohol wipes to thoroughly clean the leaf punch before beginning another sample collection. 20% of the rice plots were selected for technical replication, meaning that the process was repeated for a second plant, resulting in two distinct individual samples for each plot. Once the samples were taken and scanned, they were shipped at an ambient temperature and stored in IRRI's Bangladesh office.

Following the completion of fieldwork, SPIA recruited research assistants to work at the IRRI Bangladesh office to transfer the leaf tissue samples from the barcoded pots to 96-well plates used by genotyping laboratories. The research assistants scanned the barcodes and ensured correct placement of the material in the sample wells using the Coordinate app.[10] SPIA researchers then sealed the filled 96-well plates using heat-sealing foil and prepared them for shipping to the genotyping laboratory in October 2024.

3.3.1.2 Reference Library Compilation

SPIA consulted with the Genetic Resources and Seed Division of BRRI and the Plant Breeding Division of BINA to construct the rice varietal reference library. Both supplied 5 mg of breeders' rice seed, with 114 BRRI varieties and 15 BINA cultivars requested. This reference material was

[10] https://excellenceinbreeding.org/toolbox/tools/coordinate.

specified to be healthy rice seed devoid of pests and fungi. We received reference samples of 99 rice varieties from BRRI and 11 from BINA and placed each variety in an airtight plastic container. The discrepancy between the 129 varieties requested and the size of our final reference library (110) is explained by the fact that BRRI and BINA could only provide us with the varieties that they had in their stores, the remaining 19 being unavailable. The full list is provided in Appendix B.

The reference rice seeds were dried for 24 hours then were meticulously peeled, preserved, and their plastic containers labeled with barcodes . Before grinding, all the viable seeds from BRRI and BINA underwent additional screening for pests (weevils in particular). We employed a small sample grinder to pulverize the rice seeds and meticulously disinfect the apparatus with ethanol between reference samples to prevent cross-contamination. Rice flour from each reference sample was placed into the 96-well plates, securely sealed, and their locations systematically documented using the Coordinate application. Each well in the plates was given 0.66 ml of rice flour. The final, packaged reference library received a phytosanitary certificate from the Plant Protection Division of the Department of Agricultural Extension before it was shipped to AgriPlex Genomics in the United States of America for processing alongside the leaf samples obtained through on-farm sampling in the BIHS.

3.3.1.3 Sample Genotyping

Reference and field samples that were shipped to AgriPlex Genomics were received in good condition[11] and subjected to DNA extraction. The field samples comprised 2,202 leaf tissue samples, while the submitted references comprised 110 seed samples ground to a fine flour. These were genotyped on the PlexSeqTM platform, using the IRRI Rice Custom Amplicon Version 4 SNP panel (Arbelaez et al., 2019) – a mid-density panel with 1,024 markers (AgriPlex Genomics, Cleveland, OH, USA).

3.3.1.4 Bioinformatic Analysis

After genotyping, Agriplex Genomics delivered the genotype data in score format, indicating the type of single-nucleotide base present at each marker position. Bioinformatic analysis entailed comparing the similarity between the samples and references at each marker position and generating a genetic distance matrix using the Identity by State (IBS) method. This enabled the identification of samples that were closely related to the references. A detailed description of the bioinformatic analysis carried out on Boro rice varieties is provided in Appendix C.

3.3.1.5 Crop Varietal Adoption: Non-Rice Crops

In partnership with the various auspices of the Bangladesh Agricultural Research Council (BARC), CGIAR has collaborated on crop germplasm leading to varietal releases for wheat, maize, groundnut, lentil, potato, and sweetpotato. Details of those varieties are provided in Appendices D to J. Farmers self-report varietal adoption by variety name, following the results of Yigezu et al (2022).

[11] Sample processing was delayed by approximately two months. Initially, the procured plates and seals did not fit together tightly. SPIA then procured heat-sealing foil and shipped it to Bangladesh for the team to use. In the process of heat-sealing, some of the plasticware on the plates melted slightly around the top, confounding the robotics used by AgriPlex and requiring their technician to remove some excess plastic with a razor in a painstaking manual process. The samples were not affected by the process as we had been very conservative with our protocol, ensuring each sample was desiccated individually in their own pots. Thus, DNA recovery rate from this exercise remained high.

3.3.1.6 Aquaculture Innovations

Our stocktake featured 14 aquaculture innovations, including genetically improved strains, polyculture systems that incorporate nutrient-rich small fish, community-managed fisheries, and digital platforms that enhance market linkages along the aquaculture value chain. Of these, we identified eight that have been successfully scaled or have the potential for large-scale adoption to be the focus of data collection.

Genetically improved rohu carp and Genetically Improved Farmed Tilapia (GIFT) have a system of hatcheries that multiply these strains to make them widely available to aquaculture farmers. To assess the reach of these genetic advancements, we rely on self-reported farmer data on fish strains harvested from each pond. We also collected data on fingerling sources and hatcheries. Additionally, we conducted interviews with the most prominent fish dealer in each village's largest market, as well as with hatchery and nursery managers. To estimate the adoption of WorldFish-promoted improved pond management practices, we also gathered detailed data on practices at a pond level.

In capture fisheries, WorldFish's efforts in Bangladesh have primarily focused on conserving, restoring, and managing Hilsa populations, particularly through Phases One and Two of the Enhanced Coastal Fisheries (ECOFISH) project. To assess the reach and sustainability of these initiatives, four years after project completion, our survey includes questions on awareness of fishing bans, regulations governing sanctuary fishing, the presence of fish guards, and compensation mechanisms for livelihood disruptions caused by these restrictions.

Small indigenous fish species (SIS), such as Mola, are rich in micronutrients and can be regularly harvested and consumed. WorldFish researches and promotes the use of carp-Mola polyculture systems with an emphasis on household nutritional outcomes. To capture the adoption, the household survey includes a question on whether SIS are cultivated alongside carp, ensuring continuity with previous rounds of the BIHS.

To evaluate the integration of digital platforms into the aquaculture sector, our survey includes a dedicated section on application usage, adoption timelines, and perceived business benefits. These insights will help assess how digital technologies enhance market connectivity and whether they contribute to improved efficiency and profitability for fish farmers.

3.3.1.7 Natural Resource Management Innovations

CGIAR research projects have addressed a range of natural resource issues in Bangladesh over the past two decades. The stocktake examined 13 Natural Resource Management (NRM) innovations either arising from this body of research or promoted by CGIAR researchers while carrying out research for development interventions. Among these, Alternate Wetting and Drying (AWD) was identified as having been promoted at scale. AWD irrigation technology was introduced in Bangladesh in 2004 as an IRRI initiative, with the first trials conducted in 2005 by the Bangladesh Rice Research Institute (BRRI) in collaboration with CGIAR. In AWD, irrigation water is applied a few days after the ponded water disappears, creating alternating flooded and non-flooded conditions. The non-flooded period can range from 1 to over 10 days, depending on factors such as soil type, weather, and crop growth stage. AWD is of interest to CGIAR primarily from the perspective of its potential to reduce greenhouse gas emissions from rice production, as interruption to continuous flooding limits the generation of methane-producing bacteria. Farmers will interpret and implement AWD differently, so it is fair to consider it as a management principle rather than a specific practice (Stevenson et al, 2019).

IRRI and partners found a practical way to implement AWD safely by using a perforated PVC pipe to monitor water depth below the surface of the soil. Irrigation water can then be applied when the water level drops to 15 cm below the soil surface. This is a good rule of thumb as a safe limit, as below this, the standing rice crop could suffer yield losses. It is then reflooded to a depth of 5 cm above the soil surface. During the critical flowering stage, the field should remain flooded with periodic topping up, while during the grain-filling and ripening stages, the water level can again be allowed to drop to 15 cm below the surface before re-irrigation.

To estimate AWD adoption, we employed a multi-pronged approach. First, we asked farmers whether they were familiar with the practice. Second, we inquired whether they had adopted it. Third, we gathered detailed information on the frequency and duration of drying their rice plots. These estimates help assess whether farmers are practicing AWD even if they do not use the PVC pipe. Additionally, we asked about decision-making processes related to irrigation, including who makes these decisions, when they are made, and whether farmers participate in village-level irrigation committees. Finally, we mapped plot boundaries using GPS to attempt adoption estimation through remote sensing.

Beyond AWD, we designed survey questions to assess the adoption of various NRM-related mobile apps developed and disseminated through CGIAR Research Programs. These include Right Haat, Digital Feed Supply, Program for Advanced Numerical Irrigation, Rice Crop Manager, and Macher Gari. To understand broader app usage trends, we also inquired about the use of popular consumer apps in Bangladesh, such as Bkash, Nagad, and Rocket, to determine whether households engage with mobile applications in other areas of their lives. Additionally, we asked about the primary purposes of app usage and whether these technologies have contributed to improving their businesses.

CGIAR has also worked in the sphere of index-based insurance through WorldFish. The first activities relating to index-based insurance in Bangladesh pertain to WorldFish's role in the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). We asked households about their knowledge of crop and livestock insurance and their participation in index-based flood insurance schemes.

3.3.1.8 Farm Mechanization

The Government of Bangladesh has consistently promoted mechanization as a means for fostering agricultural intensification towards achieving agricultural self-sufficiency (Mainuddin & Kirby, 2015). SPIA's consultation meetings held in Dhaka in 2023 identified several priority innovations regarding mechanization that CGIAR has played a role in promoting, particularly through fostering both the rental market for mechanization services and the supporting services that underpin that offer. Focus innovations for the promotion of specific business models, particularly in the Feed the Future[12] zone under the Cereal Systems Initiative in South Asia (CSISA)[13] include axial flow pumps (AFPs), power tillers, and mechanical reapers. The survey

[12] Feed the Future is a USAID Initiative that aims to reduce global hunger and poverty by improving agriculture, nutrition, and resilience in developing countries. https://www.feedthefuture.org/.

[13] https://csisa.org/tag/feed-the-future/.

examines usage, ownership, participation in rental markets, associated costs, and year of purchase/sale. Furthermore, it specifically investigates the reasons behind farmers' decisions to adopt or discontinue a particular technology and whether they integrate these technologies with other equipment. To ensure accurate responses, a visual aid comprised of images of different machines was incorporated into the survey operation. The visual aid helped farmers correctly identify the technologies they used, helping to reduce measurement error.

3.4 Data Analysis

3.4.1 Estimating Reach

In Section 6, we present the adoption rates for key CGIAR innovations in both agriculture and aquaculture, based on data from the BIHS sample of rural households. Adoption statistics are reported at the household, village, and division levels. All figures incorporate sampling weights to ensure national-level representativeness. To capture the extent of CGIAR's direct contribution, we organize innovations into two distinct categories for the purposes of estimating their reach: those that make it into a conservative lower-bound estimate and those that are only in an upper-bound estimate.

For each innovation discussed, we draw on information from our stocktake to determine whether its dissemination can be attributed to CGIAR. For example, in the case of rice germplasm, we identified varieties that are CGIAR-related through parentage and used DNA fingerprinting of Boro rice plots to estimate their adoption. This conservative definition of CGIAR's contribution, based on embodied technologies – those in which the research contribution is captured in a product used by farmers – gives us the lower bound of CGIAR's contribution. For other innovations, such as Alternate Wetting and Drying (AWD) and axial flow pumps (AFPs), we acknowledge that CGIAR had a role in their design and/or dissemination, but is only one of several actors who have promoted these innovations. It is important to clarify that by AWD, we refer to farmers who reported drying their fields at least once for a period lasting five days. This differs from the International Rice Research Institute (IRRI)-defined AWD method, which involves the use of a 'field water tube' or plastic pipe to monitor water depth. Given that adoption may not be solely attributable to CGIAR's efforts, we classify these innovations under the upper-bound category to reflect a broader, shared contribution.

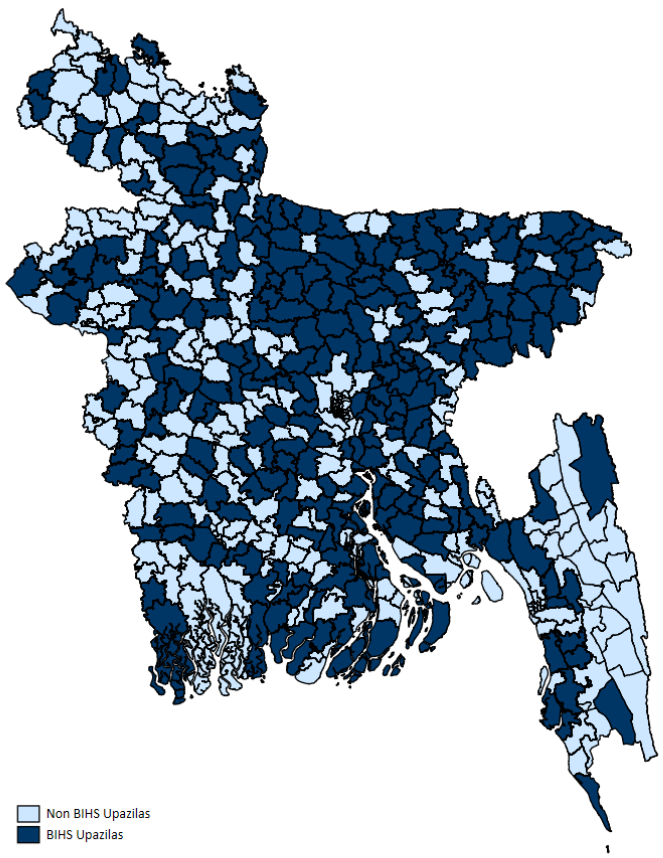
As outlined in Section 3.2, BIHS weights were constructed based on the 2022 population census, enabling household-level statistics to align with the rural household population of Bangladesh and thus providing accurate estimates of reach. BIHS's representativeness is depicted in Figure 4 where we can see the spread of the *upazila* (sub-districts) across the country. We are depicting this map at the sub-district level because this is the most granular level of location data we can disclose as per the Institutional Review Board (IRB) protocols. Within these 257 sub-districts, BIHS covers 275 villages.

DNA fingerprinting data for rice were collected for 98.3% of BIHS households cultivating rice during the 2024 Boro season.[14] Together, rural households across all surveyed regions represent 93% of Bangladesh's rural population, offering a reliable approximation of national adoption rates and the

[14] The households without leaf samples were identified as Boro households during the resurveyed sub-sample period described in Appendix A, when the Boro season had already ended.

number of households using CGIAR germplasm for rice. For CGIAR innovations measured in the 2012, 2015, 2018, and 2024 BIHS surveys, we report nationally representative changes in adoption over the past 12 years. The consistent survey interval and extended timeframe allow us to examine both agricultural trends (Section 5) and changes in adoption rates (Section 6), though only for the subset of innovations that had already been measured in prior survey rounds. While BIHS datasets for 2012, 2015, and 2018 are publicly accessible, BIHS 2024 will be available with the release of this report. For each innovation, the proportion of adopters was calculated over the population deemed most relevant for the innovation's application.

Figure 4: Distribution of BIHS upazilas (sub-districts)



Note: Total number of upazilas = 257

3.4.2 Correlates of Adoption

A set of variables was selected to describe the plot-level and household-level characteristics of households adopting CGIAR technologies (reported in Section 7). Innovations adopted by fewer than 5% of households were omitted from this analysis. Detailed definitions of each variable are available in Appendix O. Continuous variables were standardized, and an asset index was created based on the first principal component of all household assets that the household owned, as reported in BIHS 2018. To assess the impact of the chosen variables on the adoption rate, a multivariate regression model was constructed with village-level clustering to reflect clustered sampling at the village level.

4. CGIAR-Related Innovations in Bangladesh

Here we describe the CGIAR-related innovations for which adoption data are collected. We first defined the universe of CGIAR research through a desk review of multiple sources and interviews with CGIAR researchers. This stocktake methodology aims to comprehensively account for all CGIAR research activities over the last two decades. We define innovation in CGIAR research as any new technology, practice, decision-support tool, or policy/institutional design that required research engagement for its development and/or dissemination and was previously unknown to its users. CGIAR-related initiatives for developing and/or disseminating these innovations encompass CGIAR Research Programs (CRPs) as well as bilaterally funded projects, whose research outputs contributed to advancing or spreading the innovation. We further categorized innovations across five primary domains of CGIAR research: crop varietal enhancement, aquaculture and fisheries, natural resource management, mechanization, and cross-cutting research.

We used discussions with CGIAR scientists and government partners to identify innovations that were thought to be adopted on a large scale. Using the framework summarized in Table 3, for each innovation (Column 1), we began by describing the CGIAR-related initiatives responsible for its development and/or dissemination (Column 2), followed by a description of the innovation (Column 3), whether it has an observable feature that would allow us to measure adoption in a survey setting (Column 4), the scope and geographic context of activities to promote the innovation (Column 5), and prior evidence that would support the claim that the innovation has been adopted at scale (Column 6). Table 3 shows an excerpt of the stocktake for two innovations as examples – Genetically Improved Farmed Tilapia (GIFT) and axial flow pumps (AFPs).

Table 3: Snapshot of stocktake exercise

Innovation	CGIAR-related efforts for development and/or dissemination	Description	Observable feature	Scale and location	Evidence of adoption
Genetically Improved Farmed Tilapia (GIFT)	Breeding efforts by WorldFish with BFRI since 1994. Every year (starting in 2001), a new generation of GIFT is produced by WorldFish. Specific projects to promote or develop include: 1. Scaling Systems and Partnerships for Accelerating the Adoption of Improved tilapia Strains Small-Scale Fish Farmers (SPAITS) Project 2. Quality broodstock and Tilapia Breeding Nucleus (TBN) genetic selection program (2005 – 2015)	The current generation is G17 with much higher weight gain. Dissemination years: 1994, 1996, 1997, 2005, 2008, 2009, and 2012 1. Development of communication products and dissemination – posters, factsheets, and training manuals in Bangla; Training of 500 tilapia farmers, training of tilapia hatchery owners, and other actors	Household has farmed hatchery-produced GIFT-derived tilapia. Identification using fish seed source (current study) or DNA fingerprinting (for future rounds)	1. Rangpur, Khulna, and Mymensingh Divisions.	1. In 2016, 2,360,000 improved GIFT fry were produced and distributed/sold from these TBNs among 47 tilapia hatcheries in the Rangpur, Jessore, Narail, Fardidpur, Khulna and Barisal regions
Axial Flow Pump (AFP)	CSISA-MI: CIMMYT and International Development Enterprises (iDE), BARI and BARC (2013-18)	Developed Bangladeshi prototype AFPs and compared hydraulic, energetic, and economic performance of AFPs and conventional centrifugal pumps (CEN). Supported the development of the service provider/rental market for AFPs	Household has used an AFP on at least one plot. Visual-aid protocol to be used.	Southern Bangladesh (Khulna, Patuakhali, Bagerhat). Approx. 1,017 AFP service providers developed.	47,808 farmers reported to have been reached through the AFP service providers.

Acronyms = Bangladesh Agricultural Research Council (BARC), Bangladesh Agricultural Research Institute (BARI), Bangladesh Fisheries Research Institute (BFRI), Cereal Systems Initiative for South Asia - Mechanization and Irrigation (CSISA-MI), International Maize and Wheat Improvement Center (CIMMYT), Tilapia Breeding Nucleus (TBN).

The stocktake comprises 64 CGIAR-related innovations and 61 cases where research is considered to have influenced the policies of government and/or development institutions. A common route for claimed CGIAR policy influence is via the expansion of government pilot programs following CGIAR-led impact evaluations. In other cases, CGIAR expertise has shaped policy frameworks at regional or national levels.

From the 64 CGIAR-related innovations, we identified several that we considered high priority and discussed them in detail at the consultation workshop in Dhaka in July 2023. We then reduced the list to 46 innovations that were thought to be widely adopted and that would be the focus of the data collection activities in the BIHS. Some were already part of the BIHS, others required minimal adjustments, and a few needed specialized measurement protocols. Several potential DNA fingerprinting study opportunities were omitted because relevant data had already been collected in another recent CGIAR survey, namely Yigezu et al. (2022) for lentil, Gade et al. (2021) for wheat, and Kretzschmar et al. (2018) for Aman rice.

The balance of 18 innovations were either not considered likely to have been adopted at scale or were too challenging to meaningfully collect data as they lacked a clear CGIAR 'signature' that could be observed in a survey. This section outlines the innovations that met the inclusion criteria for each core domain. Additionally, we highlight excluded technologies when discussing future research priorities.

4.1 Crop Germplasm Improvement

The largest group of CGIAR-related innovations we identified fall into this category. They include rice (5 innovations), wheat (3), maize (3), potato (4), sweetpotato (5), lentil (3), groundnut (2), and chickpea (4). To describe the CGIAR contribution to breeding varieties, we use innovation to refer to a specific trait or a cluster of traits. Therefore, each innovation may have a single variety associated with it, or may have several, as outlined in the following sub-sections.

4.1.1 Rice

Following the initial decades of progress in rice improvement during the Green Revolution era, rice breeding in Bangladesh in the 1990s turned towards disease- and insect-tolerant/resistant varieties using IRRI parent lines, introducing 31 such varieties. There has been considerable work in developing stress-tolerant varieties in this century (particularly for flood, salinity, and drought). Sixteen salt-tolerant varieties have been developed by the Bangladesh Rice Research Institute (BRRI) (12) and the Bangladesh Institute of Nuclear Agriculture (BINA) (4). BRRI has also released eight drought-tolerant varieties. Since 2010, BRRI (4) and BINA (3) have released seven submergence-tolerant varieties with the sub-1 gene. In 2004, HarvestPlus began its efforts to address to develop biofortification of rice in collaboration with BRRI and the International Rice Research Institute (IRRI). In 2013, BRRI succeeded in developing and releasing the first-ever biofortified-zinc rice variety in the world, BRRI Dhan 62, through HarvestPlus support. Since then, ten such zinc-enriched varieties have been released. In addition, short-duration (13) and lodging-tolerant (11) rice varieties have been released by BRRI and BINA. In total, 139 rice varieties have been released (Table 4), designed for one or more of Bangladesh's growing seasons – Boro, Aus, and Aman. The complete list of varieties is provided in Appendix B.

Table 4: Number of rice varieties released, by germplasm origin, 1970-2022

Germplasm origin	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019	2020-2023	Total
Pure line selection BRRI/BINA	1	1	4	1	16	1	**24**
IRRI/HarvestPlus	9	13	15	14	49	15	**115**
Total	**10**	**14**	**19**	**15**	**65**	**16**	**139**

Acronyms = Bangladesh Rice Research Institute (BRRI), Bangladesh Institute of Nuclear Agriculture (BINA), International Rice Research Institute.

4.1.2 Wheat

In the early 2000s, wheat breeding addressed stress (intensifying heat and salinity) and disease problems (leaf blight and leaf rust tolerance; Ug 99-tolerance) in the Bangladeshi wheat crop. In the latter part of the 2010s, zinc-enriched wheat varieties were introduced. Leaf-blight- and leaf-rust-tolerant varieties were introduced through five varieties (*Gourob*, 1998; *Satabdi* (also known as BARI Gom 21), 2000; *Bijoy*, 2005; BARI Gom 28, 2012; and BARI Gom 31, 2017). Salt-tolerant varieties were developed jointly by BARI's Wheat Research Center (WRC) and the International Maize and Wheat Improvement Center (CIMMYT), leading to the release of BARI Gom 25 in 2010. Heat- and blast-tolerant varieties were introduced by crossing three introduced wheat varieties. Four varietal releases meet this description: *Sufi* / BARI Gom 22, 2005; Prodip/ BARI Gom 24, 2005; BARI Gom 26, 2010; BARI Gom 30, 2014.

Ug99, the deadly wheat stem rust, was a sustained target for breeding through the partnership between CIMMYT and WRC, as well as being a core theme of the activities under the Cereal Systems Initiative for South Asia (CSISA). Four Ug 99-tolerant wheat varieties were released: BARI Gom 27, 2008; Francolin, 2012; BARI Gom 29, 2014; BARI Gom 31, 2017.

Finally, following a 2016 outbreak of the mysterious wheat blast disease, BARI Gom 33 was released in 2017. This variety is blast-resistant and zinc-enriched. In total, 33 wheat varieties have been released since 1974 (Table 5). The complete list of varieties is provided in Appendix D.

Table 5: Number of wheat varieties released, by germplasm origin, 1990-2019

Germplasm origin	1970-1979	1980-1989	1990-1999	2000-2009	2010-2019	Total
Pure line selection BARI	0	0	0	0	1	**1**
CIMMYT	11	5	3	4	9	**32**
Total	**11**	**5**	**3**	**4**	**10**	**33**

Acronyms = Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA), International Wheat and Maize Improvement Center (CIMMYT).

4.1.3 Maize

The earliest maize work from the 1980s to the early 2000s focused on improved maize hybrids derived from CIMMYT populations, leading to ten varietal releases (Suvra, 1986; Barnali, 1986; BARI Maize 5, 1998; BARI Maize 6, 1998; BARI Maize 7, 2002; BARI Hybrid Maize 2, 2002; BARI Hybrid Maize 6 and 7, 2006; BARI Hybrid Maize 8 and 9, 2007). Aiming to address nutritional outcomes, protein-enriched maize was introduced with the release of BARI Hybrid Maize 3 in 2002 and BARI Hybrid Maize 5 in 2004. Stress-tolerant varieties for heat, drought, and salt have also been released. These include several heat-tolerant varieties developed by the Heat Tolerant Maize for Asia (HTMA) project with BARI and CIMMYT as collaborators, namely BARI Hybrid Maize 14, 2017; BARI Hybrid Maize 15, 2017; and BARI Hybrid Maize 17, 2019. Drought-tolerant varieties were selected from a CIMMYT trial and later single-crossed by BARI researchers, leading to BARI Hybrid Maize 12, 2016, and BARI Hybrid Maize 13, 2016. A salt-tolerant maize hybrid was produced by BARI single crossing a hybrid that had been selected from a CIMMYT trial, namely BARI Hybrid Maize 16, 2016. In total, 25 maize varieties have been released since 1980 (Table 6). The complete list of varieties is provided in Appendix E.

Table 6: Number of maize varieties released, by germplasm origin, 1980-2019

Germplasm origin	1980-1989	1990-1999	2000-2009	2010-2019	Total
Pure line selection BARI	1	1	2	0	**4**
CIMMYT	2	2	11	6	**21**
Total	**3**	**3**	**13**	**6**	**25**

Acronyms = Bangladesh Agricultural Research Institute (BARI), International Wheat and Maize Improvement Center (CIMMYT).

4.1.4 Potato

The International Potato Center (CIP) and the Tuber Crops Research Centre (TCRC) of BARI have worked towards developing improved potato varieties in Bangladesh since the 1990s. Stress-tolerant varieties include heat- and saline-tolerant potatoes. Heat-tolerant potatoes include BARI ALU-01 (HEERA), released in 1990; BARI ALU-12 (Dheera), released in 1993; and BARI ALU-73, released in 2016. Varieties bred for their saline tolerance are BARI ALU -22 (SAIKAT), released in 2004; BARI ALU-79, released in 2017; and BARI ALU-72, released in 2016. Virus- and disease-resistant potatoes were also developed. BARI ALU-81, released in 2019, was bred to be virus-resistant. The Root and Tuber Crops Research and Development Programme for Food Security in the Asia and Pacific Region (2011-15) developed late blight-resistant potatoes: BARI ALU-46, released in 2013, and BARI ALU-53, released in 2014. Potato varieties grown from true potato seeds were released in 1997 (BARI TPS-1 and 2). Finally, table potatoes: BARI ALU-78, released in 2017; BARI ALU-87, released in 2019; BARI ALU-88, released in 2019. In total, 93 potato varieties have been released in Bangladesh since the 1990s (Table 7). The complete list of varieties is provided in Appendix F.

Table 7: Number of potato varieties released, by germplasm origin, 1990-2019

Germplasm origin	1990-1999	2000-2009	2010-2019	Total
Pure line selection TCRC BARI	12	14	51	**77**
CIP	5	1	10	**16**
Total	**17**	**15**	**61**	**93**

Acronyms: Bangladesh Agricultural Research Institute (BARI), International Potato Center (CIP), Tuber Crops Research Centre (TCRC).

4.1.5 Sweetpotato

Orange-fleshed sweetpotato varieties were first introduced to Bangladesh in the 1980s by TCRC BARI, while the 2000s marked the first decade in which varieties with CIP germplasm (BARI SP-6 and 7 in 2004) began being released in Bangladesh (Table 8). The Scaling Up Sweetpotato Through Agriculture and Nutrition (2013-2019) Program introduced the following, orange-fleshed varieties: BARI SP-12 and 13, released in 2013; and BARI SP-14 and 15, released in 2017. Yellow-fleshed sweetpotatoes include BARI SP-8 and 9, released in 2008, and BARI SP 10 and 11, released in 2013. The complete list of varieties is provided in Appendix G.

Table 8: Number of sweetpotato varieties released, by germplasm origin, 1980-2019

Germplasm origin	1980-1989	1990-1999	2000-2009	2010-2019	Total
Pure line selection TCRC BARI	4	1	0	0	**5**
CIP	0	0	4	6	**10**
Total	**4**	**1**	**4**	**6**	**15**

Acronyms: Bangladesh Agricultural Research Institute (BARI), Tuber Crops Research Centre (TCRC), International Potato Center (CIP).

4.1.6 Lentil

The International Center for Agricultural Research in the Dry Areas (ICARDA) has contributed to lentil breeding efforts in Bangladesh with germplasm developed under partnerships with both BARI (the BARI Masur series of varieties) and BINA (the BINA Masur series). Disease-resistant lentils include stemphylium-blight-resistant and rust-, foot-, and root-rot-resistant varieties. Lentils with stemphylium-blight resistance were released, and in later years (from 2010), involving the HarvestPlus program, resulting in BARI Masur 4, 1996; BARI Masur 5, 2006; BARI Masur 6, 2006; BARI Masur 7, 2011; and BARI Masur 8, 2015. BARI Masur 4 to 8 are also micronutrient-enriched (with zinc and/or iron). CGIAR-related lentil varieties with rust-, foot-rot-, and root-rot-resistance are BARI Masur 1, 1991; BARI Masur 2, 1993; BINA Masur 4, 2011; BINA Masur 5, 2011; BINA Masur 6, 2011; and BINA Masur 7, 2013. Finally, a drought-tolerant lentil targeting the North-Western drought-prone districts was released as BINA Masur 10, 2016. In total, 19 lentil varieties have been released since 1990 (Table 9). The complete list of varieties is provided in Appendix H.

Table 9: Number of lentil varieties released, by germplasm origin, 1990-2019

Germplasm origin	1990-1999	2000-2009	2010-2019	Total
Pure line selection BARI/BINA	1	3	3	**7**
ICARDA/HarvestPlus	3	2	7	**12**
Total	**4**	**5**	**10**	**19**

Acronyms: Bangladesh Agricultural Research Institute (BARI), Bangladesh Institute of Nuclear Agriculture (BINA), International Center for Agricultural Research in the Dry Areas (ICARDA).

4.1.7 Groundnut

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has released four short-duration groundnut varieties: BARI Chinabadam-6 released in 1998; BARI Chinabadam-8 released in 2006; BARI Chinabadam-9 released in 2009, and BARI Chinabadam-10 released in 2016. In 2004, they also released one high-yielding groundnut variety: BARI Chinabadam-7. In total, 14 groundnut varieties have been released since 1980 (Table 10). The complete list of varieties is provided in Appendix I.

Table 10: Number of groundnut varieties released, by germplasm origin, 1980-2019

Germplasm origin	1980-1989	1990-1999	2000-2009	2010-2019	Total
Pure line selection BARI	2	1	4	2	**9**
ICRISAT	0	1	3	1	**5**
Total	**2**	**2**	**7**	**3**	**14**

Acronyms: Bangladesh Agricultural Research Institute (BARI), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

4.1.8 Chickpea

BARI and ICRISAT have released improved chickpea varieties that include those that are disease-tolerant and disease-resistant, high-yielding, and stress-tolerant. Improved varieties include BARI Chola-1, released in 1987, and BARI Chola-3, released in 1993. BARI Chola-2, released in 1993, is wilt-disease-tolerant, while BARI Chola-4, released in 1996, is tolerant to Fusarium wilt. BARI Chola-5, released in 1996, is a high-yielding variety. BARI Chola 7-9 varieties, released in 1998, are resistant to Fusarium wilt disease. BARI Chola-10, released in 2017, is heat tolerant. In total, 10 chickpea varieties have been released since 1980 (Table 11). The complete list of varieties is provided in Appendix J.

Table 11: Number of chickpea varieties released, by germplasm origin, 1980-2019

Germplasm origin	1980-1989	1990-1999	2010-2019	Total
Pure line selection BARI	0	0	0	**0**
ICRISAT	1	8	1	**10**
Total	**1**	**8**	**1**	**10**

Acronyms: Bangladesh Agricultural Research Institute (BARI), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

4.2 Aquaculture and Fisheries Improvement

Fish is Bangladesh's second most important food source after rice. It accounts for approximately 60% of the nation's animal protein intake and provides essential micronutrients. Projections indicate that by 2030, demand could rise to nearly five million tonnes annually.[15] Between 1984 and 2024, Bangladesh’s aquaculture industry experienced dramatic growth, with farmed fish production increasing from 124,000 to 2.1 million tonnes annually. Aquaculture now accounts for 55% of the country’s fish supply, up from just 16% four decades ago. This 25-fold expansion in the farmed fish market is thought to have been supported by genetically improved strains that enhance production (Gjedrem & Rye, 2018; Olesen et al., 2015) and strengthen disease resistance (Barría et al., 2021; Houston, 2017).

The sector has focused on species that are both economically viable and culturally significant. Among these, rohu (*Labeo rohita*), silver carp (*Hypophthalmichthys molitrix*), and tilapia (*Oreochromis niloticus*) have played major parts in the sector’s rapid growth. These species are adapted to polyculture systems. This maximizes land use in one of the most densely populated countries and mitigates risk as each species has different abiotic and biotic stressors. Their status as dietary staples is also significant in determining their large share of the aquaculture sector. The Aquaculture for Income and Nutrition (AIN) project, launched in 2011 by the United States Agency for International Development (USAID) in collaboration with WorldFish, has been a key initiative in promoting aquaculture development. This program focused on developing improved fish strains, enhancing technology, and building capacity in hatcheries and nurseries to promote broader dissemination and adoption among small- and medium-scale households.

Simultaneously, WorldFish has collaborated with the Bangladesh Fisheries Research Institute (BFRI) on tilapia breeding since 1994. Beginning in 2001, WorldFish produced a new generation of Genetically Improved Farmed Tilapia (GIFT) annually. The current generation, G17, demonstrates significantly higher weight gain, underscoring the success of these focused breeding initiatives.

Rohu (*Labeo rohita*) is Bangladesh’s most widely farmed carp, with production reaching 386,000 tonnes in 2019–2020 (DoF, 2020; FAO, 2020). The Carp Genetic Improvement Program (CGIP) has sought to advance productivity, particularly through the Rohu Genetic Improvement Program, which began in 2011 when WorldFish started breeding fast-growing rohu (along with Catla and Silver Carp) through the Agriculture for Income and Nutrition Initiative. In 2020, a multiplier population of highly ranked generation-three (G3) families from the WorldFish Rohu Genetic Improvement Program was released to hatcheries across Bangladesh for further development into broodstock. The G3 rohu is a genetically improved strain with superior growth rates, disease resistance, and productivity. On-farm trials in 2022 at 19 hatcheries in Jashore, Natore, and Rajshahi demonstrated that G3 rohu weighed 37% more than unimproved strains. WorldFish has played a key role in disseminating G3 rohu, initially targeting the Feed the Future zone, and later expanding nationwide through partnerships with government agencies, NGOs, and private sector stakeholders. By 2022, spawns from the G3 rohu line had been widely propagated across hatcheries, where they were developed into broodstock for large-scale production. By 2023, over 30 commercial hatcheries and 24 nurseries across Bangladesh were supplying genetically

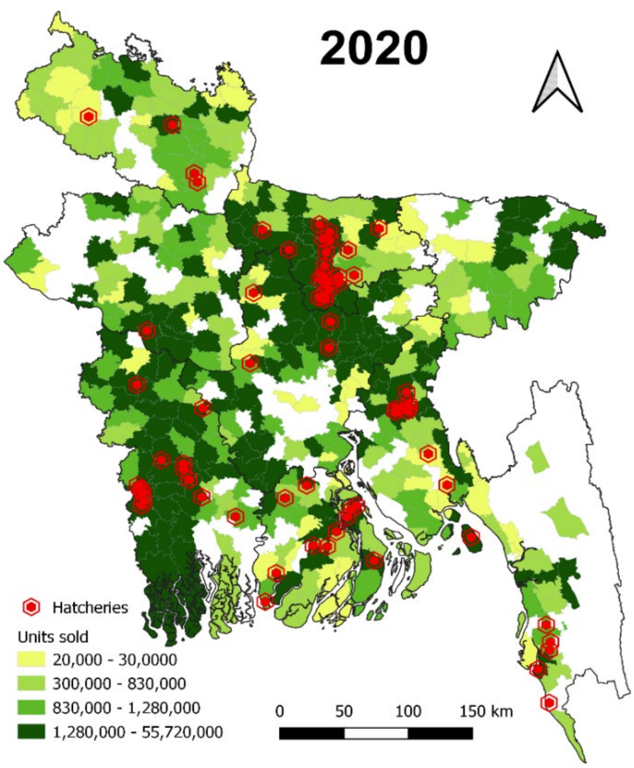
[15] https://worldfishcenter.org/project/feed-future-bangladesh-aquaculture-activity

improved rohu seed to farmers. WorldFish has been actively tracking the dissemination process, monitoring 48 nurseries (24 offering non-G3 rohu and 24 offering G3 rohu) across two divisions, Khulna and Rajshahi, to evaluate the program's impact and reach.

Genetically Improved Farmed Tilapia (GIFT) has been central to WorldFish's work in Bangladesh since 1987, with various projects aimed at enhancing nutrition and reducing ecological impact. Developed through a long-standing collaboration between WorldFish (formerly ICLARM) and BFRI since 1994, GIFT tilapia was selectively bred for faster growth, higher yields, and greater survival rates compared to other strains. New GIFT tilapia generations were introduced in multiple phases (1994, 1996, 1997, 2005, 2008, 2009, and 2012), with the latest, G17, demonstrating superior weight gain.

The expansion of tilapia hatcheries accelerated between 2011 and 2015 (Rossignoli et al, 2021), providing the conditions for the widespread adoption of GIFT tilapia. While hatcheries from 2006 to 2015 supplied diverse strains, this diversity declined after 2015, with newer hatcheries (2016-2020) primarily offering GIFT tilapia (see Figure 5 for a map of GIFT tilapia hatcheries in 2020). Broodstock management plays a critical role in seed quality, and the share of multiplier hatcheries sourcing seed from breeding nuclei or cohort-based breeding systems has steadily increased. The proportion of hatcheries using elite germplasm rose from less than 10% in 2012 to over 35% in 2020 (Rossignoli et al, 2021). Recent data from WorldFish highlight a well-established diffusion network that has driven the dramatic growth of tilapia production in Bangladesh. This structured dissemination process continues to support the industry's expansion and sustainability.

Figure 5: Distribution of hatcheries and upazila sales data for GIFT tilapia seed



Source: Rossignoli et al, 2021

Beyond providing policy recommendations for the government's Hilsa fishery management efforts, WorldFish has focused on establishing co-management bodies in the six Hilsa sanctuaries within marine protected areas and promoting alternative income-generating activities in these regions.

The WorldFish Silver Carp Genetic Improvement Program (WSCGIP) focuses on enhancing growth rates in silver carp through pedigree-based selection. Significant additive genetic variation in growth has been previously documented in Bangladeshi silver carp (Gheyas et al., 2009). The base population (Generation 0) was established in 2017 using broodstock from multiple Bangladeshi hatcheries (Hamilton et al., 2021), and the first selected generation was successfully spawned in 2019.

The Carp-Mola polyculture approach has been promoted for enhancing nutrition and income in rural Bangladesh. Small indigenous fish species (SIS), such as Mola, are rich in micronutrients and can be harvested and consumed regularly. WorldFish has been actively exploring the potential of carp-Mola systems to address micronutrient deficiency given that an estimated 70% of children are deficient in vitamin A (National Micronutrients Survey 2011/12) and 48% of women of reproductive age have anaemia (World Health Organization data). Initial dissemination efforts (2011–2014) through the Small Fish and Nutrition and Agriculture and Nutritional Extension Project (ANEP) projects laid the foundation for this approach, followed by a broader rollout between 2015 and 2023 under the Suchana program in the Sylhet Division.

Additionally, digital platforms like RightHaat and MacherGari are thought to have improved market connectivity for over 50,000 fish farmers in southwest Bangladesh, with project administrative data suggesting that 200 input retailers and approximately 100 local extension agents for fisheries (LEAFs) are using the platforms as part of efforts to facilitate better access to markets and resources.

4.3 Natural Resource Management

Over the past two decades, numerous research projects have addressed natural resource management issues in Bangladesh. While most of these had a limited geographic scope and focused on understanding and providing management insights into local challenges, one notable innovation with the potential for large-scale adoption is Alternate Wetting and Drying (AWD) in rice cultivation. AWD is a water management practice that, under specific conditions, can significantly reduce methane emissions from rice fields.

The first AWD trial in Bangladesh was conducted in 2004 by the Bangladesh Rice Research Institute (BRRI) and BRAC, with support from the International Rice Research Institute (IRRI). Awareness of the technology was expanded through workshops and seminars for National Agricultural Research and Extension Systems (NARES) staff, followed by training of trainers with key stakeholder organizations in 2007–08. Further testing and piloting took place from 2008 to 2010 (Rahman & Sanger, 2017), leading to its formal promotion to farmers during the 2010 Boro season. This effort included the distribution of 50,000 PVC pipes across six districts in northwest Bangladesh (Kuerschner et al., 2010) and was facilitated by multiple stakeholders, including BRRI, IRRI, the Department of Agricultural Extension (DAE), and the Barind Multipurpose Development Authority (BMDA). Other partners included the private sector, such as Syngenta, and NGOs like International Development Enterprises (IDE) and Katalyst. BRRI played a key role in research and training, while DAE led dissemination efforts through extension activities integrated into its major programs. AWD promotion was further expanded in the northwest in 2016–17 (Alauddin et al., 2020).

In digital innovation, IRRI and the Cereal Systems Initiative for South Asia (CSISA), under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) initiative, launched Rice Crop Manager (RCM) – an online tool where farmers answer questions about their plot and management, and receive management recommendations. RCM builds on IRRI's earlier work on Site-Specific Nutrient Management (SSNM). In 2016, the International Wheat and Maize Crop Improvement Center (CIMMYT) collaborated with Climate Services for Resilient Development (CSRD) to develop the Program for Advanced Numerical Irrigation (PANI). Additionally, Macher Gari, Digital Feed Supply Chain, and Right Haat were introduced under the five-year Feed the Future Bangladesh Aquaculture and Nutrition Activity project, managed by WorldFish and funded by USAID, to enhance aquaculture value chains through digital solutions.

4.4 Mechanization

Mechanization has been a core focus of the Cereal Systems Initiative for South Asia (CSISA), implemented in multiple phases since 2010 as a collaboration between CIMMYT, International Development Enterprises (iDE), the Bangladesh Agricultural Research Institute (BARI), and the Bangladesh Agricultural Research Council (BARC). CSISA has worked with private sector providers to tap into existing service provision networks and to try to support the upgrade private sector operations with new technologies. The CSISA Mechanization and Irrigation (CSISA-MI) project phase (2013–18) led to the establishment of the Tillage-and-Seeding Laboratory at BARI and the development of four-wheeler direct-drill maize seeders. Conservation agriculture initiatives, such as strip tillage and zero-till drilling for two-wheeled tractors, are also part of CIMMYT's efforts.

To determine the optimal configurations for water discharge in surface irrigation, CIMMYT has conducted multiple experiments comparing axial flow pumps (AFPs) – used to pump water out of rivers, canals, and ponds to irrigate crops growing nearby - with conventional pumps. They are considered particularly useful in coastal areas where groundwater sources may suffer from saline intrusion, but surface waters are not saline (CSISA Mechanization Extension Activity, 2024). Surface water is perceived as being abundant in parts of the south where river and canal networks have perennial flow, and where salinity levels do not cross crop-damaging thresholds. Compared to the investment required to sink deep tube wells and vertically pump water, low-lift surface water pumps are typically less energy intensive (Shah, 2009). AFPs are one such type of low lift pumps (LLPs), widely referred to as 'propeller pumps' on account of their design and construction, which is a boat propeller inside a pipe.

Since 2016, AFPs have been disseminated in the Barisal and Chittagong districts as part of an effort to promote their adoption by CIMMYT, in collaboration with BARI and CISA. Trials demonstrated that AFPs are more fuel-efficient and cost-effective than conventional pumps, delivering a substantial stream of water. Additionally, CIMMYT has explored a business model for a machinery rental system, including AFPs. For rice and wheat production, CSISA adapted affordable harvest services tailored for smallholder farmers. CIMMYT also partnered with commercial machinery companies like ACI to develop attachable reapers for jute harvesting in wet conditions and has supported the market promotion of the reaper machine. To strengthen capacity and encourage the adoption of mechanized technologies, CIMMYT collaborates closely with local farmers, extension agents, and agricultural equipment manufacturers through training programs and farmers' field schools.

The promotion and utilization of two-wheeled power tillers in Bangladesh has been supported by numerous NGOs, corporate enterprises, and organizations (including CGIAR, particularly CIMMYT) in collaboration with partners such as BARI, ACI, and local enterprises. These efforts have focused on raising awareness, providing training, and promoting rental services for power tillers, particularly in the Feed the Future (FTF) zone. CIMMYT has prioritized these southern zones to enhance accessibility for farmers who cannot afford to purchase power tillers, facilitating mechanized transplanting and direct-seeding techniques through attachments like the power-tiller operator zero-till seeders (PTOS). This equipment enables multiple functions in a single operation – shallow tilling, line sowing, fertilizing, seed covering, and land leveling –while minimizing tillage. Its versatility allows it to perform effectively in both wet and dry soil conditions.

Mechanized harvesting has also expanded through targeted credit financing extended to service providers for purchasing agricultural machinery. Most of these funds were allocated to 85 mechanical reaper service providers. To further improve harvesting efficiency, CIMMYT and CSISA developed 100- and 120 cm-wide attachable reapers, specifically modified for jute harvesting in wet conditions.

CGIAR has played a central role in these efforts, collaborating with local organizations and research institutes to develop and promote locally appropriate technologies. In addition to researching sustainable farming methods that balance productivity with sustainability, CGIAR has provided training programs to help farmers adopt these innovations effectively.

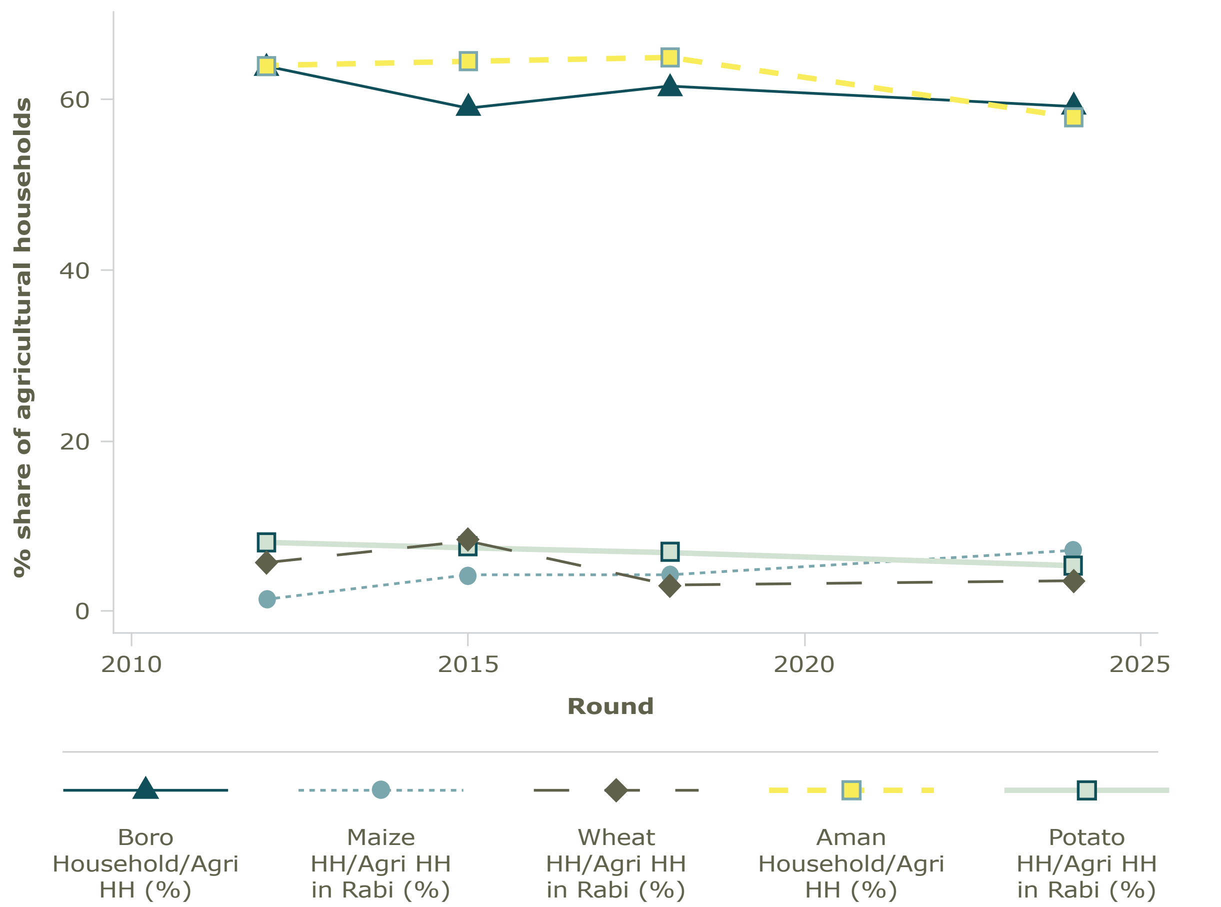
5. Insights From All Waves of the Bangladesh Integrated Household Survey

As the Bangladesh Integrated Household Survey (BIHS) is a panel survey with four waves of data collection, including the current (2024) wave, it presents us with the opportunity to explore trends over time and understand the evolution of Bangladesh's agriculture and aquaculture sectors. This section focuses on these trends.

5.1 Crop Agriculture Trends

Rice paddy production is the dominant crop in Bangladesh, with the share of farmers cultivating it during the Boro and Aman seasons remaining consistently high across the Panel Waves (Figure 6). There has been a steady increase in maize cultivation, whereas potato has seen a decline in the 2024 wave. The share of households cultivating wheat has fluctuated.

Figure 6: Incidence of cultivation of major crops in Bangladesh (2011-2024)

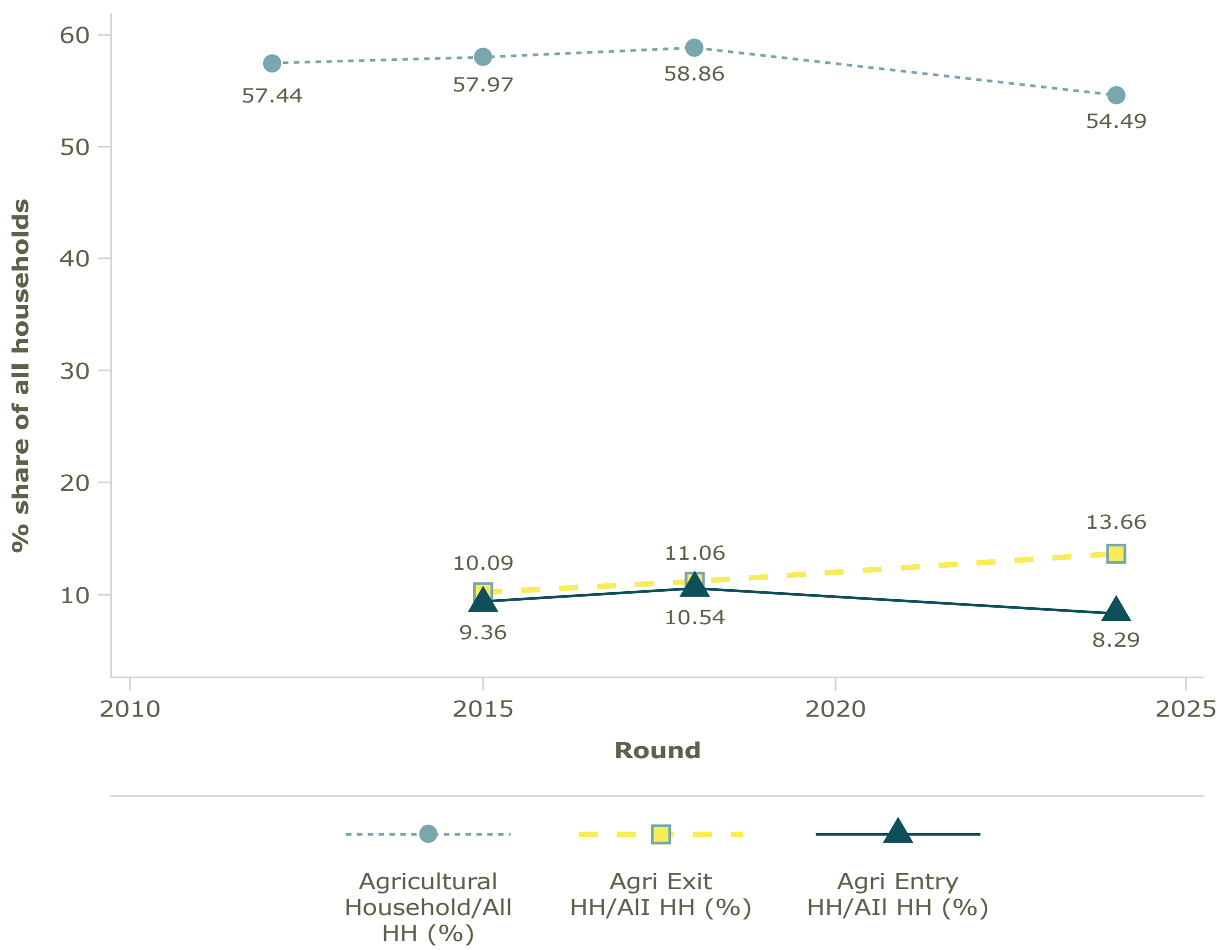


Note: Number of Agricultural Households: Round 1 (2011-12) = 3,082; Round 2 (2015) = 3,053; Round 3 (2018-19) = 3,220; Round 4 (2024) = 2,972.

5.2 Agricultural Entries and Exits

The share of households in the BIHS panel sample that practice agriculture was broadly stable at around 58% between 2012–2019, until a notable shift in the 2024 round. As we can see from Figure 7, the share of households engaged in agriculture dropped from 58.9% in 2018 to 54.5% in 2024. A household is considered an agricultural household if it has cultivated its own or leased land within the past four seasons and/or engaged in aquaculture in the past one year (either in its own or a leased pond or water body). A household is not considered agricultural if it owns agricultural land or a pond but has leased it out. The percentages for each round are calculated by taking the weighted average based on the weights for the respective round. As detailed in Figure 7, the overall drop in agricultural households in 2024 is driven by a drop in the number of new agricultural entries and an increase in exits. Agricultural exits had previously been largely offset by agricultural entries.

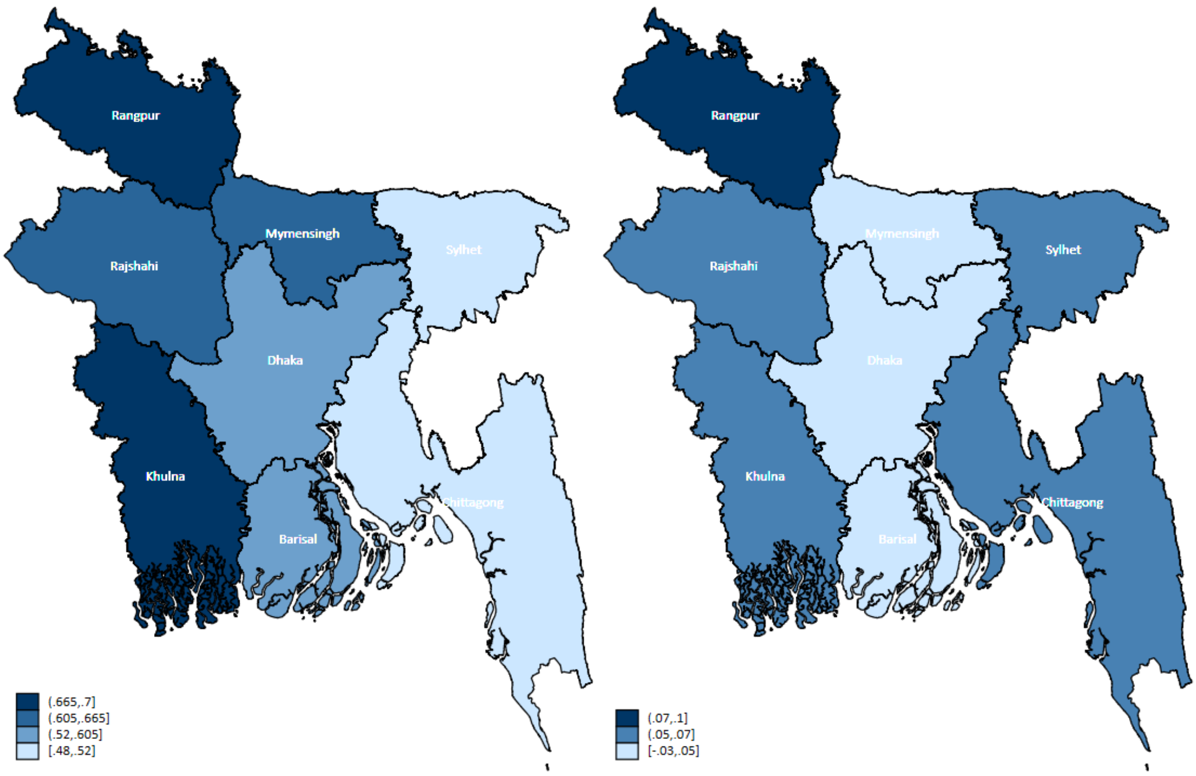
Figure 7: Time trend in households participating in agriculture in Bangladesh (2011- 2024)



Note: Number of Households (HHs) including split HHs: Round 1 (2011-12) = 5,503; Round 2 (2015) = 5,447; Round 3 (2018-19) = 5,605 (Agri HH calculations); 5,508 (entry and exit calculations because 97 HHs were not present in 2015 but were present in 2018); Round 4 (2024) = 5,554. A HH is an agricultural HH if it has cultivated its own or leased land within the past four seasons in 2024 data collection round / past three seasons in the previous rounds, and/or engaged in aquaculture in their own/leased in water body in the past one year.

In 2018, there were 3,059 agricultural households in the BIHS sample, which split and became 3,260 households in the 2024 sample. If we consider these 3,260 households as agricultural households in 2018, and base our agricultural exit analysis on this, the number of household agricultural exits is 761, and the number of entries is 472. A split household is considered to have exited agriculture if the parent household practiced agriculture in 2018 and the split household does not engage in agriculture in 2024. Conversely, a split household is considered to have entered agriculture if the parent household did not do agriculture in 2018, and the split household does so in 2024. The term net agricultural exits simply refers to the exit rate minus the entry rate. A dynamic picture emerges that varies by division, as shown in Figure 8.

Figure 8: Proportion of agricultural households in 2018-19 (left panel), proportion of net agricultural exits in 2024 (right panel)

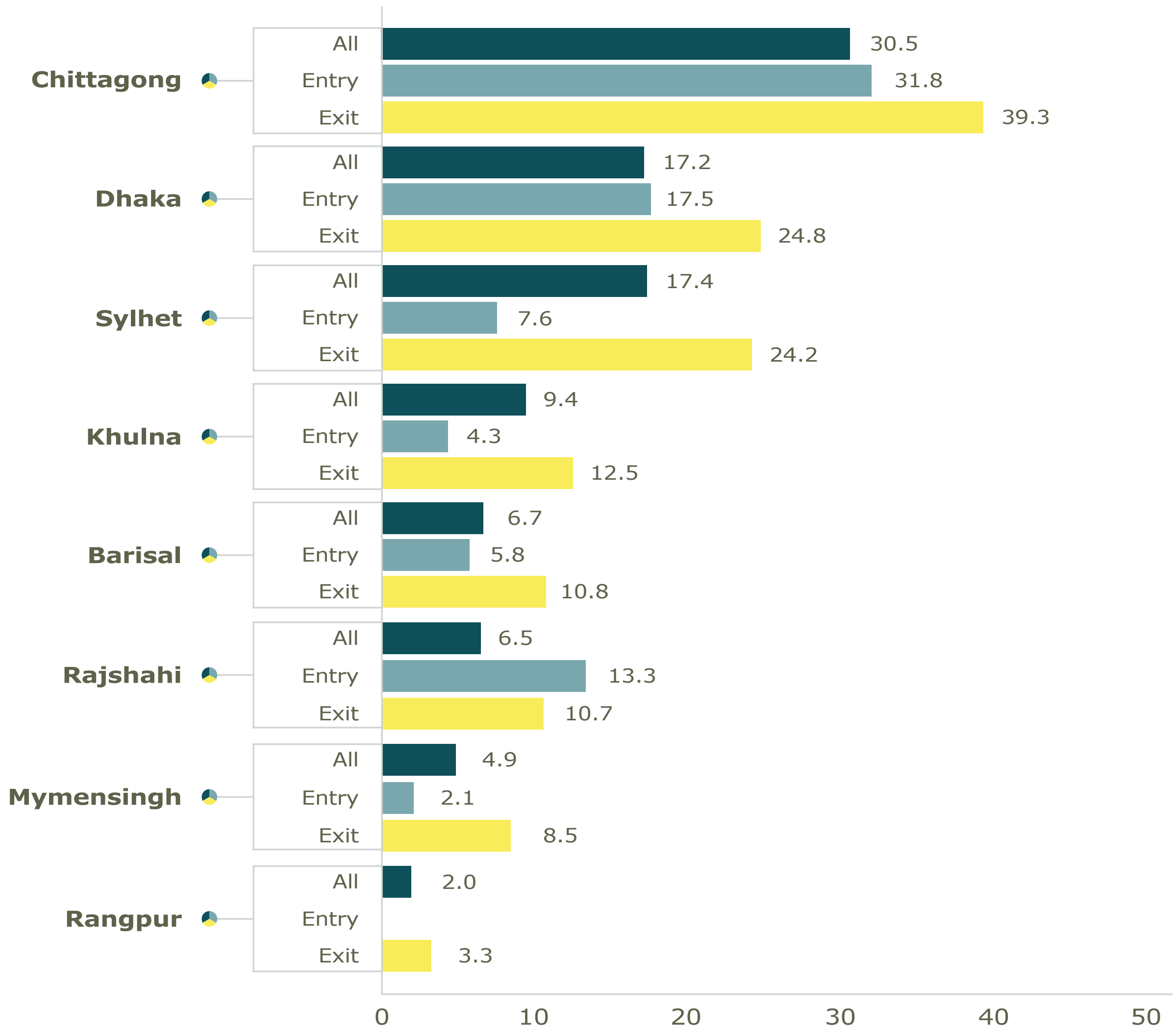


Note: Darker shades on the left panel show greater concentrations of agricultural households in absolute terms. Darker shades in the right panel show larger percentage increases in net agricultural exit. Number of agricultural households (HHs) in 2018-19 = 3,059; Number of exits in 2024 = 761; Number of entries in 2024 = 472; Net agricultural exits refer to the exit rate minus the entry rate, by division.

In these heat maps, we see that Rangpur had both the highest share of agricultural households in 2018/19 and the highest net rate of agricultural exit from 2018/19 to 2024. Sylhet and Chittagong, by contrast, had the lowest shares of initial agricultural participation in 2018/19 but also saw a high net agricultural exit. The central triplet of divisions – Mymensingh, Dhaka, and Barisal – had lower net agricultural exit rates than the divisions further out from the center.

Chittagong and Sylhet are two divisions where remittances have been at the forefront of household financial portfolios, as shown in Figure 9. Foreign remittances are one of the main income sources for 30.5% of households in Chittagong, which is a substantial share. They are also significant in both Dhaka and Sylhet at approximately 17% each. Without exception in Figure 9, we see a pattern where households exiting agriculture (light blue bars) have higher shares of households with remittances as their main source of income than for all households (dark blue bars). Remittance earnings for households exiting agriculture are also higher than for those households' entering agriculture for every division except Rajshahi. This indicates that remittances may have been an important factor underlying the transition away from agriculture in these regions.

Figure 9: Foreign remittances as a main earning source by division (%)



Note: Dark blue bars = all HHs, Blue bars = agri-entry HHs; Light blue bars = Agri exit HHs. Number of Households (HHs) = 5,554; Number of HHs with foreign remittance as main earning source = 783; Agriculture Exit HHs in 2024 = 761; Agriculture entry HH in 2024 = 472;

Consider those households that are practicing agriculture in 2024, and those that left agriculture at some point between 2018 and 2024. If we examine the level of savings held and the homestead size for the two household groups, we see that their wealth measures are statistically significantly higher for those who remain in agriculture than those who exited agriculture (Table 12).

Table 12: Comparison of wealth measures for households remaining in vs exiting agriculture using t-test

Household group	N	Household savings (BDT) (average, winsorized)	Size of homestead (average, in decimals)
Remains in agriculture in 2024	2,500	46,954.8	11.41
Exited agriculture between 2018 and 2024	761	36,714.3	9.27
Mean difference		10,240.5	2.14
p-value		0.0162	0.0000
t-statistic		2.4062	5.0611

Acronyms: Bangladeshi Taka = BDT

Similarly, if we consider the households that were not in agriculture in 2018 and entered agriculture within 2018-2024, we see that wealth measures for the group entering agriculture are statistically significantly higher than for those that did not engage in agriculture in either period (Table 13).

Table 13: Comparison of wealth measures for households outside agriculture vs entering agriculture using t-test

Household group	N	Household savings (BDT) (average, winsorized)	Size of homestead (average, in decimals)
Non-agricultural HH in 2018 and 2024	1,821	32985.63	7.47
Entered agriculture between 2018 and 2024	472	50394.3	9.58
Mean difference		17408.67	2.11
p-value		0.0004	0.0000
t-statistic		-3.5214	-4.2405

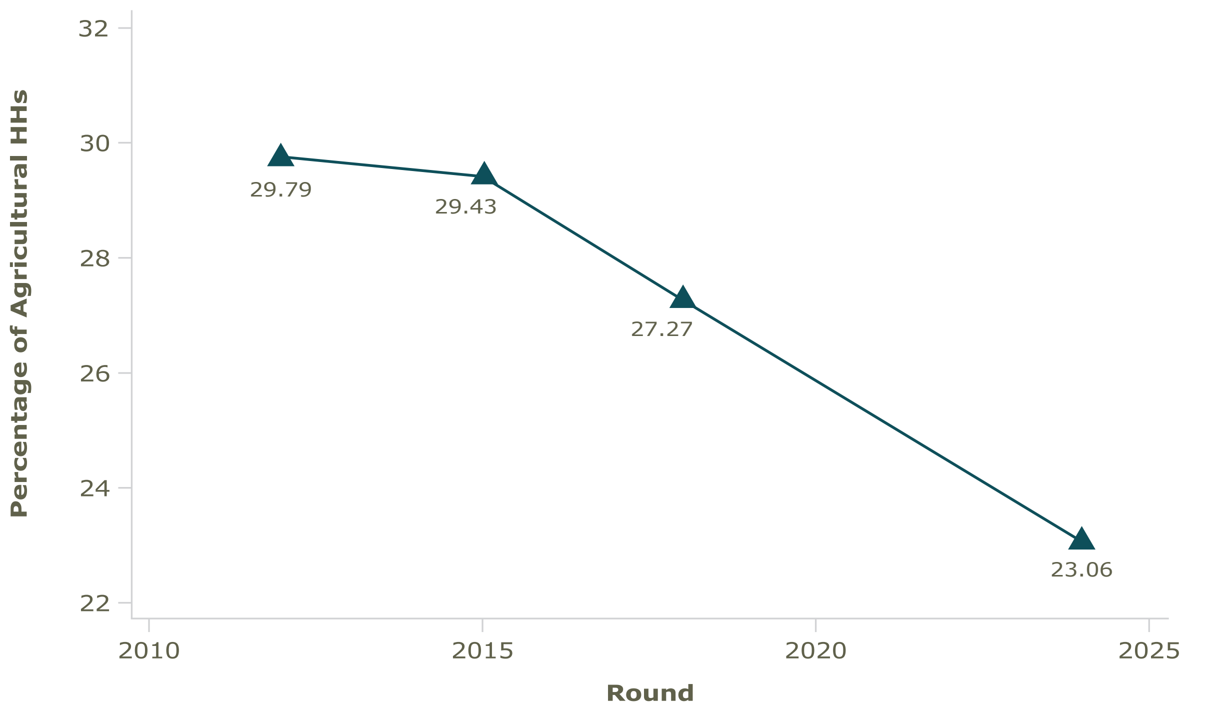
Acronyms: Bangladeshi Taka = BDT

The results reported in both Table 12 and Table 13 certainly raise questions about the changing nature of agriculture in the livelihoods of rural households in Bangladesh. Those who leave agriculture have fewer assets than those who remain. Non-agricultural households that remain non-agricultural have the lowest asset holdings of all four groups.

5.3 Aquaculture Trends

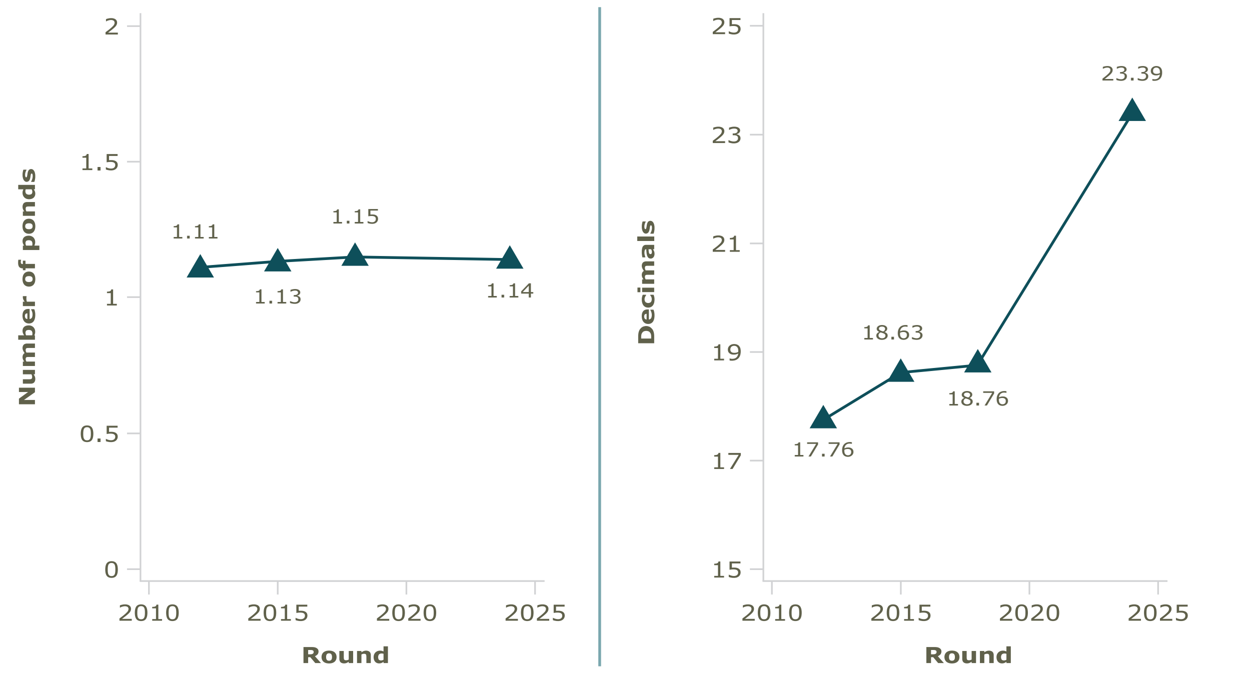
Here, we examine the dynamics of engagement in aquaculture over time in rural Bangladesh. A household is classified as an aquaculture household if it has cultivated fish in at least one water body in the past one year. Figure 10 illustrates the percentage of agricultural households practicing aquaculture across different rounds of the BIHS.

Figure 10: Percentage of aquaculture households across the Panel Waves



While the share of aquaculture households has declined over time, the average number of ponds per household has remained steady at approximately one pond per household (Figure 11, left panel and Figure 12. Distribution of ponds per household in 2024Figure 12). Notably, the average pond size has increased over the period, from 17.8 to 23.4 decimals on average over the past 12 years (Figure 11, right panel), yet it is still generally very small; 1 decimal = 0.004 ha. Taken together, these trends imply that households with the smallest ponds have exited, and the trend in pond size reflects a changing composition.

Figure 11: Average number of ponds per household (left panel), average size of pond per household (right panel)



Note: The variables are windsorized at 1% and 99% to account for extreme values. This includes all fishing households in each round.

Figure 12: Distribution of ponds per household in 2024

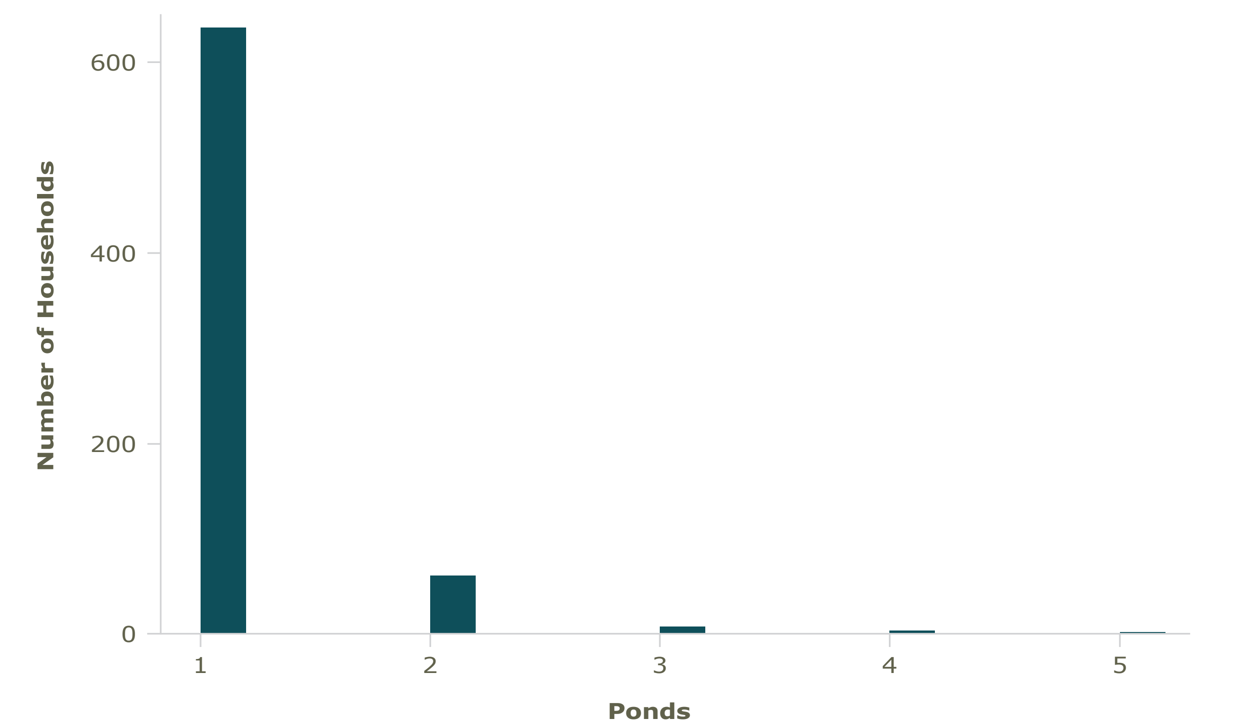
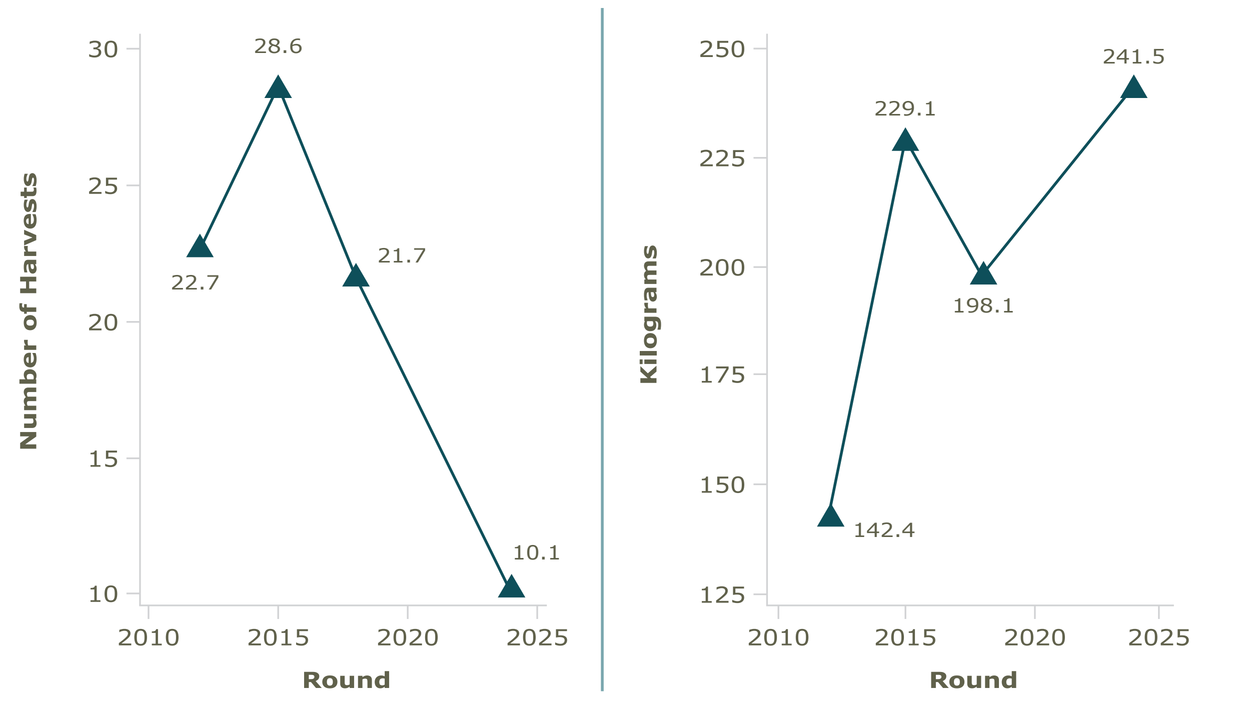


Figure 13 illustrates notable changes in harvest practices over time. While the frequency of harvests has decreased significantly, from 23 harvests per year in 2012 to just 10 harvests in 2024 (left panel), the average yield per harvest has increased (right panel). Starting at 99 kgs in 2012, the yield per harvest rose steadily to 187 kgs in 2024. Households have shifted over the period toward fewer but more productive harvests.

Figure 13: Average number of harvests per household (left panel), average harvest per household (kgs) (right panel)

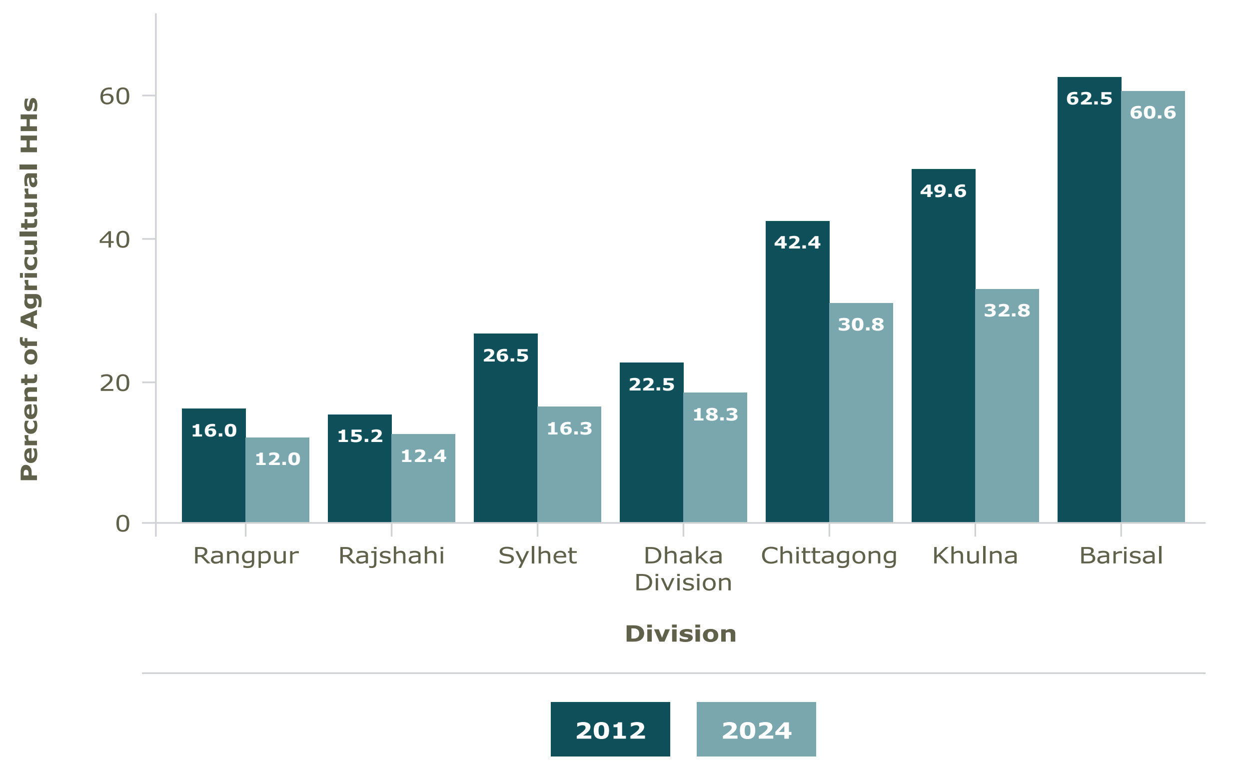


Note: The variables are windsorized at 1% and 99% to account for extreme values. This includes all fishing households in each round.

Figure 14 provides a snapshot of aquaculture households as a proportion of agricultural households across divisions in 2024. Barisal stands out as the leader in aquaculture adoption, with 61% of agricultural households engaged in aquaculture, far surpassing other divisions. Khulna (33%) and Chittagong (31%) follow as the next most prominent divisions, indicating regional variations in aquaculture adoption. Barisal aside, there have been notable declines in aquaculture participation over time. Sylhet had the highest percentage of households exiting aquaculture at 66%, followed by Rangpur with 56% and Chittagong at 52%.

Out of 913 total aquaculture households active in 2018 in the BIHS, 418 households (46%) exited aquaculture by 2024. Among these, the majority (69%) shifted to other forms of agriculture, while the rest exited the agricultural sector entirely. Moving in the other direction, 215 new households entered the sector by 2024, and 495 households (54%) continued aquaculture practices across time periods, resulting in a total of 710 active aquaculture households in BIHS 2024.

Figure 14: Aquaculture households (%) by division across the panel



Note: This is the percentage of all aquaculture households amongst agricultural households within each region.

A closer examination of the characteristics of households that exited, remained in, or recently entered aquaculture reveals some interesting patterns (Table 14). Households that exited aquaculture between 2018 and 2024 had an average monthly consumption of 5,187 Taka in 2018 (42.12 USD, as 1 Taka = approx. 0.008 USD). This is lower than those who remained in aquaculture and higher than the average consumption among new entrants. By 2024, savings levels varied substantially, with households that exited aquaculture holding 51,379 Taka in savings, compared to 79,669 Taka among new entrants. Taken together, these trends indicate that households joining aquaculture after 2018 are relatively wealthier.

As noted previously, households with smaller ponds were more likely to exit aquaculture. Households remaining in aquaculture manage larger ponds, averaging 20.3 decimals in 2018 and increasing to 23.8 decimals by 2024, while those that exited had ponds averaging 14.1 decimals, and new entrants averaged 17.4 decimals. Profits per decimal show significant gains for those who stayed in aquaculture, rising from 1,738 Taka/decimal in 2018 (USD 3,509/ha) to 3,086 Taka/decimal (USD 6,253/ha) by 2024. In contrast, those who exited averaged 1,847 Taka per decimal, while new entrants recorded lower profits at 769 Taka per decimal, indicative evidence of the learning costs associated with starting a new enterprise.

Table 14: Comparisons between households remaining, entering, and exiting aquaculture within 2018 and 2024

Indicators	Households that were aquaculture in 2018 but left in 2024	Households that joined after 2018 for the first time	Households that remained in aquaculture both in 2018 and 2024
Household monthly consumption in 2018 [Taka]	5,186.6	5,144.6	5,471.3
Household savings in 2024 [Taka]	51,378.6	79,669.4	56,242.3
Household size	4.6	4.2	4.6
Size of pond [decimal]	14.1	17.4	20.3 in 2018 (23.8 in 2024)
Amount of Harvest [kg/year]	150.9	137.3	174.5 in 2018 (190 in 2024)
Percentage of houeholds that also did agriculture in 2018	68.7	55.2	73.4
Profits/decimal [Taka]	1,847	769	1738 in 2018 3086 in 2024

Two fish varieties of prime importance in the aquaculture landscape of rural Bangladesh are rohu and tilapia. Figure 15 highlights the prominence of these two species, with 63.9% of fish-cultivating households raising rohu and 55.6% raising tilapia.

Figure 15: Household adoption by fish breed (% of fish-cultivating households)

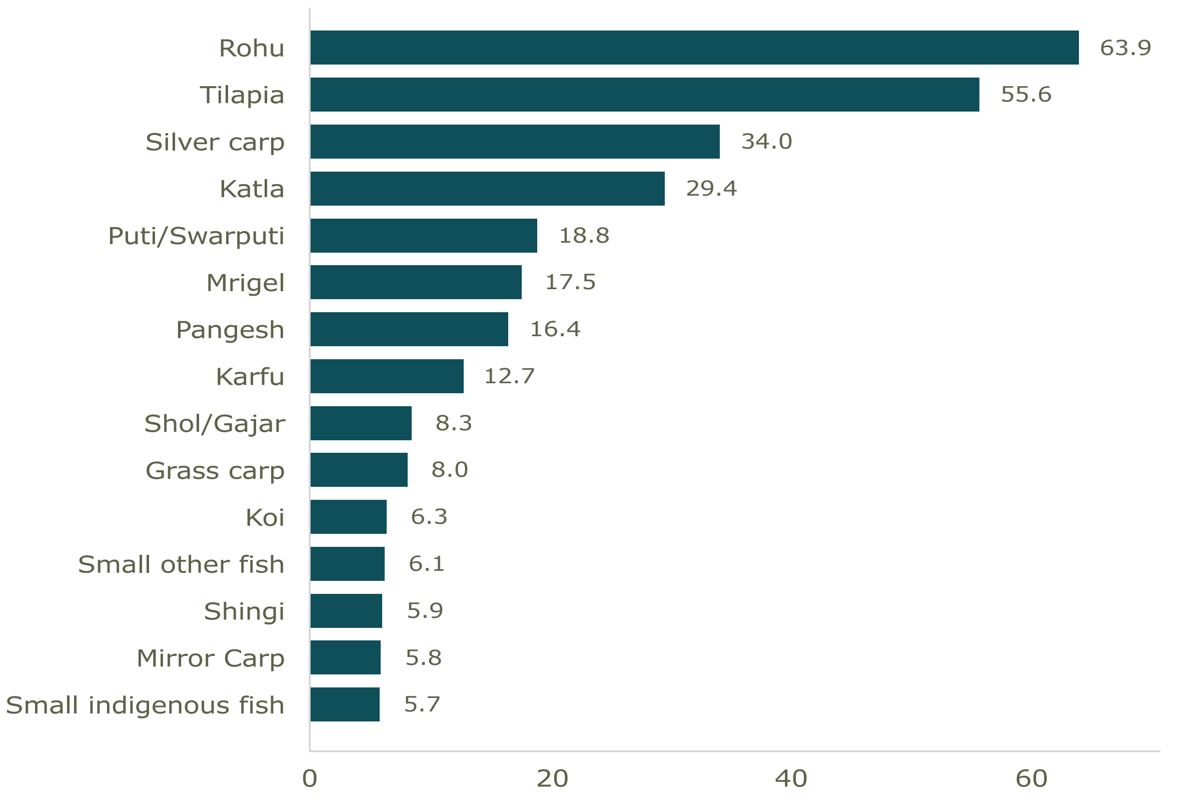
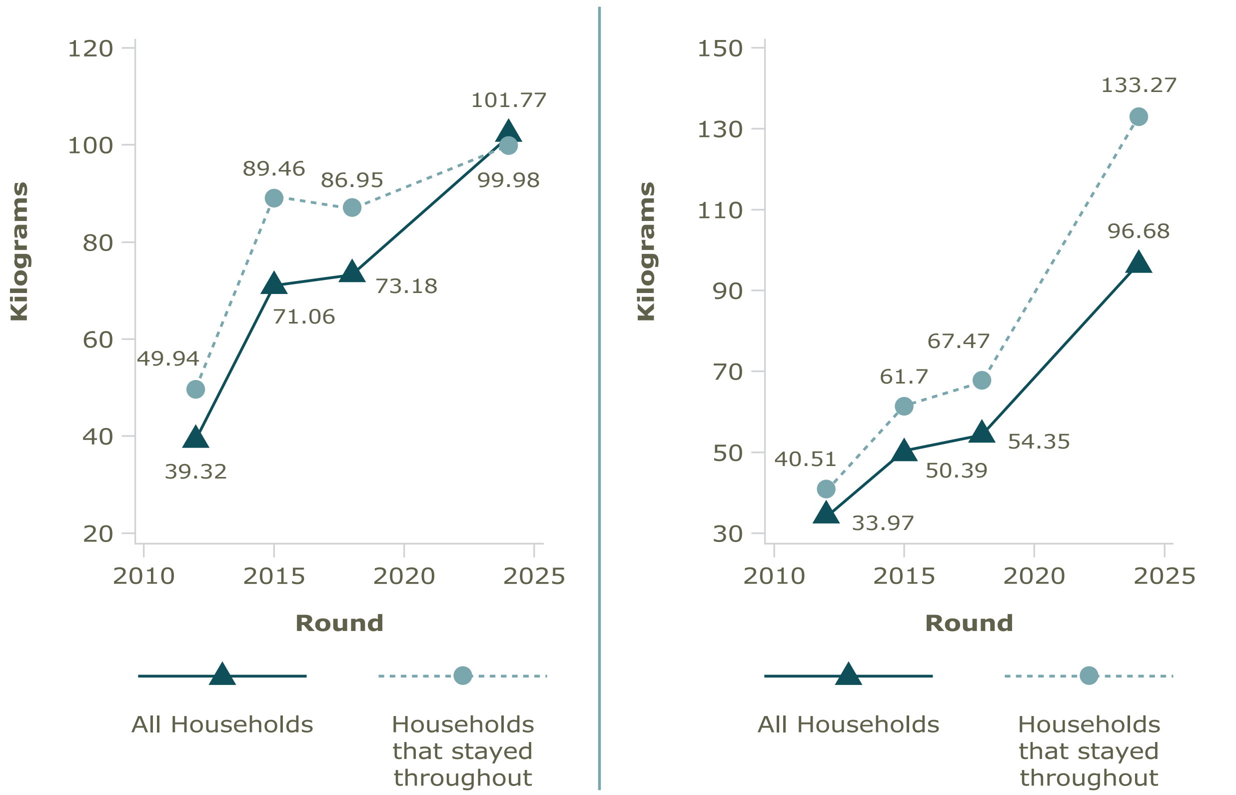


Figure 16 shows that over the past decade, harvests of both tilapia and rohu have consistently increased, in line with the overall trend towards fewer, larger harvests seen in the sector (shown earlier in Figure 13).

Figure 16: Average tilapia and rohu harvest per household (kg/annum)



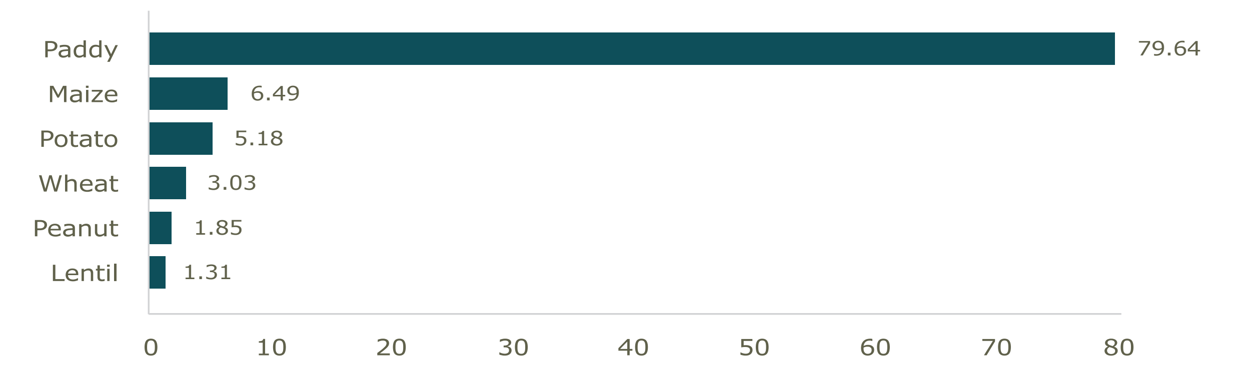
Note: The variables are windsorized at 1% and 99% to account for extreme values.

6. Adoption Rates of CGIAR-Related Innovations

6.1 Crop Germplasm Improvement

Before turning to varietal adoption, we describe which crops are being cultivated. Figure 17 shows the percentage of agricultural households[16] cultivating different crops in the past three seasons, showing the importance of paddy in the agricultural landscape of Bangladesh. It remains by far the dominant crop. Given that we are conducting nationally representative sampling, we limited our focus and genotyping efforts to Boro season rice, as the limited incidence of cultivation for other crops would result in small sample sizes.

Figure 17: Crop cultivation of agricultural households in the past three seasons (%)



Note: Agricultural households are those that cultivated their own land, or leased in land, within the past three seasons and/or engaged in aquaculture in the past one year (N = 2,972)

6.1.1 Boro Rice DNA Fingerprinting

6.1.1.1 Estimating the Reach of CGIAR-Related Varieties

We first randomly selected a Boro plot from all the Boro plots a household farms, based on probability proportional to size. The survey has 1,733 Boro rice households (HHs). We successfully collected leaf samples for DNA fingerprinting from 98.3% of these households.[17] We retained 98.77% (1,683 HHs) of the leaf samples collected while sending the leaf samples for DNA extraction to Agriplex Genomics. Samples for 21 HHs were dropped due to duplicate barcodes, fungus-infected samples, or other quality-related issues. Thus, among all Boro households, we sent leaf samples for 97.11% of the HHs. For the DNA fingerprinting results, we

[16] As before, a household is considered an agricultural household if they have cultivated their own land, or cultivated leased land, within the past four seasons and/or engaged in aquaculture in the past one year (either in their own pond or a leased pond/water body).

[17] The households without leaf samples were identified as Boro paddy households during the resurvey period when the Boro season had already elapsed and it was impossible to collect samples.

could not retrieve data from 18 leaf samples, which left us with a final sample size of 1,665 HHs (96.08% of total Boro HHs). For 20% of randomly selected HHs, we took two samples, which means the number of samples stood at 2,005 for 1,665 HHs. Appendix K details the process of assigning varietal identities to farmer samples. Table 15 has the headline results from the DNA fingerprinting exercise.

We report lower- and upper-bound estimates. For the lower-bound estimates, we have considered CGIAR-related rice varieties as varieties containing IRRI parents or grandparents. For upper-bound estimates, we have considered varieties for which the International Network for Genetic Evaluation of Rice (INGER)[18] entry has been used as a parent, or INGER entries (inbred and hybrid) have been released directly as varieties without further modification. The lower-bound and upper-bound estimates in the table are separated by "/" where applicable.

Table 15 shows the overall reach of CGIAR Boro rice varieties. Column 2 illustrates the percentage of households using CGIAR varieties in the Boro season. In Column 3, we consider a village to be using a variety if one or more households in the village use the variety. The estimated number of households in Column 4 is calculated by multiplying each adopting household by its weight and then summing the corresponding results. The weights for this round of the survey have been updated based on the latest census and population growth, details for which are provided in Section 3.2.1. Column 5 provides the weighted average of the release year of varieties, where the weight is the percentage of households cultivating each variety.

The difference between the lower and upper bounds is negligible. Approximately 52% of the Boro rice-cultivating households cultivate CGIAR-related varieties, suggesting a significant influence of CGIAR in the development and dissemination of rice varieties. These varieties have reached 80% of villages, and the estimated reach is approximately 4.5 million households.

[18] The International Network for Genetic Evaluation of Rice (INGER) is a global network for the evaluation of advanced pre-variety breeding lines developed by rice breeding programs at IRRI and National Agricultural Research and Extension Systems (NARES) partner organizations. INGER helps NARES partners to access diverse rice germplasm for fast-tracking varietal release, enabling breeding programs to release varieties even if they do not have crossing and selection infrastructure. As these INGER entries are not IRRI parents or grandparents rather collected from the INGER repository, these are posited as the upper bound.

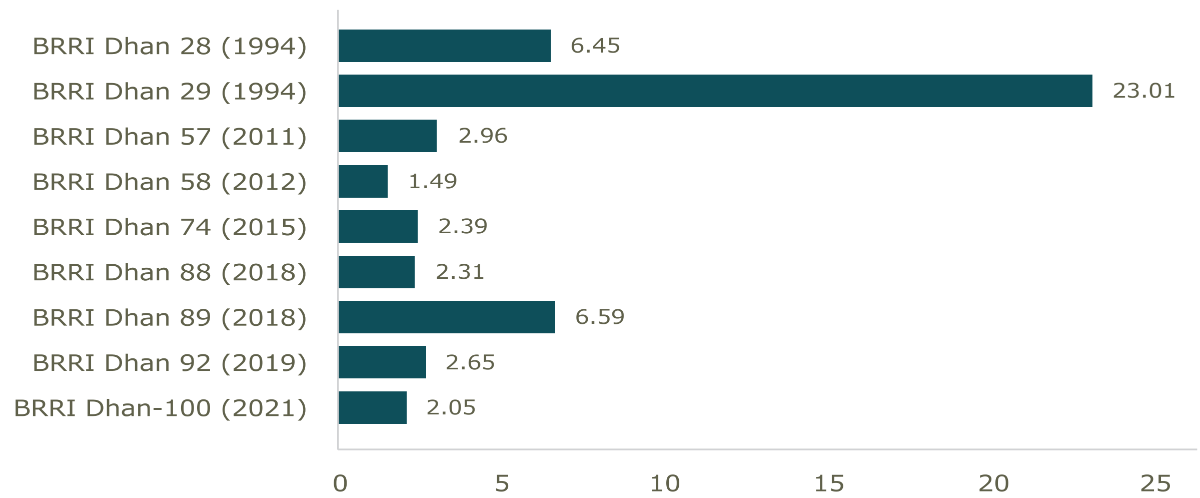
Table 15: DNA fingerprinting results reach estimates for rice in Boro 2023-24 for the PPS sampling selected plot

Name of crop innovation	% of households with innovation among the crop cultivating HHs (lower/ upper bound)	% of villages with innovation (lower/upper bound)	Estimated number of households (in millions; lower/ upper bound)	Variety adoption percentage weighted release year of crop innovation (lower/upper bound)
CGIAR-related rice varieties	51.92/52.02	79.4/79.83	4.55/4.56	2004
Salt-tolerant rice	0.48	3.86	0.04	2015
Lodging-tolerant rice	8.21	33.05	0.72	2017
Zinc-enriched rice	2.05	10.3	0.18	2021
CGIAR varieties (year 2000 and onwards)	22.51/22.61	63.52/63.95	1.97/1.98	2016

Note: The second column illustrates the percentage of households using CGIAR varieties. In the third column, we consider a village to be using a variety if one or more households in the village use the variety. The estimated number of households in Column 4 is calculated by multiplying each crop innovation adopting household by its weight and then summing the corresponding results. Column 5 provides the weighted average of the release year of varieties, where the weight is the percentage of households cultivating each variety. Varietal trait information from Bangladesh Rice Research Institute's Knowledge Bank and Bangabandhu Sheikh Mujibur Rahman Agricultural University's (BSMRAU) Digital Herbarium.

However, the weighted year of release shows that varieties are on average 20 years old. This indicates that while CGIAR varieties are widespread, older releases still dominate. Figure 18 shows that this is driven mostly by BRRI Dhan 28 and 29, the two most popular varieties, both of which were released in 1994. While varietal replacement has been slow, some recent varieties have spread fast. These include BRRI Dhan 74, 89, and 100, all of which were released after 2014. These results show why there have been efforts by numerous stakeholders to replace BRRI Dhan 28 and 29 with newer varieties (Lojo, n.d.). If we limit the analysis to CGIAR varieties released since 2000, we find a little less than one quarter of households cultivating these newer CGIAR-related releases, corresponding to 2 million households.

Figure 18: Adoption of major Boro varieties for DNA fingerprinting plot in 2023-24 (%)

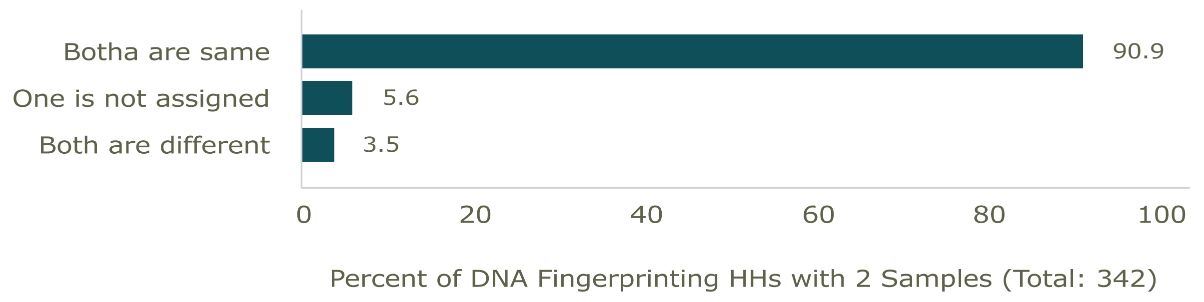


Note: DNA fingerprinting Boro Households: 1,665

6.1.1.2 Within-Plot Heterogeneity

Out of 342 households where we took two duplicate samples, we compared the results of these two observations about the sample rice plot. As we show in 19, approximately 91% of these households had both samples matched to the same variety. This shows us that seed uniformity must be relatively high for us to find this low rate of mismatch, and that farmers must only rarely cultivate mixed plots featuring multiple rice varieties (either intentionally or unintentionally). This result also provides us with an important *ex-post* quality check on the sample collection and fingerprinting exercise, both of which must have been done well to recover this high rate of successful replication.

Figure 19: Mixing of Varieties on DNA Fingerprinting Plot



6.1.1.3 Misclassification in Farmer Self-Reported Data

By comparing the DNA fingerprinting results to the survey responses from farmers, we can understand the extent to which survey data is a reliable proxy for the more detailed and reliable insights we get from DNA fingerprinting. The first comparison to make is categorical - whether the varietal identities reported by farmers lead to similar inferences about adoption as we get from DNA fingerprinting. The two rows of data in Table 16 show that farmer self-reported data would only slightly over-estimate reach. Interestingly, measurement error in farmer self-reported data results in the varietal age being pushed even higher from 20 years to 23 years.

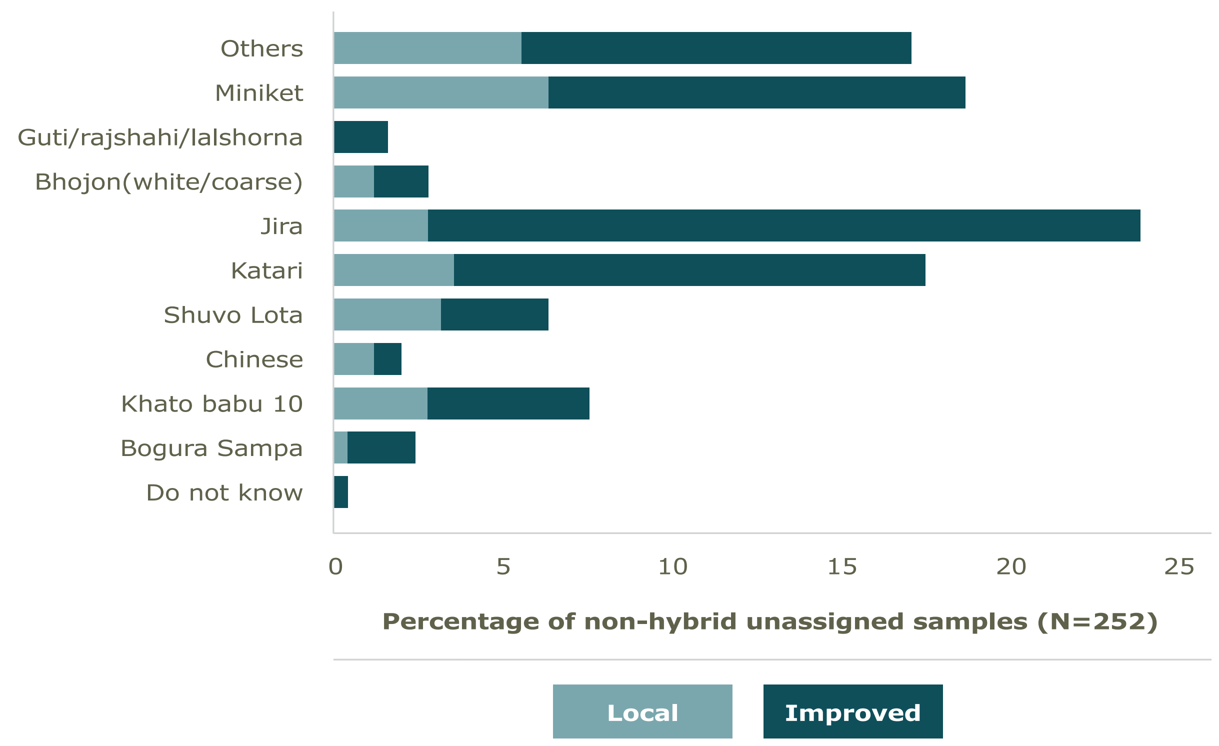
Table 16: Comparison of reach estimates between DNA fingerprinting and self-reported varieties in Boro 2023-24 for the PPS sampling plot

Category	% of Boro rice-growing households growing CGIAR-related varieties (lower / upper bound)	% of villages with innovation (lower/upper bound)	Estimated number of households (in millions, lower / upper bound)	Variety adoption percentage weighted release year of crop innovation (lower/upper bound)
DNA fingerprinting results	51.92/52.02	79.4/79.83	4.55/4.56	2004
Self-reported estimates	55.85/55.96	84.98/85.41	4.9/4.91	2001

Note: Column 2 illustrates the percentage of households using CGIAR varieties. In the third column, we consider a village to be using a variety if one or more households in the village use the variety. The estimated number of households in Column 4 is calculated by multiplying each crop innovation adopting household by its weight and then summing the corresponding results. Column 5 provides the weighted average of the release year of varieties, where the weight is the percentage of households cultivating each variety.

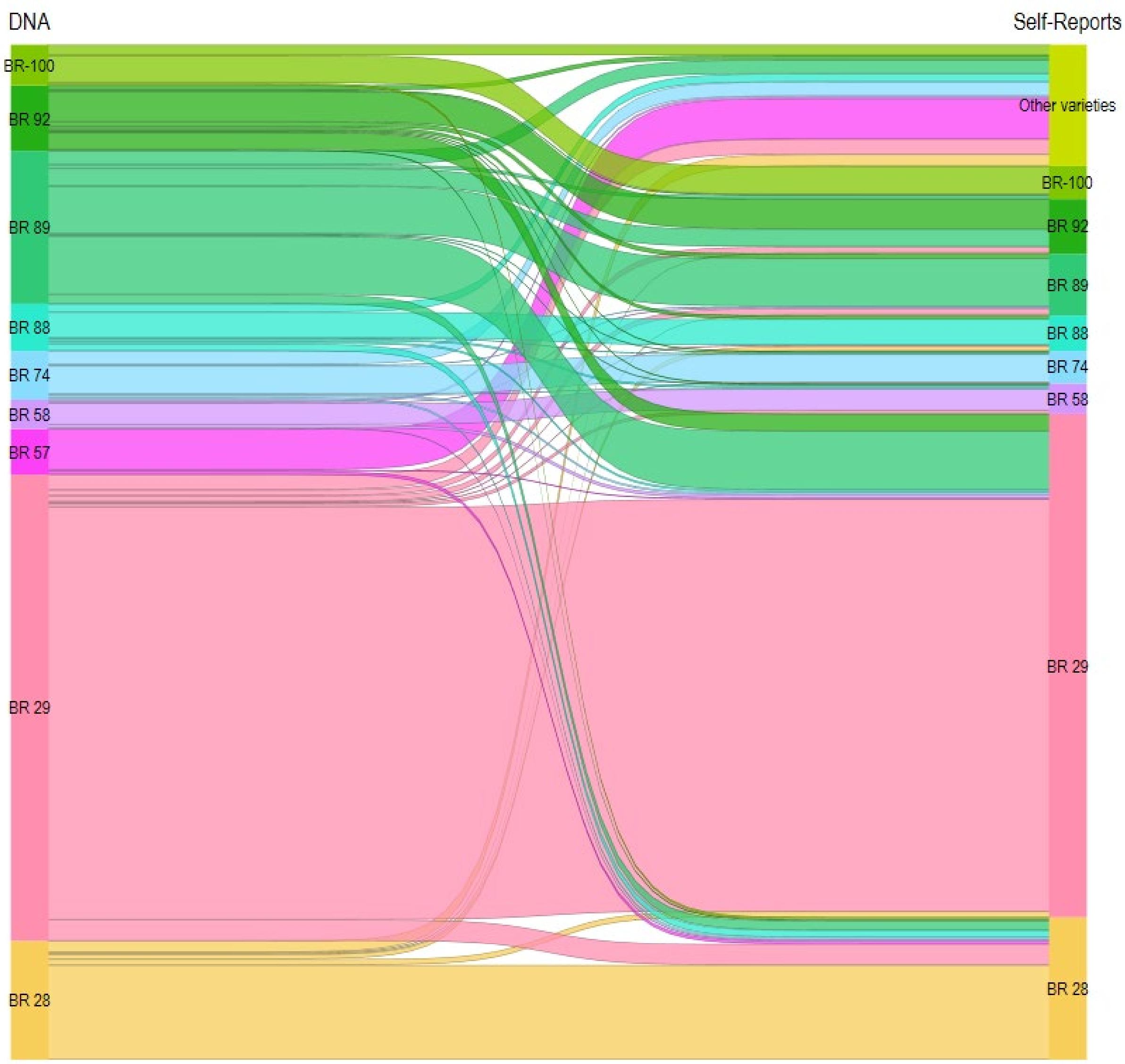
In Figure 20, we see that most of the varieties grown are predominantly referred to by farmers as improved varieties, except for Bhojon, Chinese, and Shuvo Lota. From the DNA fingerprinting results, we get some interesting insights regarding what farmers refer to as "Miniket". Miniket is made by taking varieties of rice with medium-slender shapes and transforming them into more slender grains using a high degree of milling. As raw rice typically breaks when milled to a high degree, processors parboil the grains, so they withstand breakage during milling. This process strips off edible portions of the grain, wasting food and removing essential nutrients. Notably, miniket rice has up to 70% less zinc than rice cooked at home (Taleon et al., 2024). The varieties self-reported as "Miniket" can be grouped under three distinct clusters based on their genetic traits. The largest of these clusters, with 25 samples, is from the Khulna division. These are probably all very genetically similar varieties that are processed to prepare slender rice by specific companies.

Figure 20: Variety-wise division of 'local' and 'improved' self-reports with corresponding self-reported variety names



If we do a comparison between the self-reported reach and the DNA fingerprinting results for the DNA fingerprinting plot, we can see that the estimates are higher for self-reports. This points to the fact that farmers are misclassifying non-CGIAR varieties as CGIAR-related varieties, largely for BRRI Dhan 28 and BRRI Dhan 29, which is illustrated in Figure 21.[19] The converse is happening for BRRI Dhan 57 and BRRI Dhan 89, where the DNA fingerprinting result is 3 and 3.2 percentage points higher, respectively. For BRRI Dhan 89, many farmers mistake it for its parent variety BRRI Dhan 29. BRRI Dhan 57 is always misclassified. The common names given for it are Jira and Miniket.

Figure 21: DNA fingerprinting results (left side) vs. self-reported data (right side) comparison for major Boro varieties



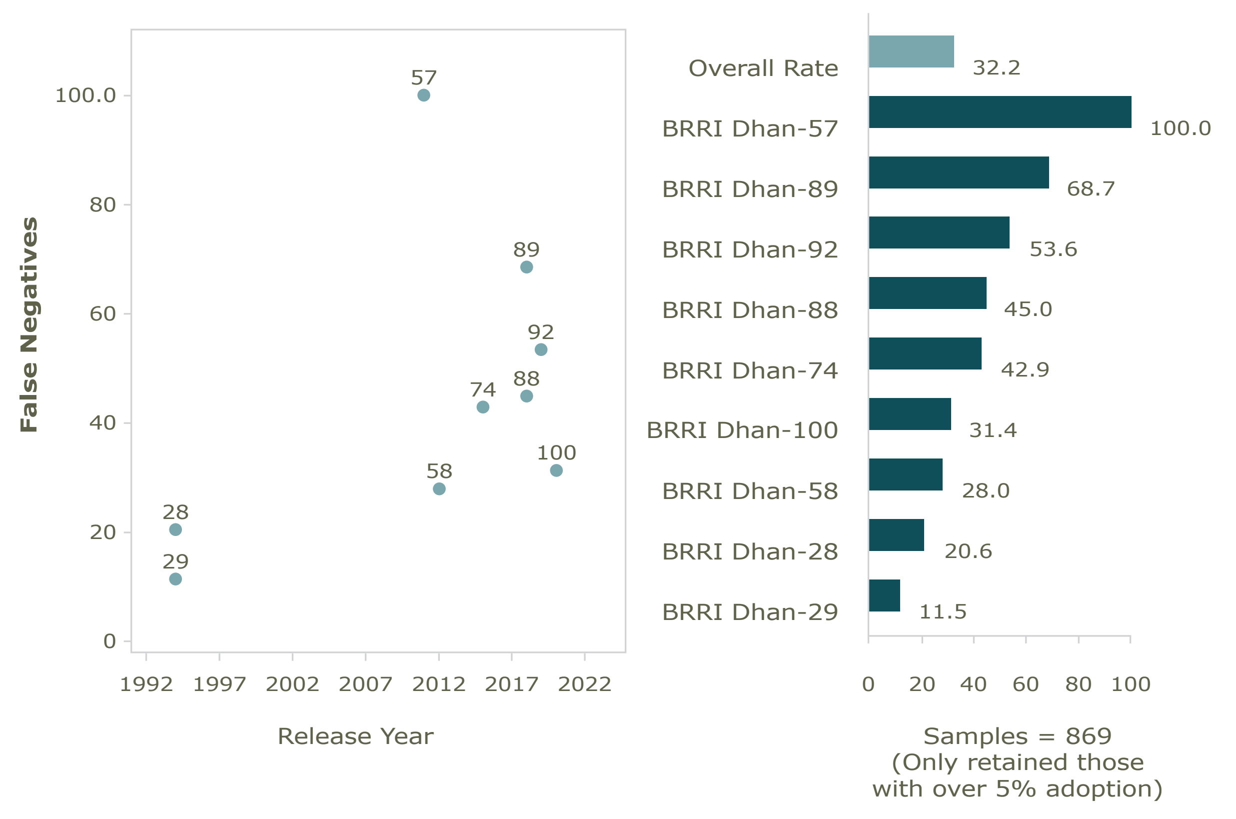
Note: Number of samples: 869; we have retained the varieties with considerable adoption in the DNA fingerprinting part and bundled several varieties in self-reports as other varieties for clarity within the figure.

[19] For the self-reports, we bundle several varieties for easier visualization.

Figure 22 shows that misclassification is much more common for newer releases. Farmers are seemingly unaware that they are purchasing newer varieties. In the course of the survey, we took photos of the seed bags (if available). Within the successfully DNA fingerprinted samples, 130 samples had photos of the seed bags. Among the misclassified samples, 26 samples had photos of seed bags. Within those, 14 samples had seed bags that clearly mentioned the self-reported variety names. This shows that the misclassification occurred because the seed companies are marketing varieties with incorrect names, which reflects an issue with the seed systems. BRRI Dhan 28 and 29 are the common varieties being sold as other varieties in this case. Other varieties include BRRI Dhan 75, 81, 88, 89, and 92. One possible explanation is that older varieties have a stronger brand value, which leads to newer varieties being packaged as older varieties to more easily market them.

A further implication of this finding is that farmers lack knowledge about the stress-tolerant and micronutrient-enrichment qualities of the newer varieties, which could be a further barrier to adoption. Valera et al. (2025) examined the effect of nutrition training on the adoption of high-zinc rice in Bangladesh and found that unavailability of seeds and low yields were cited as the major reasons for not using high-zinc rice for trained households, whilst the lack of knowledge about high-zinc rice was the dominant reason among the untrained farmers.

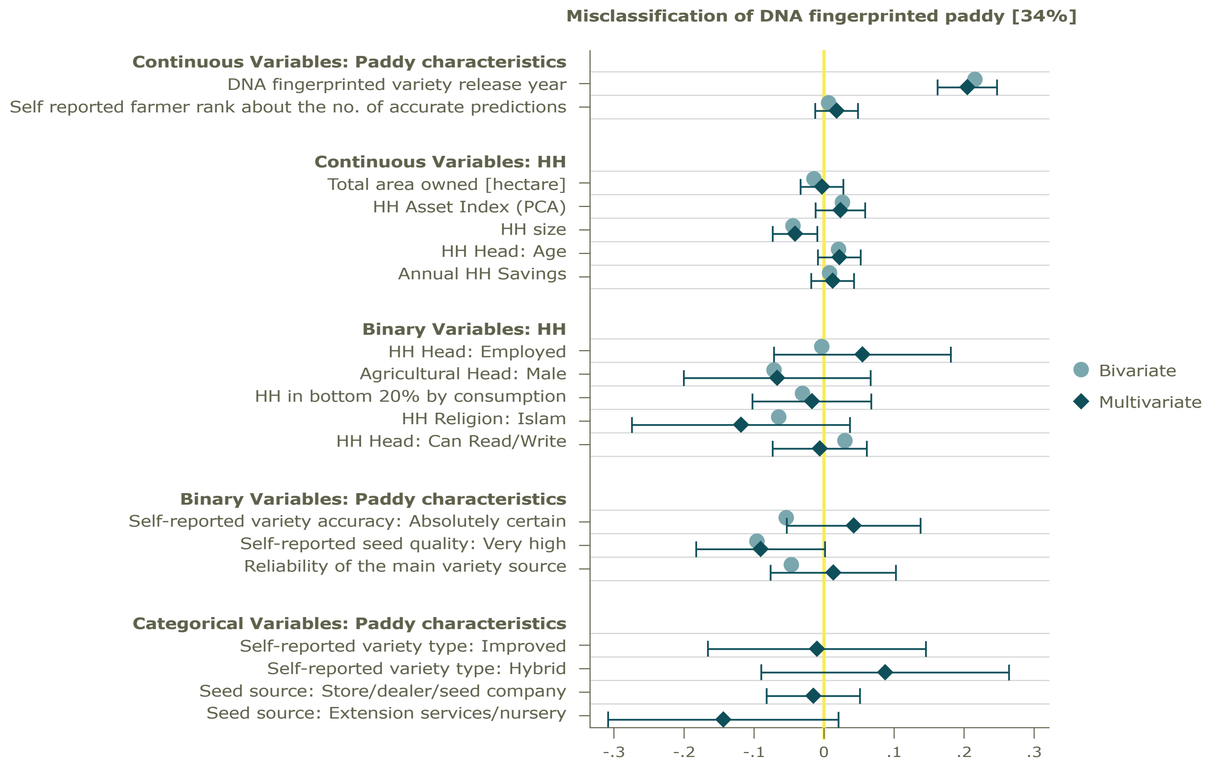
Figure 22: Misclassification of DNA fingerprinting samples. Left panel: Scatterplot of false negatives vs release year; right panel: false negatives by variety



To estimate the factors influencing misclassification, we look at household and rice level continuous and categorical variables. In terms of the categorical variables for rice, we recode the accuracy, reliability, and quality-related variables as binary variables: absolutely certain or not, extremely reliable or not, and very high quality or not[20] (this is broken down in Appendix L). In the case of seed sources, we categorize the different types of sources into three categories, where the informal source includes the following sources: saved from last year (produced seed), farmer group/seed club, and friends/family/neighbors.

From the correlates, (Figure 23), we can see that misclassification is positively correlated with the variety release year, in line with the previous figures presented. In the categorical variables, if the self-reported variety type is hybrid (base category traditional), it is misclassified more. Moreover, being certain regarding variety accuracy is positively correlated with misclassification. Thus, these farmers lack complete information about the varieties they are farming, even though they are certain that they have it. If reported seed quality is high, misclassification is less likely. If the seed source is from the government or from a nursery, the likelihood of misclassification decreases meaning that seeds from informal sources and seed companies have lower fidelity to their true genetic identity – a finding reinforced from the evidence reported above comparing the DNA fingerprinting results to the identity on the seed bags.

Figure 23: Correlates of misclassification of DNA fingerprinted rice



Note: Misclassification refers to DNA fingerprinting results and self-reports providing different varietal identifications. The DNA release year is for the DNA fingerprinted variety. The self-reported farmer rank illustrates the ranking each farmer assigns themselves within 1-20 for their village in terms of the number of varieties correctly predicted. The total area owned is the area owned/under operation that is being cultivated by the household in the past four seasons. The Household asset index is constructed by conducting principal component analysis. The annual household savings are the savings on the day of the interview. The binary variables for rice

[20] This is because the four other options on the Likert scale do not warrant separate categories and may overstate the impacts of outlier observations.

characteristics are constructed by converting Likert scale variables to binary variables. The self-reported variety type's base category is local. Seed source's base category is informal sources: saved from last year (produced seed), farmer group/seed club, and friends/family/neighbors.

6.1.2 Self-Reported Reach Estimates for Rice Across All Plots by Season

Next, we report the self-reported reach estimates for rice across all seasons and plots (Table 17). For the Boro season, among 1,665 DNA fingerprinted households, 906 planted a CGIAR-related or CGIAR-promoted variety. Among the remaining 759 households, 418 planted rice on multiple plots. Of all households, 759, 15.3% (27.8% of households with rice on multiple plots) stated that they use a CGIAR-related or CGIAR-promoted variety on at least one of their non-DNA fingerprinted crops. Thus, if we do not account for these plots whilst calculating the self-reported reach, the Boro season reach will be under-reported. However, the caveat is that incorporating these means that we would be incorporating misclassified samples, as seen from the figures above. Nonetheless, we calculate the total reach by considering the DNA fingerprinting results from the sampled plot, coupled with the self-reported varieties for the non-DNA fingerprinting plots in the Boro season.

Table 17: Combined DNA fingerprinting plot and self-reported other plots' reach estimates for Boro rice

Name of crop innovation	% of rice-growing households with CGIAR-related varieties (lower/upper bound)	% of villages with CGIAR-related varieties (lower/upper bound)	Estimated number of households (in millions; lower/upper bound)	Variety adoption percentage weighted release year of crop innovation (lower/upper bound)
All CGIAR-related rice varieties	59.52/59.67	85.29/86.13	5.45/5.47	2003
Salt-tolerant rice varieties	0.86	6.72	0.08	2014
Flood-tolerant rice varieties	0.32	2.1	0.03	2012
Lodging-tolerant rice varieties	10.09	36.55	0.92	2017
Zinc-enriched rice varieties	3.04	14.29	0.28	2021
CGIAR-related varieties (year 2000 and onwards)	26.35/26.5	69.33/69.75	2.41/2.43	2016

Note: The second column illustrates the percentage of households using CGIAR varieties. In the third column, we consider a village to be using a variety if one or more households use it. The estimated number of households in Column 4 is calculated by multiplying each crop innovation adopting household by its weight and then summing the corresponding results. Column 5 provides the weighted average of the release year of varieties, where the weight is the percentage of households cultivating each variety.

We do not have DNA fingerprinting data for the Aman season. We have a point of reference (Kretzschmar et al., 2018) reporting DNA fingerprinting results for the Aman season 2014/15. Table 18 gives a comparison of our self-reported results from Aman 2023 with the DNA fingerprinting results from Kretzschmar et al.(2018). The blue highlighted rows indicate CGIAR varieties. The self-reported estimates in Column 2 are based on the 1,696 households that cultivated Aman rice in 2023. Adoption of some varieties has been stable, even though the two surveys were almost nine years apart. For other varieties, there has been substantial growth. For instance, the adoption of BRRI Dhan 49 and 51 (both CGIAR varieties) has increased by over four times since 2014.

Table 18: Comparison of major Aman variety adoption between the SPIA-BIHS survey and Kretzschmar et al. (2018)

Rice variety	% of Aman-cultivating households in 2023 (self-reported)	% of Aman-cultivating households in 2014-15 from Kretzschmar et al. (2018)
Guti/rajshahi/lalshorna	23.21	18.45
BRRI Dhan-49 (2008)	**12.71**	**2.99**
BRRI Dhan-51 (2010)	**5.51**	**1.37**
BRRI Dhan-11 (1980)	**3.95**	**4.53**
BRRI Dhan-22 (1988)	**3.79**	**Breeder seed unavailable at the time of Kretzschmar study. 9 out of 23 self-reported samples clustered with Bangladeshi Modern Varieties. Cluster analysis sorted the farmer samples according to their relatedness.**
Ronjit	3.74	NA
Dhani gold / Danigol / Dhanikul / Dhanigul	3.34	NA
Jira	2.74	NA
Paijam	2.54	20 (1.7%) of the 32 (2.7%) samples named by farmers as Paijam closely matched with Patisail, suggesting a relationship.
BRRI Dhan-23 (1988)	**2.13**	**NA**
Bhojon (white/coarse)	2.02	NA
BRRI Dhan-39 (1999)	1.70	NA
BRRI Dhan-28 1994)	**1.55**	**NA**
Katari	1.41	NA
BINA 7 (2007)	1.37	Although more than 30 farmers were reported to be growing BINA Dhan 7, not a single match could be made with the respective breeders' references.
Mota [Bold round grain]	1.27	Secondary comparison using 3k genome reference set found that most of the self-reported *Mota* [6.2%] variety closely matched TK Deep Straw
BRRI Dhan-75 (2016)	1.26	NA
BRRI Dhan-29 (1994)	**1.2**	**NA**
BRRI Dhan-52 (2010)	1.2	5.21
BRRI Dhan-32 (1994)	1.09	NA
Haridhan	1.15	Predominantly matched Indian accession UPRH265 and was commonly named Horidhan, a farmer-made variety that became famous in the press and whose origin is still under dispute.
Mamun	1.05	NA

Note: CGIAR-related varieties highlighted in blue.

Table 19 shows aggregate reach estimates of CGIAR rice varieties during Aman season, based on farmer self-reported data. In aggregate, we estimate that 3.53 million households use CGIAR-related Aman varieties. The difference between the lower and upper bounds continues to be minimal. Furthermore, the adoption of flood-tolerant, salt-tolerant, and lodging-tolerant rice varieties has grown in recent years, but none of these categories of varieties occupies more than an 8% share of rice-growing households. Like with Boro varieties, the weighted year of release indicates that the average adopter of a CGIAR-related variety is using a variety over 20 years old. This is also reflected in the lower estimates for CGIAR-related varieties released post 2000, shown in the bottom row of Table 18.

Table 19: Self-reported reach estimates for rice for Aman season across all plots

Name of crop innovation	% of rice-growing households with CGIAR-related varieties (lower/upper bound)	% of villages with CGIAR-related varieties (lower/upper bound)	Estimated number of households (millions; lower/upper bound)	Variety adoption % weighted release year of crop innovation (lower/ upper bound)
All CGIAR rice varieties	39.44/39.81	75.11	3.53/3.56	2001
Salt-tolerant rice	3.01	8.44	0.27	1994
Flood-tolerant rice	7.24	21.94	0.65	2010
Lodging-tolerant rice	3.11 / 3.59	13.08/14.35	0.28 / 0.32	2014/2012
Zinc-enriched rice	0.66	2.11	0.06	2019
CGIAR varieties (year 2000 and onwards)	24.91/24.96	52.74	2.23	2010

Note: The second column illustrates the percentage of households using CGIAR varieties. In the third column, we consider a village to be using a variety if one or more households in the village use the variety. The estimated number of households in Column 4 is calculated by multiplying each crop innovation adopting household by its weight and then summing the corresponding results. Column 5 provides the weighted average of the release year of varieties, where the weight is the percentage of households cultivating each variety.

Compared to the Boro and Aman seasons, the Aus season is of minor importance. Only 12% of agricultural households planted crops in the Aus season, with a similar pattern for rice-producing households. This explains why only approximately 400,000 households (lower bound) are using CGIAR Aus varieties (Table 20). While this number is small, in aggregate, it represents just less than half of the Aus rice-cultivating households. The varieties released post 2000 also follow a similar trajectory, where they account for only half of the CGIAR paddy adoption.

Table 20: Self-reported reach estimates for rice for Aus season across all plots

Name of crop innovation	% of rice-growing households with CGIAR-related variety (lower/upper bound)	% of villages with CGIAR-related variety (lower/upper bound)	Estimated number of households (millions; lower/upper bound)	Variety adoption percentage weighted release year of crop innovation (lower/upper bound)
All CGIAR rice varieties	42.26/46.5	63.16/65.79	0.39/0.43	2000
Salt-tolerant paddy	0.26	1.32	0.002	2010
Flood-tolerant paddy	0.52	2.63	0.005	2013
Lodging-tolerant paddy	2.9	5.26	0.027	2017
Zinc-enriched paddy	0.67	1.32	0.006	2015
CGIAR varieties (year 2000 and onwards)	21.67/22.74	32.89/34.21	0.2 / 0.21	2010 / 2011

Note: The second column illustrates the percentage of households using CGIAR varieties. In the third column, we consider a village to be using a variety if one or more households in the village use the variety. The estimated number of households in Column 4 is calculated by multiplying each crop innovation adopting household by its weight and then summing the corresponding results. Column 5 provides the weighted average of the release year of varieties, where the weight is the percentage of households cultivating each variety.

6.1.3 Wheat

Approximately 60% of wheat-growing households report cultivating a CGIAR-related variety (Table 21). Gade et al. (2021) conducted DNA fingerprinting of wheat samples across the six wheat-growing regions in Bangladesh during the 2018–2019 cropping season. However, as ours was a rural representative sample, it did not only focus on wheat-growing regions. Except for the landrace variety Kheri, all the other DNA fingerprinted varieties are either from CIMMYT or have a CIMMYT origin. Thus, 99% of the samples are a CGIAR-related variety.[21] As this comes from the DNA fingerprinting results instead of self-reports, we consider this more reliable than our self-reported data. From the self-reports in our data, the majority of these are relatively recently released stress-tolerant wheat varieties. Zinc-biofortified wheat represents a smaller share (18% of wheat-growing households). The most reported wheat variety name is BARI Gom 33, released in 2017, which is rich in zinc and resistant to blast. The variety is adopted by 17.98% of wheat-growing households. CGIAR-related wheat varieties are estimated to be grown by 348,000 households in 2024.

6.1.4 Maize

We find that 12.4% of maize-growing households report cultivating a CGIAR-related variety (Table 21). Of these, approximately half (6.1% of maize-growing households) cultivate varieties considered stress-tolerant. The most widely reported variety name is BARI Hybrid Maize 1, released in 2000, which we do not consider to be a CGIAR-related variety. BARI Hybrid Maize 1 was developed by crossing three inbred lines collected from Thailand. The variety is adopted by 12.1% of maize-growing households. The adoption-weighted average year of release is 2011. Stress-tolerant varieties are much more recently released (2017) than other types of improved maize varieties. CGIAR-related maize varieties are estimated to be grown by 145,000 households in 2024.

6.1.5 Lentil

We find that 41.8% of lentil-growing households cultivate a CGIAR-related variety (Table 21). All of these CGIAR-related varieties are disease resistant, and most of these (34%) are also micronutrient-rich. The most widely reported variety name is BARI Masur 8, released in 2015, which is disease resistant to stemphylium blight. The variety is adopted by 30.9% of lentil-growing households. Yigezu et al. (2022) conducted DNA fingerprinting in ten major lentil-growing districts in western Bangladesh and found that about 69.5% of the sampled area had improved CGIAR-related lentil varieties. Like wheat, we consider the DNA fingerprinting results to be a more accurate representation of CGIAR lentil adoption. CGIAR-related lentil varieties are estimated to be grown by 92,000 households in 2024.

[21] We aim for consistent treatment across crops so use the same decision rule about parentage as we do for rice varieties.

6.1.6 Potato

We estimate that CGIAR-related potato varieties are cultivated by 14.4% of potato-growing households (Table 21). Most of the varieties reported by farmers are considerably older than for the other crops, with the average adoption weighted year of release being 1998. For example, the most widely reported variety name is Diamond (white-fleshed), which is a non-CGIAR-related local variety. The variety is adopted by 8.85% of potato-growing households. More recently released virus- and disease-resistant potato varieties are cultivated by approximately 5% of potato-growing households. CGIAR-related potato varieties are estimated to be grown by 126,000 households in 2024.

6.1.7 Sweetpotato

Only 11 households cultivated sweetpotato, among which 4 households cultivated CGIAR-related sweetpotato varieties.

6.1.8 Groundnut

We estimate that 34.4% of the groundnut-growing households cultivate CGIAR-related varieties, with most of them being short-duration groundnuts. The most reported variety is BARI Chinabadam-6, released in 1998. The variety is adopted by 18.1% of groundnut-growing households.

6.1.9 Chickpea

Only one household cultivated chickpea, and it was not a CGIAR-related variety.

Table 21: Self-reported reach of crop germplasm innovation

Name of crop innovation	% of households with a variety among the households cultivating that crop	% of all villages with variety	Estimated number of households (in millions)	Adoption weighted year of release
CGIAR-related wheat varieties	**61.43**	**9.45**	**0.348**	**2005**
Stress-tolerant wheat	40.0	4.7	0.226	2015
Disease-tolerant wheat	51.13	6.91	0.289	2011
Zinc-biofortified wheat	18.0	1.8	0.102	2017
CGIAR-related maize varieties	**12.4**	**8.4**	**0.145**	**2011**
Stress-tolerant maize variety	6.1	4.0	0.071	2017
Protein-enriched maize variety	1.5	0.7	0.018	2003
Other improved maize varieties	3.8	2.9	0.045	2006
CGIAR-related lentil varieties	**41.8**	**2.9**	**0.092**	**2011**
Disease-resistant lentil	41.8	2.9	0.092	2011
Micronutrient-enriched lentil (zinc and/or iron)	34.0	1.8	0.075	2014
CGIAR-related potato varieties	**14.4**	**8.7**	**0.126**	**1998**
Stress-tolerant potato	10.5	6.2	0.092	1992
Virus/disease-resistant potato	4.9	3.6	0.043	2004
CGIAR-related groundnut varieties	**34.4**	**2.9**	**0.096**	**2006**
Short-duration groundnut	31.5	2.6	0.088	2006

Note: The second column illustrates the percentage of households using CGIAR varieties. In the third column, we consider a village to be using a variety if one or more households in the village use the variety. The estimated number of households in Column 4 is calculated by multiplying each crop innovation adopting household by its weight and then summing the corresponding results. Column 5 provides the weighted average of the release year of varieties, where the weight is the percentage of households cultivating each variety.

6.2 Aquaculture Innovations

In the following section, we highlight the two key CGIAR-related aquaculture strains: G3 rohu and Genetically Improved Farmed Tilapia (GIFT). As shown in Table 22, 10.6% of tilapia-growing households purchased GIFT tilapia in the last year, and 6.5% of rohu-cultivating households purchased the G3 strain, despite it having only been released in 2020. We must note that fish strain data were only collected from households that bought fingerlings. Therefore, Column 2 presents the weighted percentage of households that have purchased the CGIAR-related strain among all households farming the relevant species in the past one year. Column 4 shows the percentage of all aquaculture households that purchased fingerlings.

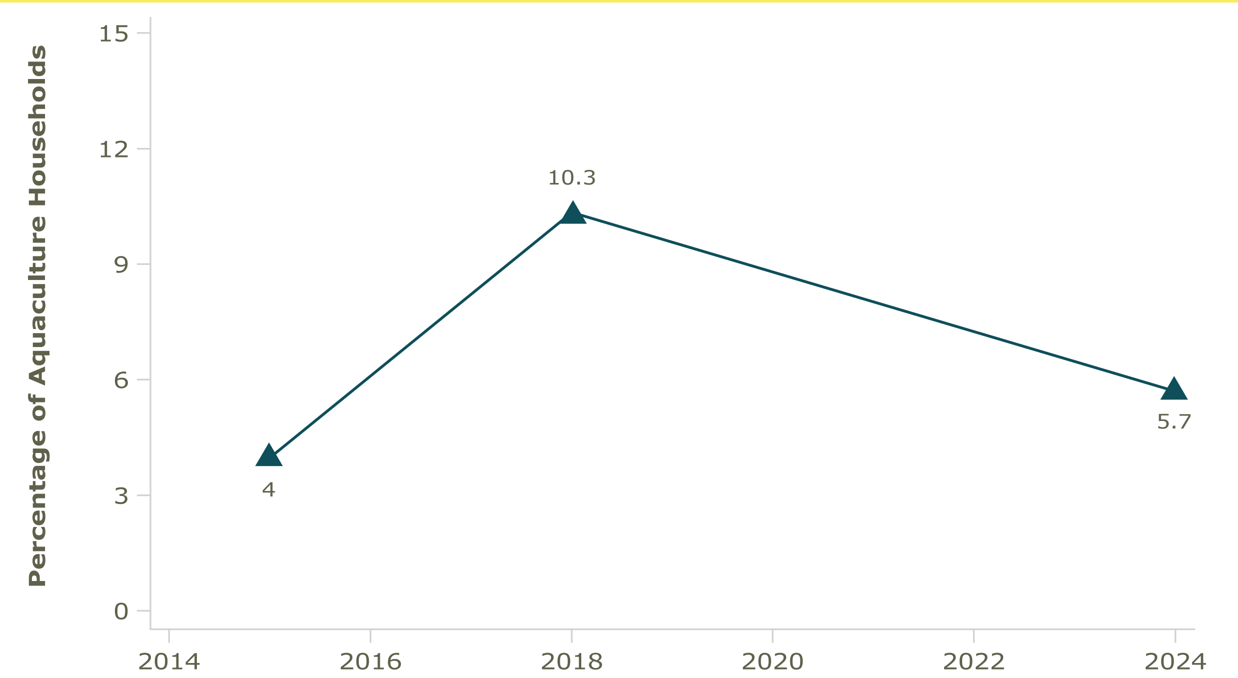
Beyond individual households, GIFT tilapia was found in 25.68% of all villages where at least one household in the village farmed tilapia; similarly, G3 rohu has already expanded to 15.2% of villages farming rohu. The estimated reach of GIFT tilapia and G3 rohu stands at approximately 218,090 and 151,630 households, respectively. As previously noted, these estimates represent a conservative lower bound, accounting only for the 63.8% of rohu and 56.6% of tilapia households that purchase fingerlings each year, indicating that the actual reach of these strains in rural Bangladesh might be considerably higher.

Table 22: Reach estimates for improved fish strains in the past one year

Name of fish strain	% of households purchasing strain among all households farming the species (past 1 year)	% of villages with at least one household purchasing strain (past 1 year, among all villages with households farming the species)	% of all aquaculture households purchasing any fingerlings in the past 1 year	Estimated number of households (in thousands)
G3 rohu	6.46	15.23	63.8	151.63
GIFT tilapia	10.64	25.68	56.6	218.09

Finally, we examine the culture of small indigenous fish species, such as Mola, Dhela, Kachki, and Chapila. Traditionally harvested from open waters, CGIAR research on the nutritional benefits of consumption of these small indigenous species (SIS) has aimed to enhance their availability and the sustainability of supply. Figure 24 illustrates that the percentage of aquaculture households growing SIS increased from 4% in 2015 to 10.3% in 2018, reflecting significant promotional efforts. However, in the past six years, this figure has declined to 5.7%, suggesting potential challenges in sustaining support for these practices and/or shifting priorities among aquaculture households.

Figure 24: Percentage of aquaculture households raising small indigenous species of fish (2015-2024)



Strikingly, of the 10.3% of aquaculture households that raised SIS in 2018, over half (54%) had exited aquaculture by 2024. This aligns with the findings of Aziz et al. (2021), Khan et al. (2022), and Hossain et al. (2014), which highlight a significant decline in natural fish habitats across Bangladesh. Our data reveals that 50% of these exiting farmers were based in Dhaka, followed by 12% each in Barisal and Chittagong. Among the SIS farmers who remained in aquaculture, 65% had transitioned to raising rohu, and 52% shifted to raising tilapia by 2024. Only 8% of farmers who were raising SIS in 2018 continued to do so in 2024; the remaining farmers currently raising SIS are either new entrants or those who switched from other species.

Despite these changes, our estimates indicate that approximately 203,000 households continue to cultivate SIS. Additionally, 12.3% of fishing villages reported cultivating these species in the past one year, underscoring their continued significance as a food and income source for many rural households (Table 23).

Table 23: Reach estimates for improved fish strains in the past one year

	% of aquaculture households with species (past 1 year)	% of aquaculture villages with species (past 1 year)	Estimated number of households (in thousands)
Small Indigenous Species (SIS)	5.71	12.3	203.1

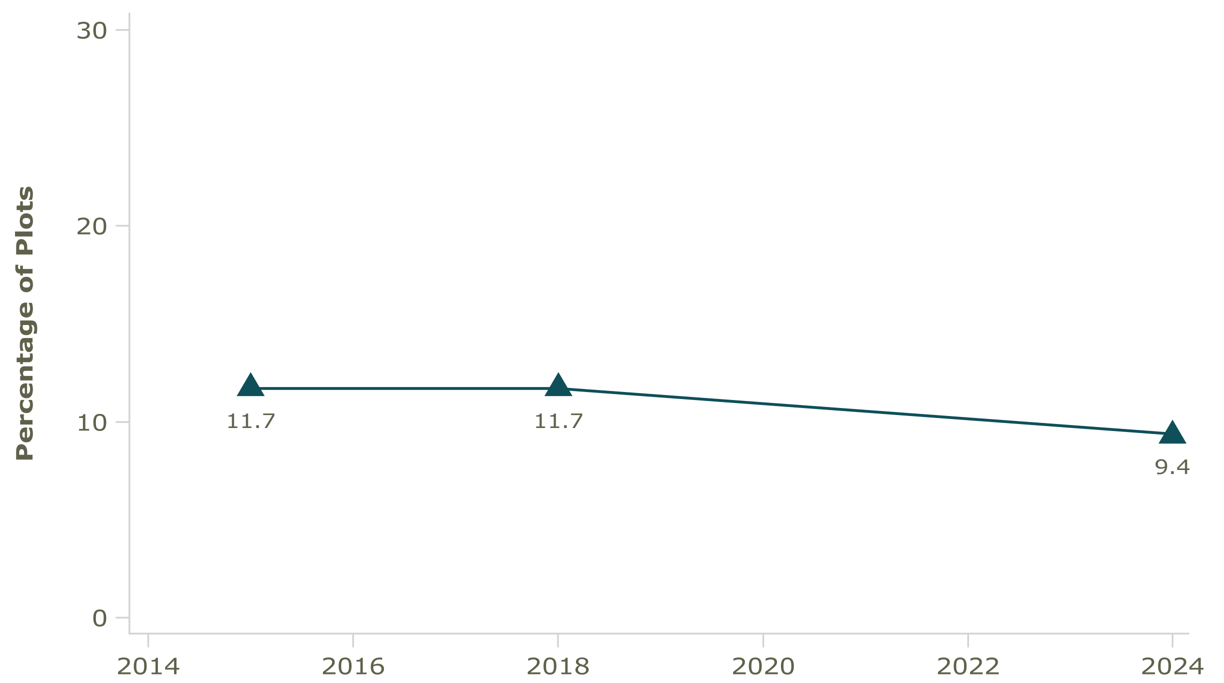
6.3 Natural Resource Management

6.3.1 Irrigation

Over the past three decades, Bangladesh has increasingly transitioned toward irrigated dry-season cultivation, driven by the development of an extensive irrigation network (Moniruzzaman, 2015). As depicted in Figure 25, the proportion of rain-fed plots during the dry season has slightly declined since 2015, dropping to 9.4% by 2024.[22] This shift has significantly increased the demand for both surface and groundwater resources.

As reviewed in Section 4.3, to address these growing pressures, the International Rice Research Institute (IRRI) and the Bangladesh Rice Research Institute (BRRI) have introduced various strategies to encourage sustainable agricultural practices. These efforts include techniques such as Alternate Wetting and Drying (AWD), solar-powered irrigation pumps, zero-tillage farming, direct seeding, drip irrigation, and mechanical weeding. Additionally, mobile applications have been developed to assist farmers in tracking crop management practices.

Figure 25: Percentage of rainfed plots (2015-2024)

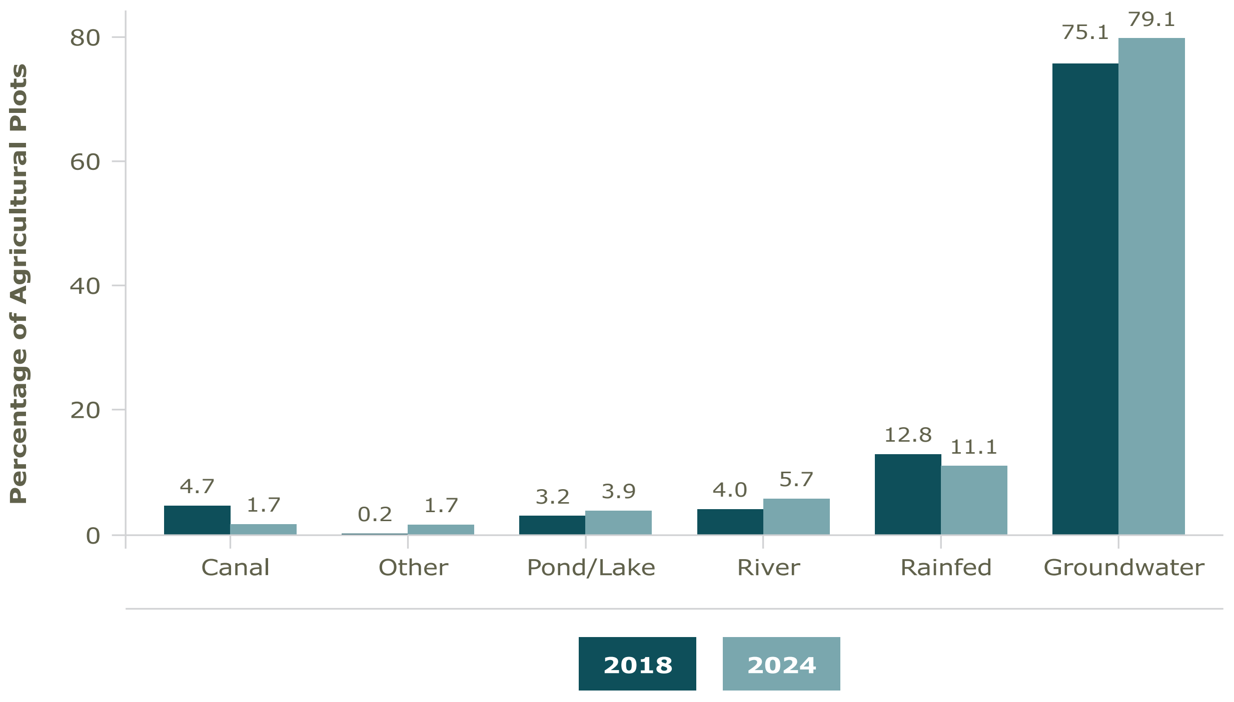


Note: This covers all plots that were agriculturally active in the dry season in each BIHS round.

[22] Farmers reported primarily cultivating Rabi crops such as mung bean, lentil, mustard, chickling vetch, and soybean on these rain-fed plots.

Similar to 2018, most irrigated plots in 2024 continue to rely on groundwater as their primary water source (79.1% of plots; Figure 26). The 4-percentage-point increase from 2018 to 2024 can be attributed to plots transitioning from canal and rainwater to groundwater for irrigation. There is an increase in the use of ponds, lakes, and rivers for irrigation. This change has also led to increased adoption of axial flow pumps (AFPs) promoted by the International Maize and Wheat Improvement Center (CIMMYT), which is discussed in Section 6.3.2. Despite these emerging trends, these alternate water sources remain much less widely used than groundwater pumping.

Figure 26: Primary water source for percentage of agricultural plots in the dry season

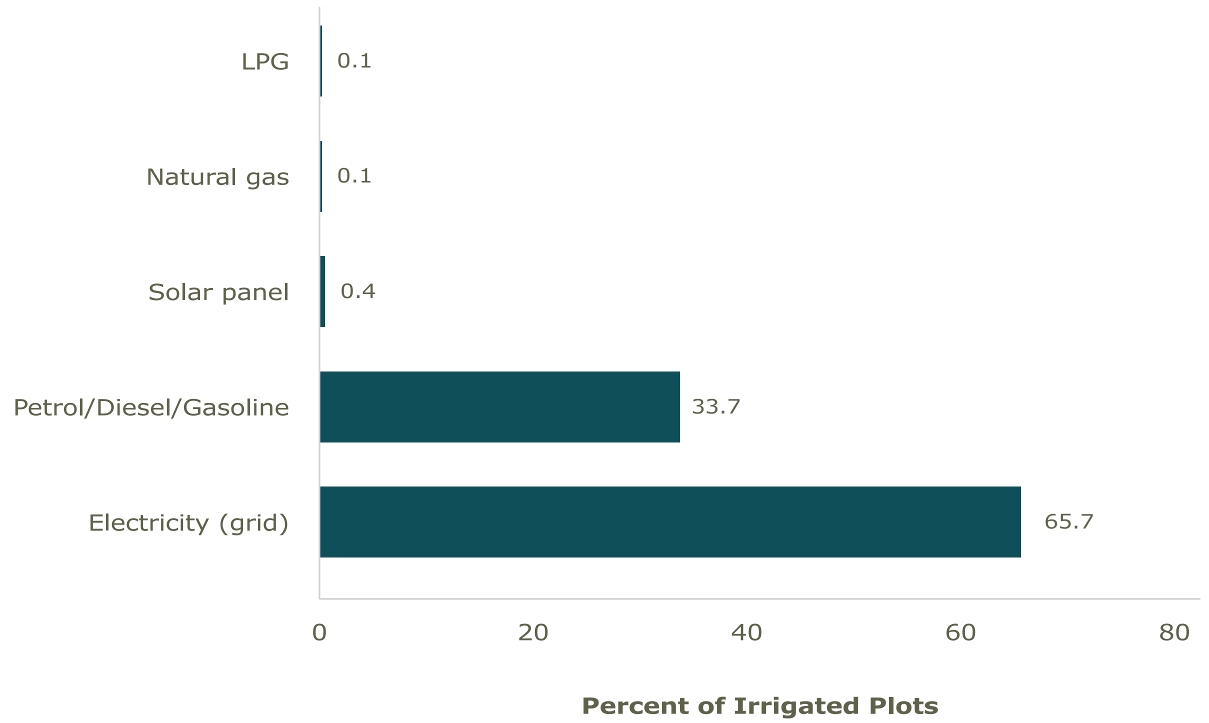


Note: This includes all plots that were agriculturally active in the dry season in each BIHS round.

We analyze the primary power sources for irrigation pumps to evaluate the adoption of solar-powered pumps compared to traditional energy sources. The Solar Irrigation for Agricultural Resilience (SoLAR) project, initiated by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and the CGIAR Research Program on Water, Land and Ecosystems (WLE), has been implemented by the International Water Management Institute (IWMI) in Bangladesh since 2010. Despite these initiatives, only 0.4% of irrigated plots[23] currently utilize solar-powered pumps (Figure 27), with the majority still dependent on grid electricity or fossil fuels.

[23] Out of all irrigated plots, only 70 reported using a solar-powered pump.

Figure 27: Primary fuel source for irrigated plots in the dry season (%)



Note: This includes all irrigated plots that were agriculturally active in the dry season in BIHS 2024.

6.3.2 Alternate Wetting and Drying

In Figure 28 we observe the water management practices of irrigated Boro rice plots in 2024. Continuous flooding remains the predominant method, practiced on 66.1% of plots. This is followed by 14% of plots that had at least one drying cycle with a minimum five-day dry-down period. Approximately 7.1% of plots report no standing water at all, and 4.1% of plots have at least two drying cycles with over 5 days of drying. When farmers were asked about using perforated pipes to check water depth, no households reported using the technology on their plots in 2024. This indicates that while farmers do dry their fields, their version of Alternate Wetting and Drying (AWD) does not fully correspond to the version promoted by the CGIAR.

A household, in this analysis, is considered as practicing AWD if it has at least one plot that is deliberately dried for five days at some point during the Boro season. Among the 1,553 BIHS households that cultivated irrigated Boro rice, 19.3% practiced AWD on at least one plot, and 15.4% practiced AWD on all their plots. By contrast, 62% maintained continuous flooding on all their plots. The remaining households either had plots that drained automatically or dried their fields for fewer than five days.

Figure 28: Water management practices of plots in the Boro season in 2024

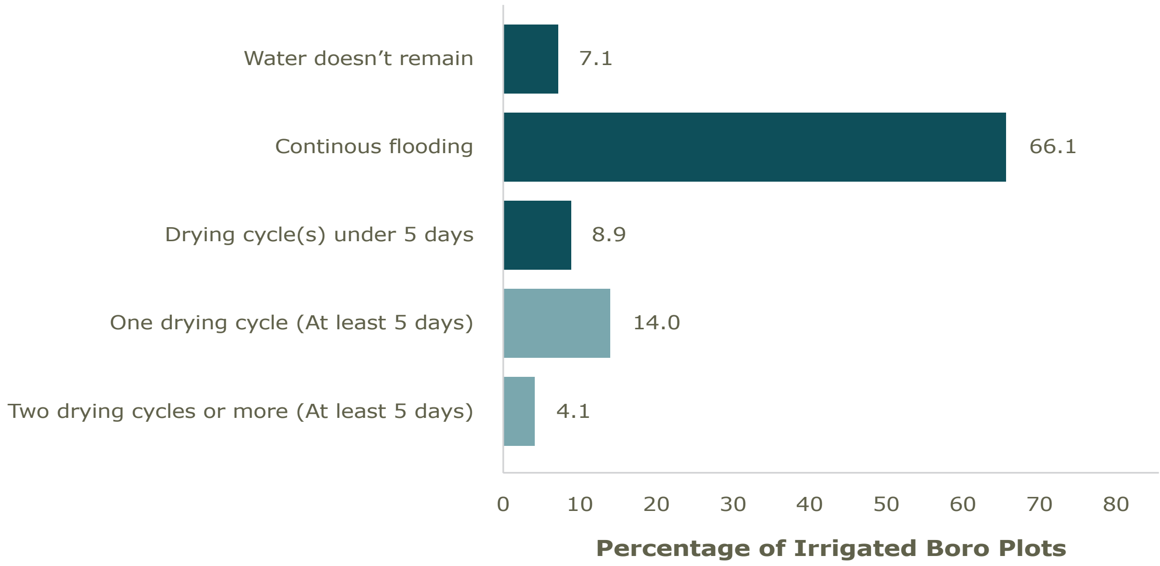
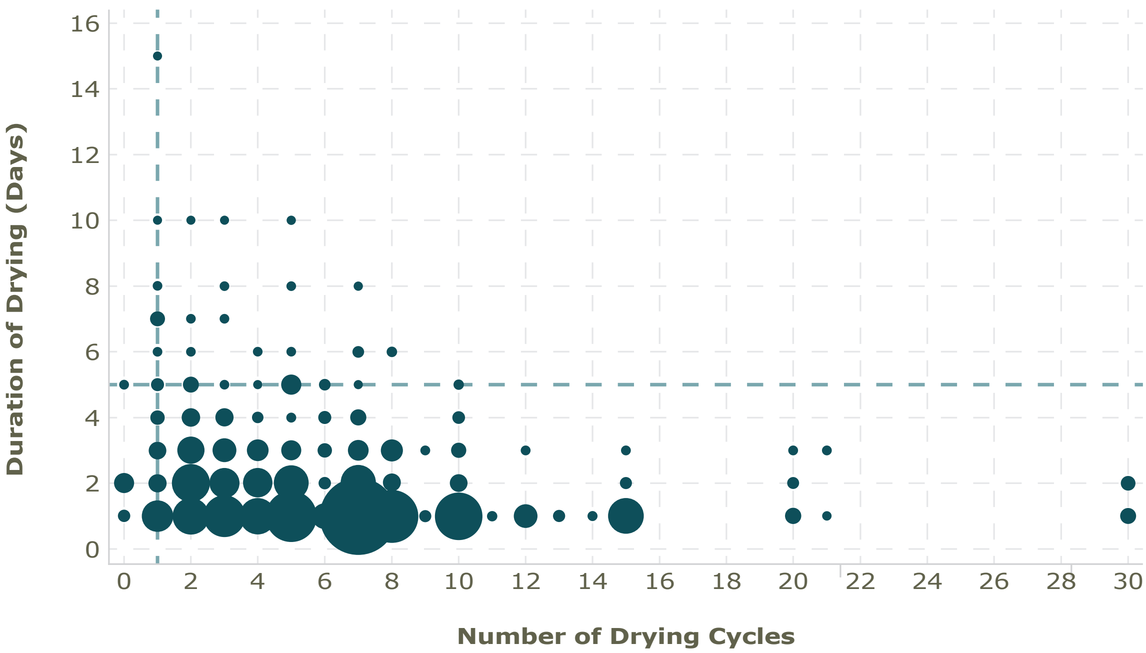


Figure 29 illustrates the bivariate distribution of the variables used to define AWD in this report. It reveals a general preference for shorter and less frequent drying periods among irrigated Boro rice plots in 2024. While the number of drying cycles during a growing season shows significant variation, ranging from 1 to 8 cycles, the duration of drying is predominantly concentrated between 1 to 3 days. This pattern indicates that the AWD drying practice is typically limited due to the duration of drying.

Figure 29: Duration and frequency of drying cycles on irrigated Boro plots in 2024



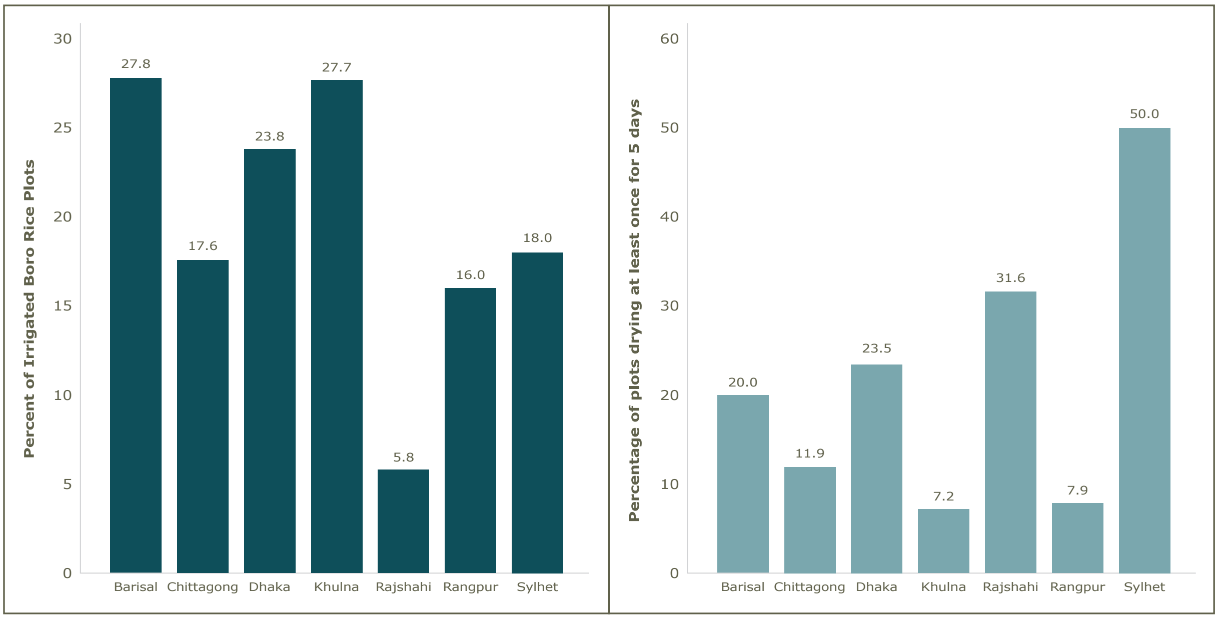
Note: The size of each bubble represents the frequency of plots exhibiting the corresponding combination of drying cycle count and duration.

Figure 30 (left panel) highlights substantial divisional variation in the adoption of drying practices on irrigated Boro rice plots in Bangladesh during the 2024 growing season. Here, AWD is defined as at least one drying cycle lasting a minimum of five days. Many farmers report having dry fields. But these drying spells last only 1-2 days.

We see that Barisal leads with 27.8% of Boro plots practicing AWD, as defined by at least one drying cycle for at least 5 days, closely followed by Khulna (27.7%) and Dhaka (23.8%). In contrast, Rajshahi exhibits the lowest adoption rate at 5.8%. It is important to note that these differences may not be attributed solely to AWD as an innovation package, as other local practices or environmental factors could also produce the same observable characteristics.

To determine whether water shortages alone drive this behavior or whether farmers are intentionally using AWD, we refer to Figure 30 (right panel), which shows the percentage of AWD plots experiencing water shortages across divisions. In Sylhet, half (50%) of AWD[24] plots faced water shortages, whereas only 7.2% of AWD-practicing plots in Khulna and 11.9% in Chittagong reported similar issues. These findings suggest that the adoption of AWD is not solely a response to water scarcity. The summary figures for adoption of AWD using two different definitions (one plot vs all relevant plots) are provided in Table 24.

Figure 30: Divisional distribution of AWD practices (left panel) and water shortages (right panel) on Boro plots in 2024



Note: A plot practicing AWD is defined as a plot that has at least one drying cycle of at least 5 days duration in the 2024 Boro season. This differs from the IRRI-defined AWD method, which involves the use of a 'field water tube' or plastic pipe to monitor water depth. Farmers using the pipe are a small subset of those drying their plots.

[24] It is important to clarify that by AWD, we refer to farmers who reported drying their fields at least once for a period of five days. This differs from the IRRI-defined AWD method, which involves using a 'field water tube' or plastic pipe to monitor water depth. Farmers who use the pipe represent a small subset of those who report drying their plots.

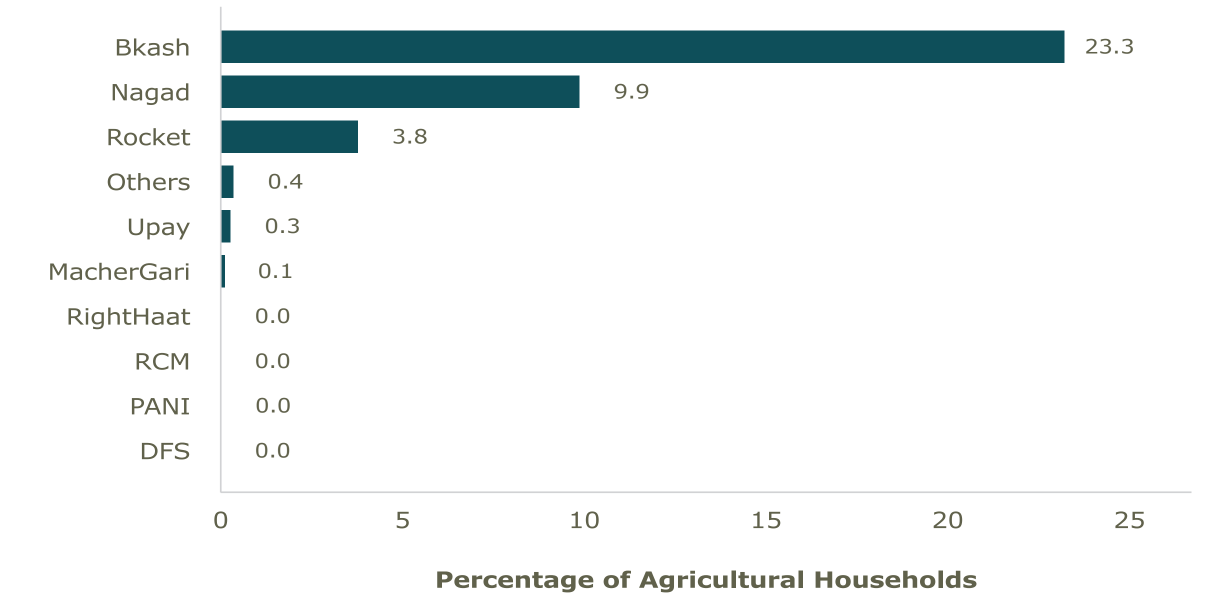
Table 24: Reach estimates for Alternate Wetting and Drying (1 plot drying cycle of at least 5 days)

AWD used on:	% of adopter households meeting the condition	% of villages with ≥1 adopter household	% of rural households meeting the condition	Estimated number of adopter households (millions)	Conditions applied
at least one plot	19.56	52.41	29.36	1.73	Rice-growing households that irrigated their land in the 2024 Boro season
all plots	15.41	47.35	29.36	1.36	Rice-growing households that irrigated their land in the 2024 Boro season

6.3.3 Digital agronomic applications

The penetration of digital agronomic applications among agricultural households in Bangladesh remains extremely limited. As shown in Figure 31, while a significant proportion of households use platforms like Bkash (23.3%) and Nagad (9.9%), primarily serving their financial transaction needs, specialized agricultural applications such as MacherGari, RightHaat, PANI, and Rice Crop Manager have negligible usage, each registering less than 0.1%. This indicates that despite the hopes vested in those who developed them to support the adoption of better agricultural practices, these specialized apps do not reach a broad audience in Bangladesh.

Figure 31: Duration and frequency of drying cycles on irrigated Boro plots in 2024

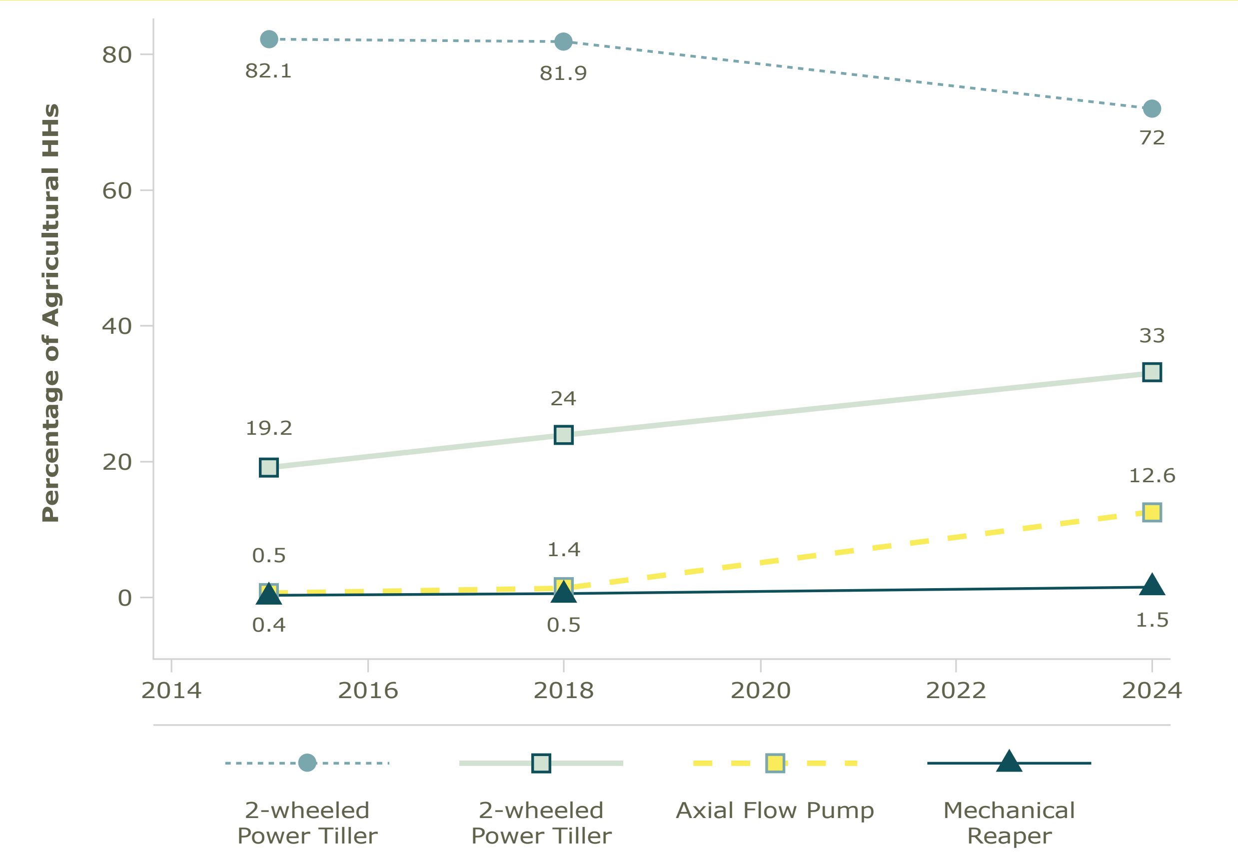


Note: Total agricultural households with a smartphone/internet is 1,588.
RCM = Rice Crop Manager

6.4 Farm Mechanization

As discussed in Section 4.4, mechanization in Bangladesh aims to address challenges related to labor shortages, inefficient farming methods, and the rising food demand driven by a rapidly growing population and climate change. In the BIHS-SPIA 2024 survey, we focused on the usage of mechanization technologies (axial flow pumps, reapers, power tillers, and tractors). Initial results show increased adoption of axial flow pumps, four-wheeler tractors, and mechanical reapers in 2024 compared to previous survey rounds Figure 32.

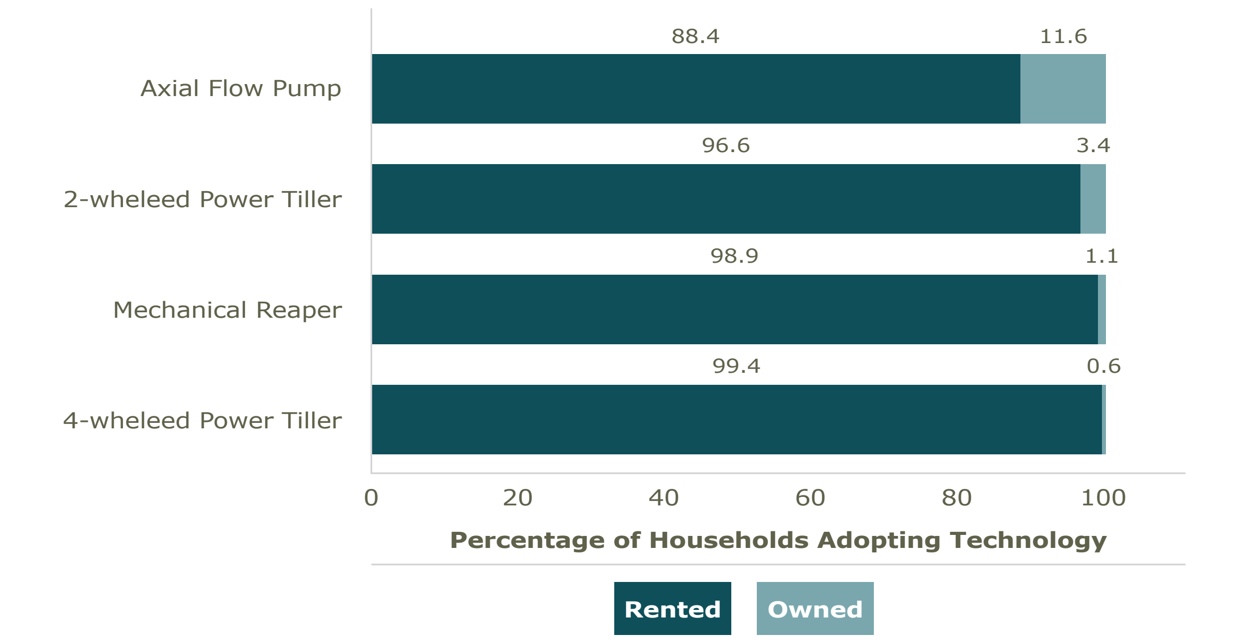
Figure 32: Agricultural technology adoption trends over time, 2015-2024



Note: Agricultral households in 2024 are 2729, 2018 are 2937, and 2015 are 2768. This excludes aquaculture HHs.

It seems that four-wheel power tillers are starting to displace the two-wheel power tillers that have dominated the sector. A thriving rental market for machinery is evident in Bangladesh, as the proportion of rented mechanical technology far exceeds the percentage of owned machines (Figure 33).

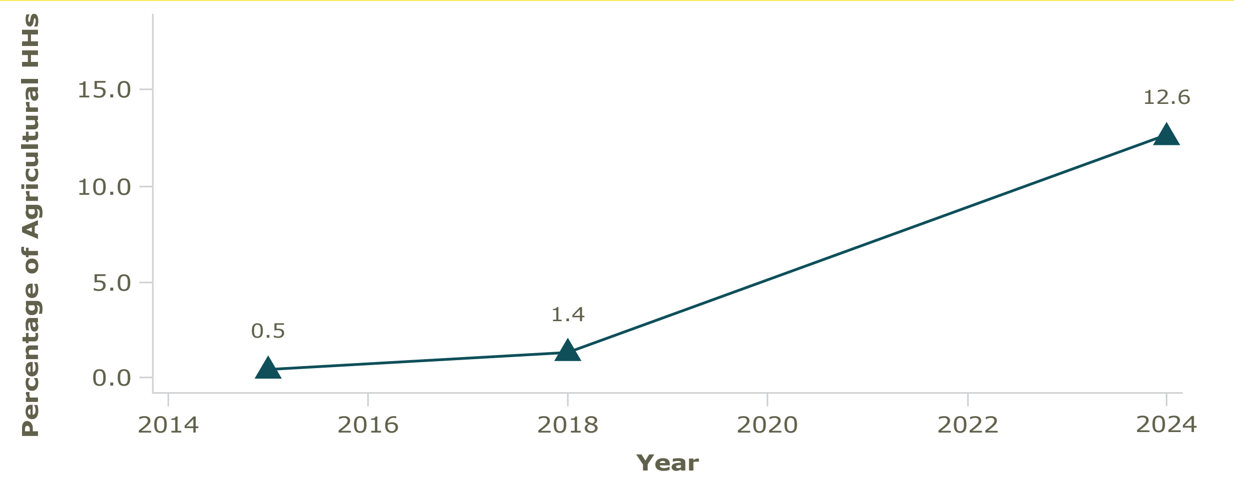
Figure 33: Rented vs owned agricultural technology in 2024



6.4.1 Axial Flow Pumps

Adoption of axial flow pumps (AFPs) has increased significantly, rising from 1.3% of agricultural plots (1.4% of households) in 2018 to 10.3% of plots (12.6% of households) in 2024 (Figure 34). We analyze trends in AFP adoption across divisions where the technology was actively promoted versus other divisions in Bangladesh.

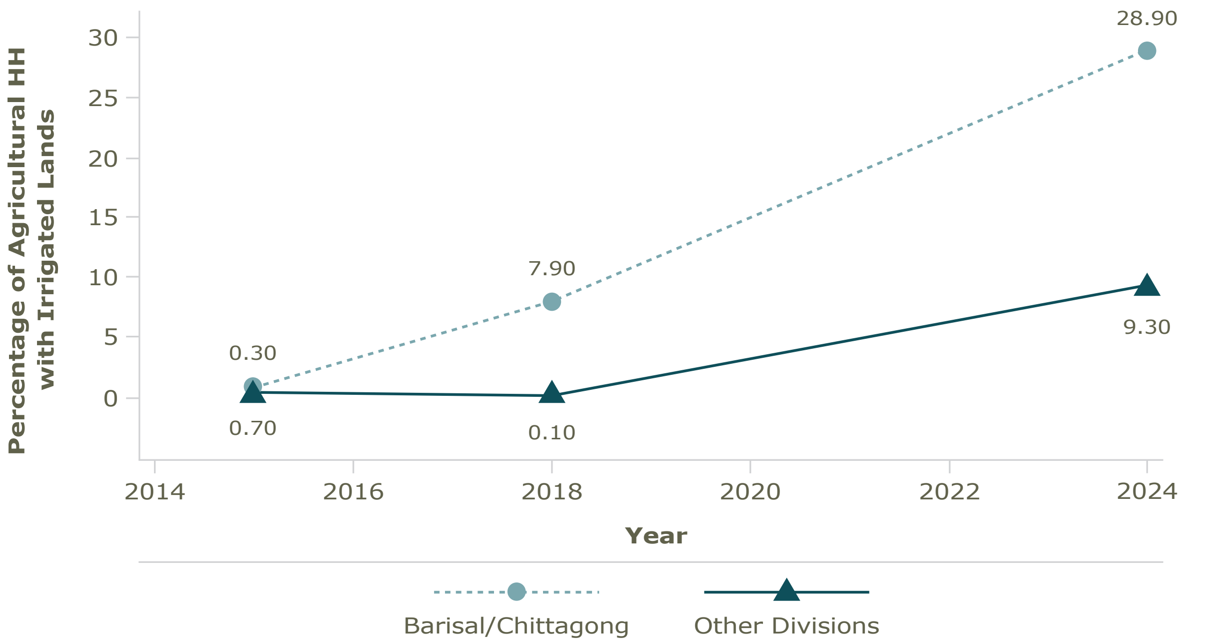
Figure 34: Axial Flow Pump Usage Over Time (2015-2024), National



Note: Agricultural households in 2024 = 2,729; in 2018 = 2,937; and 2015 = 2,768. This excludes aquaculture households.

Figure 35 highlights the significant growth in AFP usage across all divisions. Regions targeted by CGIAR initiatives, particularly through experimental programs offering AFPs in 2013–2014, experienced a much steeper rise. For example, in Barisal and Chittagong, 29.1% of households with irrigated plots adopted AFPs on at least one plot by 2024, with both divisions having been the focus of efforts to increase awareness and dissemination. Among the other divisions, Sylhet stands out, with AFP adoption increasing rapidly from 0.1% in 2018 to 29% in 2024.

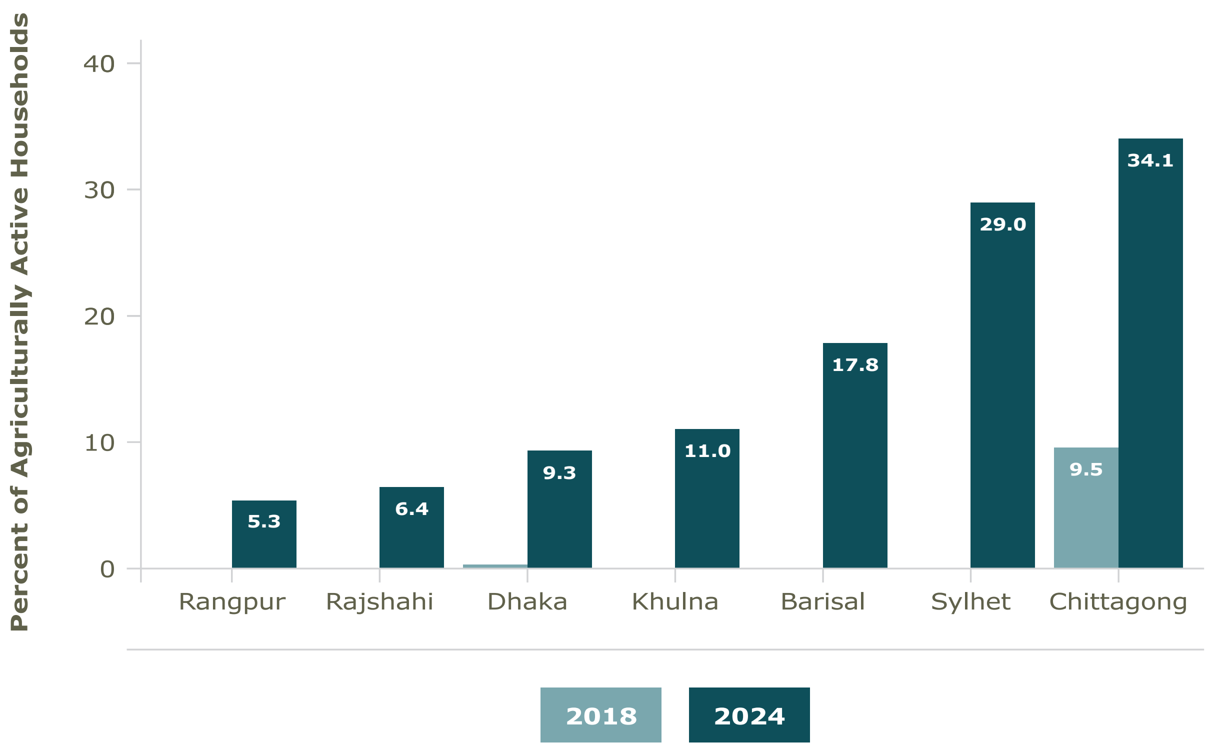
Figure 35: Axial flow pump usage in Barisal and Chittagong vs other divisions in Bangladesh



Note: Total agricultural households with at least one irrigated plot in 2015 = 3,384; in 2018 = 2,937; and 2024 = 2,512. Other divisions include Rangpur, Sylhet, Khulna, Dhaka and Rajshahi.

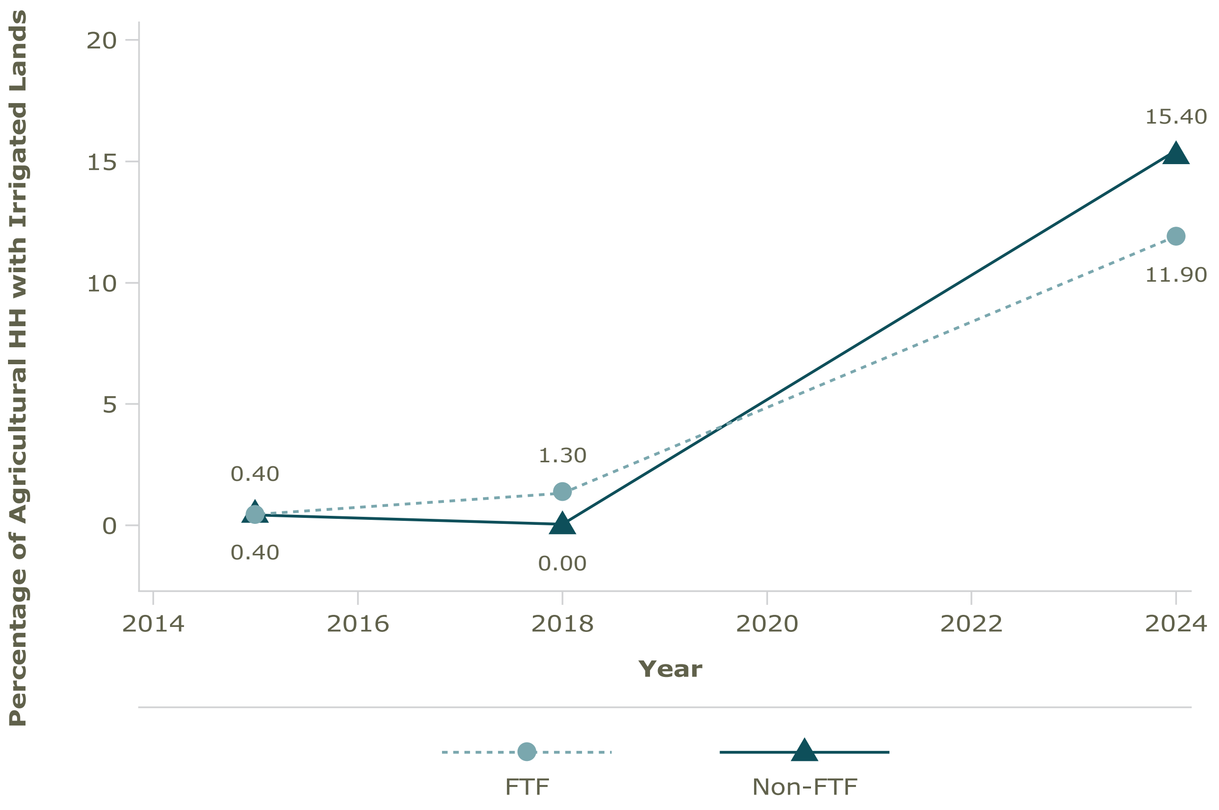
Interestingly, while AFPs were already present in Chittagong in 2018 (Figure 36), no households in Barisal or Khulna reported using AFPs as their primary pump at that time. However, in less than six years, AFP usage has risen sharply, with 11% and 17.8% of irrigated plots in Khulna and Barisal, respectively, adopting this technology.

Figure 36: Axial flow pump adoption by division (2024 vs 2018)



As a final perspective on the dynamics of AFP adoption, Figure 37 illustrates the trends among agricultural households with irrigated lands inside the Feed the Future (FTF) Zone of Influence, compared to areas outside the FTF zone, from 2015 to 2024. In the FTF zone, AFP usage began at 0% in 2015, increased marginally to 0.4% in 2018, and then sharply rose to 15.3% in 2024. Non-FTF zones, in contrast, started with a 0.4% adoption rate in 2015, growing steadily to 1.3% in 2018 and reaching 11.9% in 2024. Of these different visualizations of AFP adoption, we think that Figure 37 provides the sharpest picture of the contribution of specific interventions to promote them. The change over time in Barisal and Chittagong, leading to a 20-percentage-point higher adoption rate in 2024 for those divisions compared to all others, is a strong basis for future investigation. Broadening out to the whole of the FTF zone allows us to be consistent in our comparison to other innovations in this report, but dilutes the effect, as many areas of the FTF zone were not the priority for promoting AFPs.

Figure 37: Axial flow pump usage across Feed the Future and non-Feed the Future zones



Note: Total agricultural households with at least one irrigated land in 2015 = 3,384, in 2018 = 2,937, and 2024 = 2,512

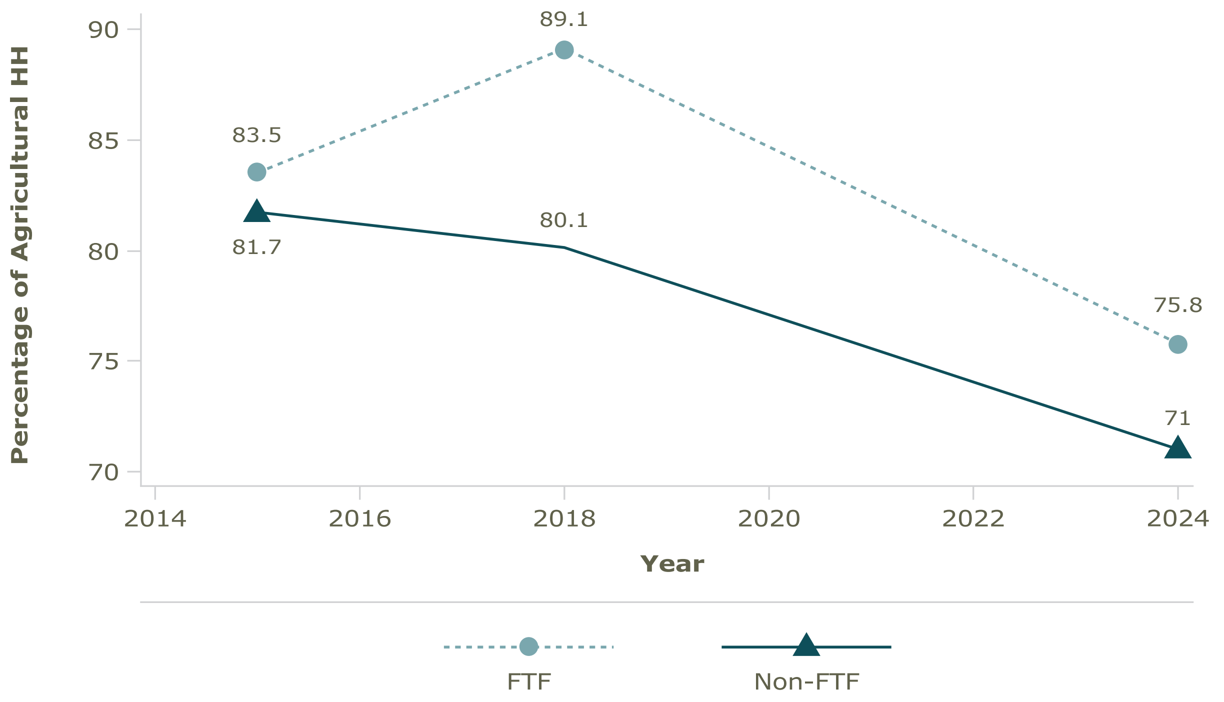
AFPs have partially offset a decline in the use of shallow tubewells seen over the period 2018 to 2024 (see Appendix M, Figure 50). When examining the characteristics of plots in 2018 that were irrigated by AFPs, we observe several key trends. Marginally more of the 2024 AFP (54.6%) plots than non-AFP (52.7%) plots were categorized as non-agricultural in 2018. As expected, we observe that 2024 AFP plots were closer to surface water sources (ponds and canals) than 2024 non-AFP plots, prior to the adoption of AFPs. In contrast, 2024 non-AFP plots reportedly were more dependent on groundwater and/or being rainfed. Clearly, AFP adoption depends on access to suitable surface water resources. We find that AFP adoption does not tend to cluster strongly within villages, because in most villages, less than 30% of the plots use AFPs (Appendix M, Figure 51) Finally, we see that AFPs are typically not combined with the use of tubewells at the household level, except in Rajshahi where groundwater is very limited. Here, almost one in four households use both AFPs and tubewells (Appendix M, Figure 52).

6.4.2 Two- and Four-Wheeled Power Tillers

The use of two-wheeled power tillers in Bangladesh has been, and remains, very widespread (Figure 32). The rental market for power tiller services has remained strong, reflecting their ongoing importance in rural farming practices, with the Agricultural Census in 2019 recording 342,598 active two-wheeled power tillers across rural Bangladesh. Nonetheless, we observe that approximately 72% of agricultural households used two-wheeled power tillers in 2024, a notable decline from a stable level of 82% in 2015 and 2018 (Figure 38). This observed decline reflects a movement towards four-wheeled power tillers/tractors. Of those not using a two-wheel power tiller in 2024, 60% had transitioned to using a four-wheeled power tiller.

The decline in two-wheel power tiller use has been more pronounced outside of the FTF Zone, reaching 71.0% in 2024 (vs 75.8% in the FTF Zone). Conversely, the trend towards greater adoption of four-wheeled power tiller/tractor use has progressed faster outside the FTF Zone than inside.

Figure 38: 2-Wheeled Power Tiller usage over time across Feed the Future and non-Feed the Future zones (2015-2024)



Note: This is the percentage of agricultural households in FTF vs non-FTF zones that responded yes to using a 2-Wheeled Power Tiller.

6.4.3 Mechanical Reapers

The adoption of mechanical reapers in Bangladesh has remained very low over the past decade, despite labor shortages experienced during peak harvesting periods. Figure 33 shows the overall trend, with usage rising from 0.33% in 2012 to 1.5% in 2024. This is a five-fold increase, but still of very minor importance overall.

In summary, axial flow pumps (AFP) have been adopted by 12.6% of agricultural households that irrigated their land in the past three seasons, with the innovation present in 50.2% of villages meeting the same conditions (Table 25). An estimated 1.65 million households across Bangladesh use AFPs, suggesting a significant impact on irrigation practices. On the other hand, two-wheeled mechanical reapers for rice, wheat, and jute are used by only 1.6% of households engaged in cultivating these crops over the past four seasons and are found in 10.4% of eligible villages. Approximately 0.21 million households have adopted the mechanical reaper, highlighting a limited role in mechanizing harvesting activities, albeit one that is growing from a low base. These are both specific examples of mechanization that have been promoted by CGIAR centers and their partners, which is why we consider them CGIAR-related innovations, but only as part of the upper bound of estimating the reach of CGIAR.

We do not include the use of two- or four-wheel tractors in the upper bound of CGIAR reach, owing to the numerous institutional and private sector players associated with promoting mechanization. We limit our presentation to considering the trends within and outside the FTF Zone of Influence.

Table 25: Reach estimates for CGIAR-related mechanization innovations

Name of machine	% of households with innovation (among condition households satisfying the conditions)	% of villages with innovation (among villages with at least one adopter)	% of agricultural households satisfying the conditions	Estimated number of households (in millions)	Conditions applied
Axial Flow Pump	12.6	50.2	77.84	1.65	Agricultural households that irrigated their land in the past three seasons
Two-wheeled mechanical reaper for rice/wheat/jute	1.60	10.37	82.94	0.21	Rice/wheat/jute cultivating households in the past four seasons

7. Who Are The Adopters?

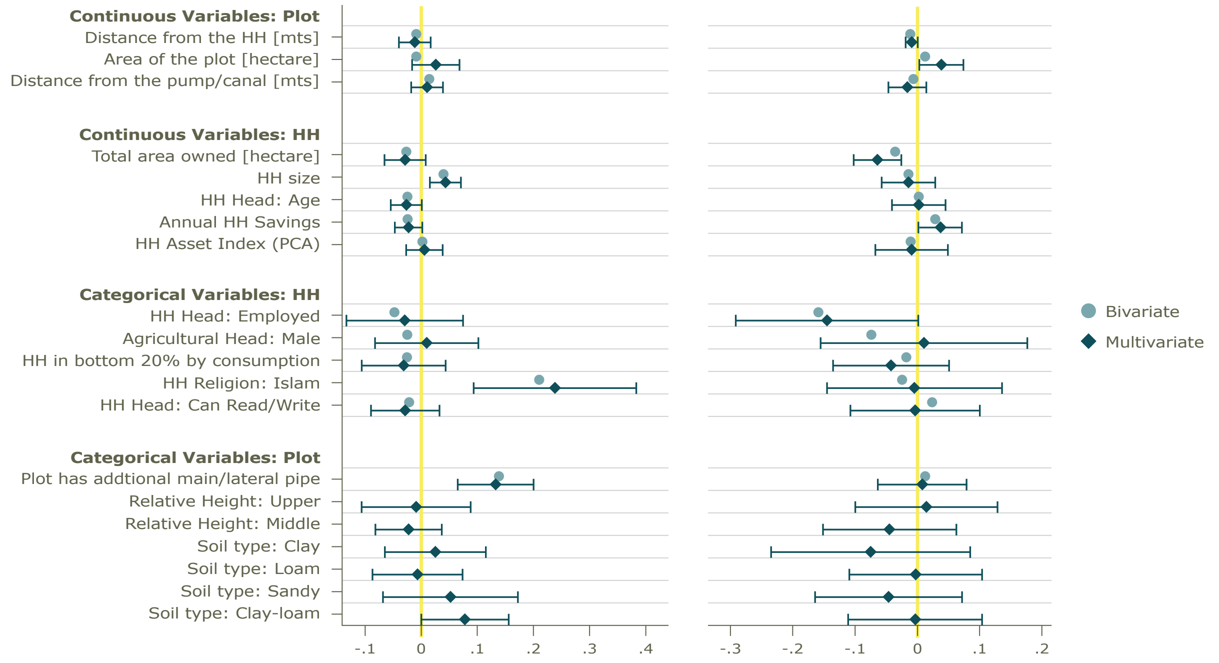
To evaluate how CGIAR-related innovations contribute to larger-scale processes of agricultural and human development, it is essential to examine not only the number of farmers reached but also the characteristics of the farmers adopting these innovations. This section examines the data from the Bangladesh Integrated Household Survey (BIHS) dataset, which allows for detailed documentation of household characteristics to identify who is adopting CGIAR-related innovations.

We analyze the adoption of CGIAR-related innovations at the plot level, using characteristics of plots and households as explanatory variables (see Appendix N). Farm size is an important first variable to consider as smallholders are typically the primary intended beneficiaries for CGIAR innovations, either implicitly or explicitly stated. We also use other geographic variables relevant for agricultural management, such as elevation and the proximity of the plot to the household. Additionally, we include variables capturing the dimensions of gender, age, social group, and economic status of household members. We focus on innovations with an adoption rate of at least 5%, ensuring a sufficient number of observations to derive meaningful insights. We examine and discuss both bivariate and multivariate relationships. The confidence interval is shown only for the multivariate regression. The BIHS sampling framework randomly selected 275 villages across seven divisions of Bangladesh and sampled 20 households per village. To account for this sampling structure, standard errors are clustered at the village level.

7.1 Crop Varieties

We examine the covariates of adoption of both Boro rice varieties (Figure 39, left panel) and other non-rice crops (Figure 39, right panel). For CGIAR-related Boro rice varieties, there are very few variables that are statistically significantly different from zero, with adoption of CGIAR varieties being uncorrelated with farm size and slightly more likely to be cultivated by households with lower levels of savings. Otherwise, CGIAR-related Boro rice varieties are evenly distributed across households with these different characteristics. For the CGIAR varieties of other crops (maize, groundnut, potato, lentil, wheat) we find that smaller farms with household heads without outside employment are more likely to be adopting CGIAR-related varieties. Covariates of adoption based on Boro and Aman self-reported data is provided in Appendix P.

Figure 39: Covariates for CGIAR-related Boro varieties (left panel) and CGIAR-related varieties for all non-rice crops (right panel)

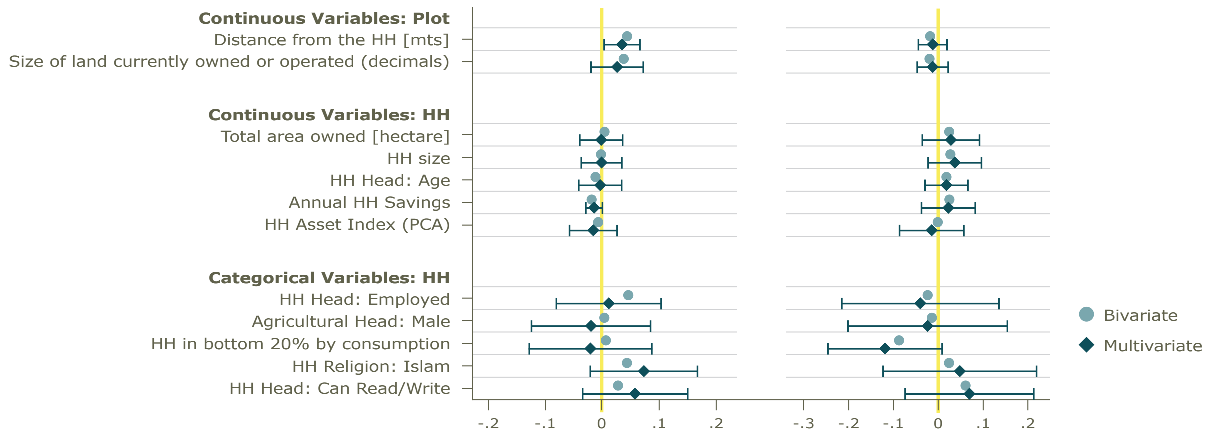


Note: For Boro paddy adoption, we examine the 1,657 plots that were DNA fingerprinted during the Boro 2024 season. In contrast, adoption of non-paddy crops, including maize, lentil, potato, groundnut, and wheat, is based on self-reported information on CGIAR varieties. For non-paddy crops, we consider all agricultural seasons and include all plots that cultivated at least one of these crops.

7.2 Aquaculture Innovations

Adoption of both the G3 rohu strain and the GIFT strain of tilapia is uncorrelated with all household-level characteristics, suggesting that these CGIAR-related aquaculture innovations are broadly applicable to households engaged in aquaculture (Figure 40).

Figure 40: Covariates of adoption of G3 rohu strain (left panel) and GIFT tilapia (right panel)

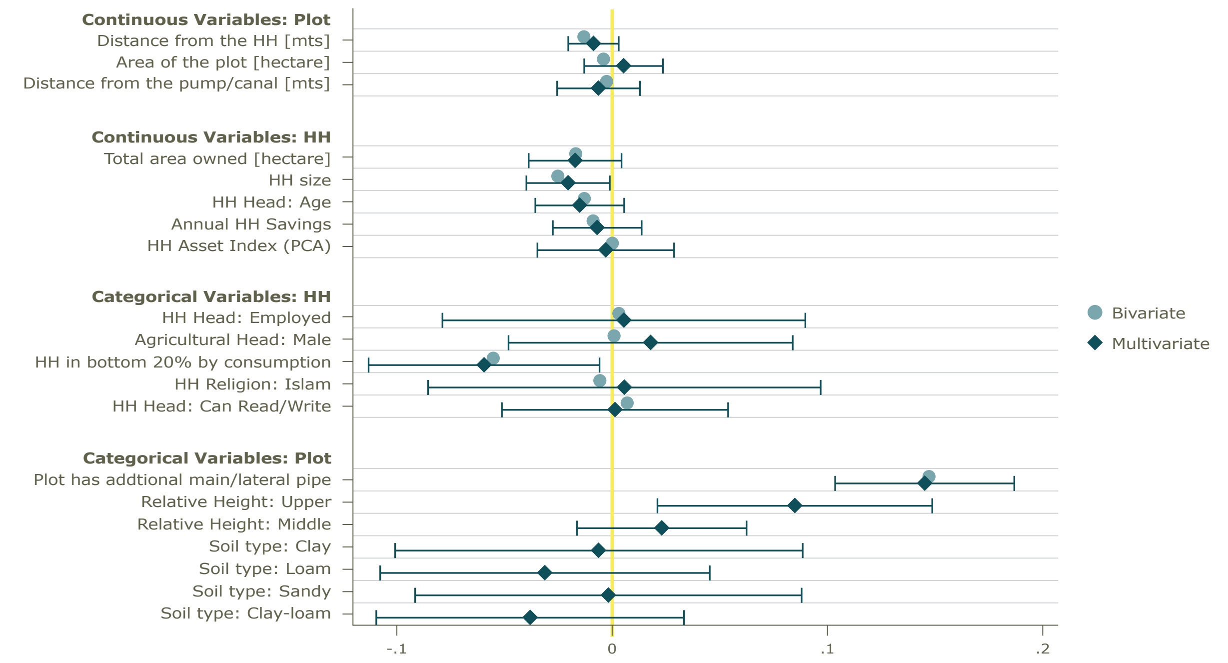


Note: For G3 rohu adoption, we analyze the 395 plots that reported the use of purchased rohu fingerlings. Similarly, for GIFT tilapia, we consider the 281 plots where farmers reported using purchased tilapia fingerlings.

7.3 Natural Resource Management

We focus on the single Natural Resource Management (NRM) practice that we observe as being adopted at scale – Alternate Wetting and Drying (AWD) in rice. To reiterate, by AWD we refer to farmers who reported drying their fields at least once for a period of five days. This differs from the International Rice Research Institute (IRRI)-defined AWD method, which involves using a 'field water tube' or plastic pipe to monitor water depth. Farmers who use the pipe represent a small subset of those who report drying their plots. According to our definition, AWD adoption is correlated with both agronomic variables and socioeconomic variables (Figure 41). From the agronomic side, AWD adoption is correlated with larger plot size, and very strongly with variables related to topography, such as the plot having an additional main or lateral pipe, and its position having relatively higher elevation. Taken together, these physical characteristics are suggestive of plots that have higher demands and costs for pumping irrigation water. In terms of soil type, clay-loam soils are negatively correlated with AWD adoption compared to sandy-loam soils, likely due to differences in moisture retention and drainage suitability. In terms of socioeconomic variables, adoption is a mixed picture, with households in the bottom 20% of the distribution of consumption being less likely to adopt. The total area owned is also negatively correlated with adoption.

Figure 41: Covariates of adoption of Alternate Wetting and Drying

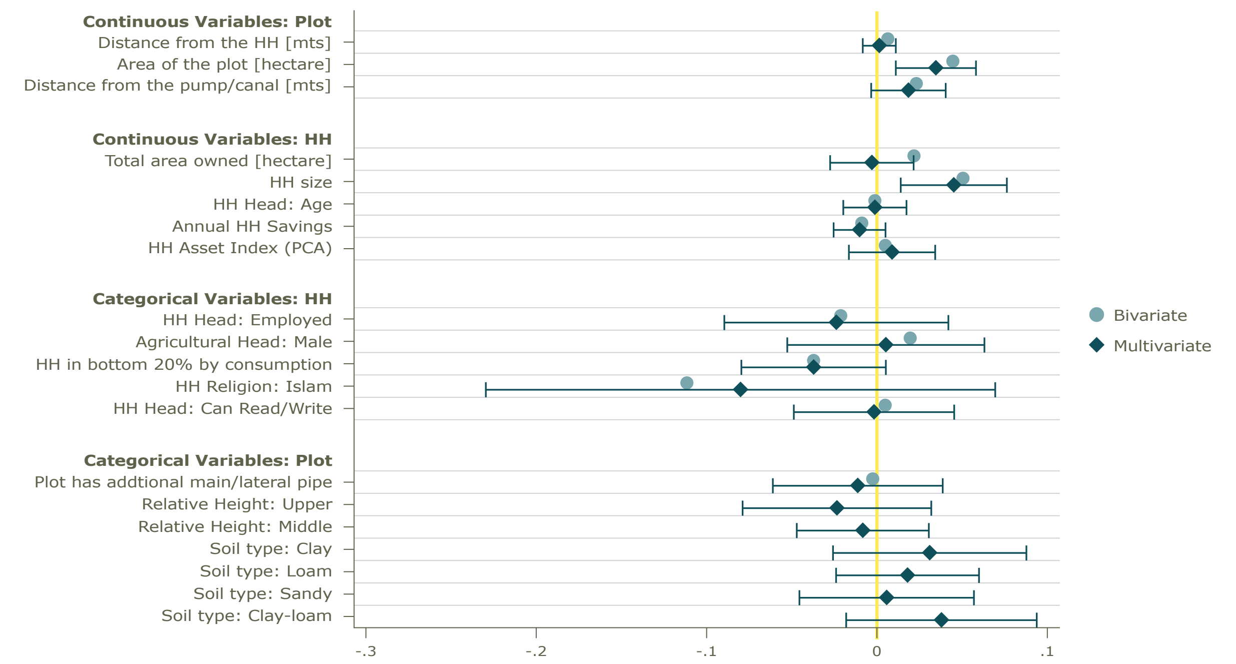


Note: The analysis includes only paddy plots where the household reported making agricultural decisions during the 2024 Boro season. All rainfed plots are excluded, retaining only irrigated plots, resulting in a final sample of 3,765 plots. Alternate Wetting and Drying (AWD) is defined as any plot with at least one drying cycle lasting five days or more. This differs from the IRRI-defined AWD method, which involves using a 'field water tube' or plastic pipe to monitor water depth. Farmers who use the pipe represent a small subset of those who report drying their plots.

7.4 Mechanization

Finally, we examine the characteristics of adopters of axial flow pumps (AFPs). In Figure 42, we see the pattern we would expect. Larger plots, further from the main pump or canal, are more likely to be irrigated using an AFP. In terms of socioeconomic correlates, only total household size is significantly correlated with AFP adoption. For additional context, in Appendix O we provide additional figures for three additional mechanization innovations that are less closely related to CGIAR research: two- and four-wheel power tillers and shallow tubewells.

Figure 42: Covariates of adoption of axial flow pumps



Note: The analysis is restricted to paddy plots where the household reported making agricultural decisions during the 2024 Boro season. All rainfed plots are excluded, retaining only irrigated plots. The resulting sample consists of 3,765 plots.

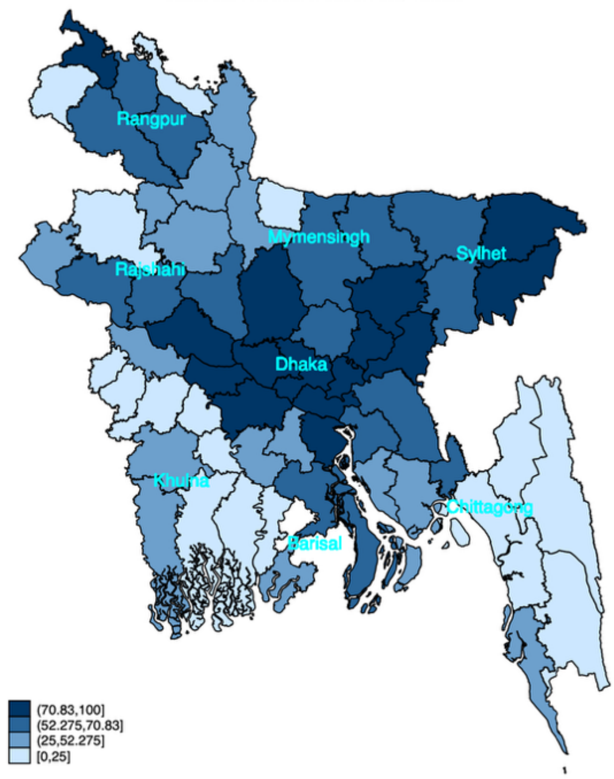
8. Where Are The Adopters?

In this section, we analyze spatial variations in adoption by examining the concentration of adoption within administrative divisions and districts, as well as the relationship between CGIAR-related research activities and the spatial distribution of adopters observed in the BIHS. This geographic analysis offers valuable insights into the reach of innovations and highlights potential regional disparities. Additionally, it evaluates whether innovations have diffused beyond the Feed the Future zone, which has been a focal point for many of USAID's initiatives. Such spatial analysis is crucial for informing the geographic targeting of future efforts and ensuring broader diffusion of innovations.

8.1 Rice Varieties

Figure 43 shows the spatial distribution of households cultivating CGIAR-related rice varieties during the Boro season (among all households cultivating rice in the 2024 Boro season). We focus on the conservative lower-bound estimate for CGIAR-related Boro varieties, including varieties such as BRRI Dhan 29 (released in 1994), BRRI Dhan 89 (released in 2018), BRRI Dhan 28, BRRI Dhan 74, and BRRI Dhan 100. We can see that the adoption is concentrated in and around Dhaka and Sylhet.

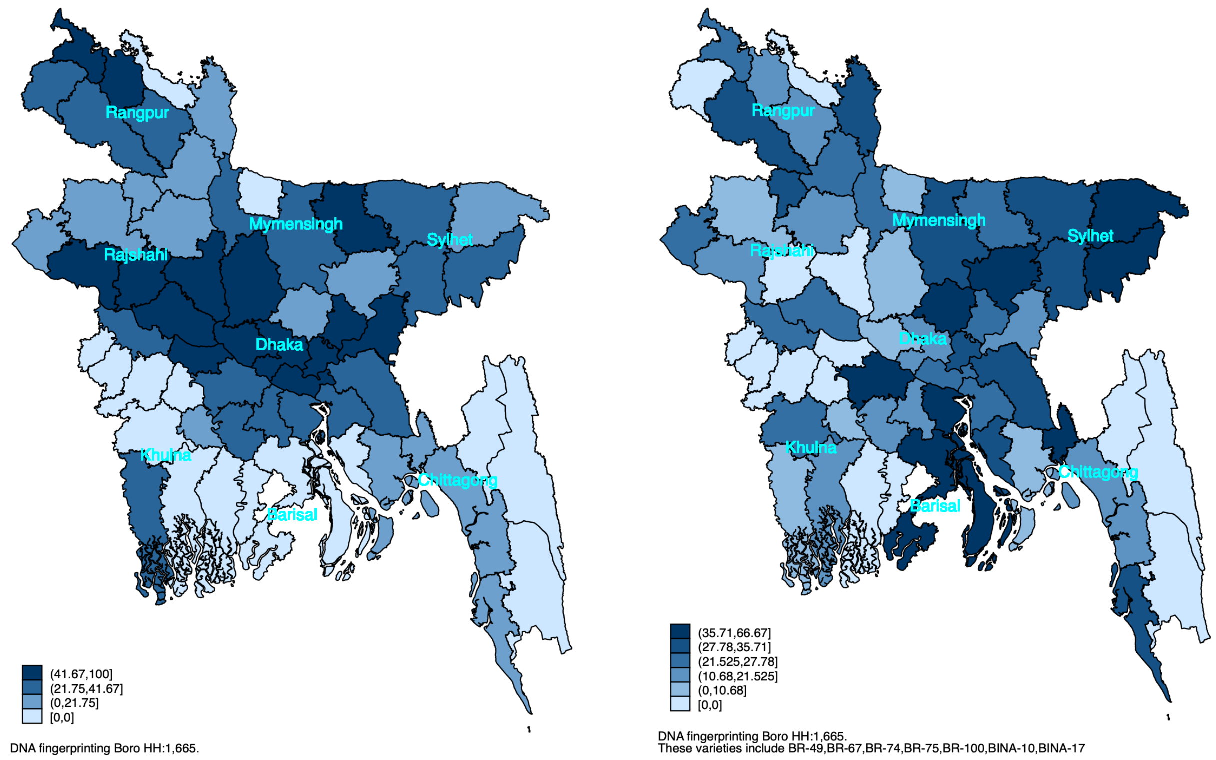
Figure 43: District-wise share of CGIAR-related Boro rice varieties



DNA fingerprinting Boro HH:1,665.
These varieties are BR-28,BR-29,BR-49,BR-57,BR-67,BR-74,BR-75,BR-89,BR-100,BINA-10,BINA-17.

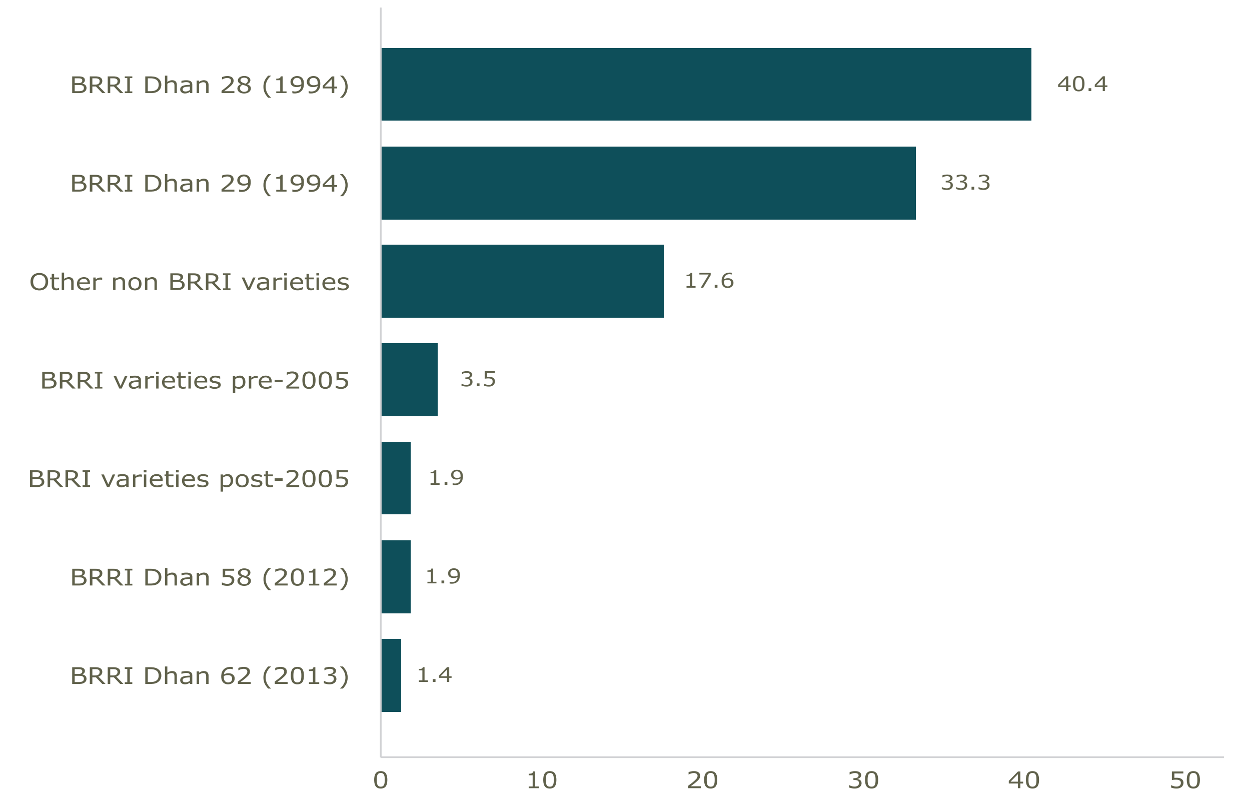
Figure 44 shows the breakdown of this adoption in relation to older CGIAR-related varieties of BR-28 and BR-29 (left panel) and CGIAR-related varieties released since 2005 (right panel). The two main varieties in Bangladesh, BRRI Dhan 28 and BRRI Dhan 29, both released in 1994, have a more distinct spatial distribution, densely concentrated in central Bangladesh and particularly around the affluent capital areas (with some dissemination to Rangpur and Rajshahi). In contrast, varieties released after 2005 are less intensely adopted than these two dominant varieties but do show a broader geographic spread well beyond the center of the country. These newer varieties have a notable presence in Sylhet, Mymensingh, Barisal, Khulna, and Chittagong, possibly reflecting a successful shift in targeting efforts towards more diverse and peripheral regions.

Figure 44: District-wise share of BR-28 and BR-29 (left panel) and more recent CGIAR-related releases (post 2005, right panel)



Furthermore, if we compare the adoption data of post-2005 releases with self-reported adoption estimates from the third wave, we can see that pre-2005 varieties were dominant among those households then. 412 households cultivated BRRI varieties released post 2005 in Boro 2024. Among these households, 299 cultivated Boro in the third wave on 788 plots. If we look at the plot-based self-adoption percentages, we can see a clear dominance of BRRI Dhan 28 and 29. This indicates the older varieties have been replaced by newer varieties between the third and the fourth wave (Figure 45).

Figure 45: Self-reported Boro rice variety in 2018-19 at the plot level (%)



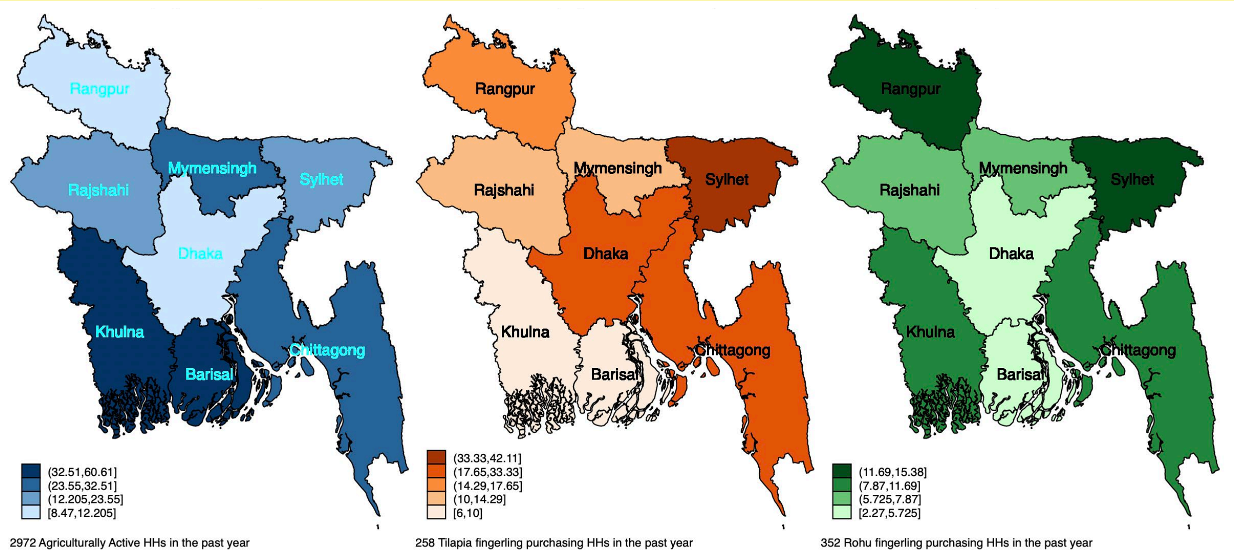
Note: Figure 45 considers the DNA fingerprinting of households that have adopted post-2005 BRRI varieties in 2024.
Number of households = 299, number of plots = 788

8.2 Aquaculture Innovations

Figure 46 shows three distinct geographic distributions. The left panel depicts the distribution of all aquaculture households in the sample. These households are somewhat concentrated in three divisions, namely Barisal, Khulna, and Mymensingh, where up to 60%, 33%, and 32% of agricultural households actively engage in aquaculture as of 2024, respectively. Chittagong and Sylhet follow, with up to 30% and 16% of households practicing aquaculture, respectively. This geographic distribution underscores that aquaculture activities are somewhat concentrated in southern Bangladesh. For example, in 2011, diversification into higher-value and more nutritious aquaculture production was identified as a key intervention within the Feed the Future (FTF) country strategy. To address this, the USAID-Aquaculture for Income and Nutrition (AIN) project, implemented by WorldFish, was launched across 68 upazilas in 18 districts within 20 FTF districts, primarily in Dhaka (now partly Mymensingh), Khulna, and Barisal divisions. The project was managed through four regional hub offices in Khulna, Jessore, Barisal, and Faridpur, with the main office located in Khulna. The project's primary focus was on shrimp and G3 rohu.[25]

The distribution of Genetically Improved Farm Tilapia (GIFT) (middle panel) and G3 rohu-rearing households (right panel) is quite geographically balanced. Households reporting purchasing GIFT tilapia fingerlings are found in regions such as Sylhet, Dhaka, and parts of Chittagong. For G3 rohu, despite being released only a few years prior to the survey, Rangpur and Sylhet have reached the range of 11-15% of all reported fingerling purchases, with all other divisions also reporting non-zero shares in these early stages of the rollout of the G3 rohu strain.

Figure 46: Three distinct geographic distributions of aquaculture innovations



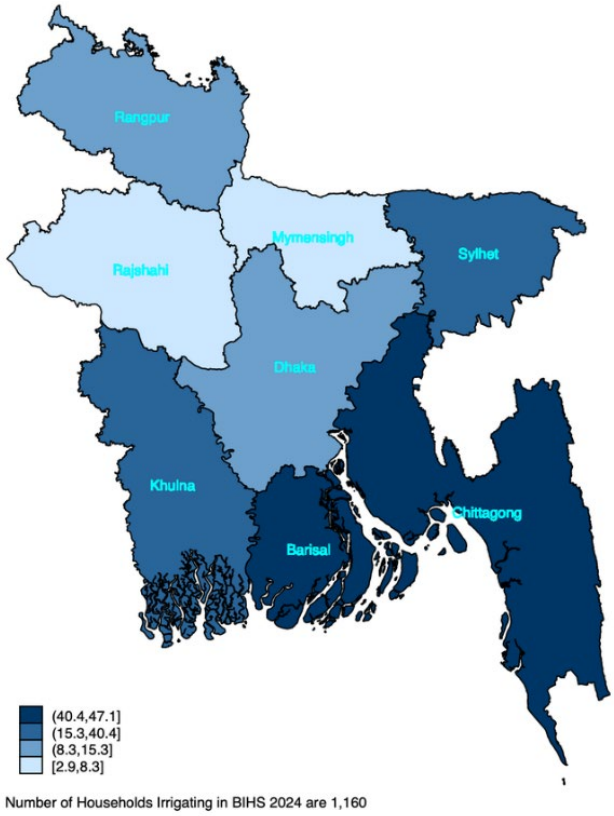
Note: Division-wise proportion of aquaculture households (left panel) amongst all agricultural households; households reporting purchasing GIFT fingerlings (of all tilapia aquaculture households purchasing fingerlings, middle panel); and households reporting purchasing G3 rohu fingerlings (of all rohu aquaculture households purchasing fingerlings, right panel).

[25] It must be noted that, according to the final evaluation report on Aquaculture for Income and Nutrition, project activities, particularly the sale of improved seed, extended beyond the FTF Zone of Influence (ZOI). As a result, approximately 40%–50% of the project’s impacts were observed outside the FTF ZOI.

8.3 Natural Resource Management

As discussed in Section 4.4, axial flow pumps (AFPs) were primarily tested and disseminated by CIMMYT in the divisions of Barisal and Chittagong. Through training programs facilitated by the Cereal Systems Initiative for South Asia Mechanization Extension Activity (CSISA MEA), small businesses in Cox's Bazaar and Bandarban districts in Chittagong began manufacturing these machines and making spare parts available to allow maintenance. These efforts have seemingly contributed to significant adoption, with up to 47% of agricultural households in Barisal and Chittagong divisions using AFPs, along with some spread into Khulna and Sylhet (Figure 47).

Figure 47: Proportion of households using AFPs at the division level (as a share of all households that apply irrigation in 2024)



9. Discussion

Within Bangladeshi agriculture, rice is dominant. The collaborative research efforts of the International Rice Research Institute (IRRI), the Bangladesh Rice Research Institute (BRRI), and the Bangladesh Institute of Nuclear Agriculture (BINA) together have delivered varieties that reach substantial shares of the rice-growing households across the Boro, Aman, and Aus seasons. In the irrigated Boro season, for CGIAR-related rice varieties to reach almost 60% of households, a reach of over 5 million households in 2024, represents a major contribution to Bangladesh's agricultural development (Table 26). CGIAR-related varieties are also reaching very large numbers of households during the predominantly rainfed Aman season, a reach of around 3.5 million households. Yet, quite a large pool of potential beneficiary households is not adopting CGIAR-related Aman varieties.

At a varietal level, we find that the stress-tolerant varieties, for salt- or flood-tolerance, have so far only reached a relatively small share of households growing rice during the Aman season that they target (3% share for salt tolerance, 7% for flood tolerance). Older varieties across both Boro and Aman seasons still occupy large shares. In the Boro season, BRRI Dhan 28 and 29 remain the most popular varieties despite being released in 1994. This stickiness to adoption suggests that farmers must have built a degree of trust in the performance of these varieties and may be reluctant to deviate. The DNA fingerprinting results from the Boro season show that farmers are quite well-informed regarding varietal identity, both in terms of the evidence from comparing self-reported data to DNA for a single variety (moderate rates of misclassification at 34%), and in comparison of two replicate DNA samples from within the same plot (i.e. high test, re-test validity at 90%). We do, however, observe a tendency for some farmers to report newer varieties they are cultivating as being the older, well-known BRRI Dhan 28 and 29, reinforcing the sense that these varieties have reputations that are valued.[26]

CGIAR-related varieties are present in most of the wheat-growing households and occupy important niches within the relatively small populations growing lentil and groundnut. CGIAR-related maize and potato varieties have only small shares by comparison, reflecting a more competitive commercial seed market for these crops.

In aquaculture, we observe a decline in the number of households engaged in from 2018 to 2024, dropping from 27% to 23% of agricultural households. The sector has undergone consolidation, with farmers managing fewer but larger ponds. Regarding our evidence on aquaculture strains, we have good reasons to think we are under-counting the contribution of Genetically Improved Farmed Tilapia (GIFT) and G3 rohu owing to both the structure of the data (only asking about strains when farmers have purchased fingerlings that year) and from the fact that the strains can disseminate without the correct name of the strain travelling with the genetics. G3 rohu, despite being released only in 2000, has quickly reached a non-trivial share of aquaculture households, and well beyond the initial geographic centers of dissemination.

[26] Data from a limited sub-sample where we can compare all three of the following - DNA results, farmer self-reports, and images of the seed bags farmers report using – we find suggestive evidence that seed is sometimes mis-sold as being these older varieties, presumably to appeal to farmers through name recognition, despite actually being newer varieties.

Tracking the further adoption of this strain over time represents a high-value opportunity for future research. These caveats notwithstanding, we find that G3 rohu is already attracting 8% of reported fingerling purchases among rohu farmers and reaching a very conservative lower bound of 150,000 aquaculture households. GIFT tilapia has been in Bangladesh for much longer and reaches over 200,000 aquaculture households.

Alternate Wetting and Drying (AWD) has been promoted extensively in Bangladesh. When we ask farmers about their use of the promoted 'safe AWD' pipe (to observe the water level below the soil so they can trigger irrigation at the appropriate moment), we find zero adoption. However, the pipe itself is not a necessary or sufficient condition for the adoption of the principles behind AWD. The principle – that farmers would intentionally dry down their plots to save water, fuel costs on pumping, and/or reduce methane emissions – is not easily observed. All we can do is observe the share of households that dry either all of their plots, or at least one of their plots, at least once during the growing season cycle, and for at least five days.

The corresponding reach estimates for all plots (1.4 million) or at least one plot (1.7 million) suggest that the practice is quite widespread. However, given that drying spells can happen for lots of reasons, including unintentionally or against the will of the farmer (i.e., water shortages, pump failures, etc.), what is not clear from this analysis is the link back to CGIAR's efforts to promote AWD.[27] It would be preferable to have access to administrative data on locations and dates regarding AWD dissemination efforts to allow us to interrogate the spatial dimensions of adoption. AWD adoption is somewhat more pronounced in Mymensingh, Sylhet, Barisal, and Khulna, the latter two divisions being where CGIAR partners have conducted awareness-raising projects. We are cautious about interpreting all the observed adoption as evidence of the reach of CGIAR efforts. This caution is informed by evidence from an empirical study in Bangladesh that promoted AWD to farmers. It shows that only those farmers who face volumetric pricing for water will adopt AWD, as they have an immediate economic incentive to do so (Chakravorty et al, 2023). Farmers rarely face such volumetric pricing for water and instead are charged a standard fee for receiving irrigation water for the season.

Apps to support agricultural decision-making – examples include Macher Gari (Fish Car), Right Haat, Digital Feed Supply, Program for Advanced Numerical Irrigation (PANI), and Rice Crop Manager – are not being used by farmers. The endeavor to build and disseminate apps has not succeeded, even though large shares of households in our sample report using well-known apps from other areas of their lives (financial/commercial/lifestyle). Only 5.3% of households report having heard about livestock insurance, and 6.4% of having heard about crop insurance. None of the agricultural households in our sample participates in an index-based flood insurance scheme.

Mechanization has played a crucial role in Bangladesh's recent agricultural development. While the dissemination of new mechanized technologies cannot be attributed solely to CGIAR, CGIAR efforts have been significant through its partnerships in the development, testing, refinement, and promotion of machines. One example is the axial flow pump (AFP), first introduced and

[27] It is important to clarify that by AWD, we refer to farmers who reported drying their fields at least once for a period of five days. This differs from the IRRI-defined AWD method, which involves using a 'field water tube' or plastic pipe to monitor water depth. Farmers who use the pipe represent a small subset of those who report drying their plots.

tested by CIMMYT in 2015. AFP adoption has jumped over a short period, from 1.4% in 2018 to 12.6 % in 2024, suggesting relatively rapid uptake by farmers to better use surface water where available, and in the context of scarce and increasingly saline groundwater. AFPs have been particularly successful in Barisal and Chittagong, where dissemination efforts were concentrated, but they have also expanded into other divisions. For other machinery promoted in the Feed the Future zones, we do not observe a significant difference in the adoption of CGIAR-promoted machinery compared to other regions.

Table 26: Summary table on reach of CGIAR-related innovations in Bangladesh, 2024

Innovation	Adoption %	Population of interest	Reach estimate (millions)
LOWER BOUND			
Rice varieties: Boro season	59.5	Boro rice-growing households	5.45
Rice varieties: Aman season	39.4	Aman rice-growing households	3.53
Rice varieties: Aus season	42.3	Aus rice-growing households	0.39
Wheat varieties	61.4	Wheat-growing households	0.348
Maize varieties	12.4	Maize-growing households	0.145
Lentil varieties	41.8	Lentil-growing households	0.092
Potato varieties	14.4	Potato-growing households	0.126
Groundnut varieties	34.4	Groundnut-growing households	0.096
G3 rohu	8.2	Rohu-growing households that purchase fingerlings	0.152
GIFT Tilapia	16.6	Tilapia-growing households that purchase fingerlings	0.218
UPPER BOUND			
Small Indigenous Species	5.7	Aquaculture households	0.203
Alternate Wetting and Drying	19.6	Rice-growing households that irrigated their land in Boro season – AWD practiced on at least one plot	1.73
Axial Flow Pump	12.6	Agricultural households that irrigated their land in the past three seasons	1.65
Two-wheeled mechanical reaper	1.6	Rice/wheat/jute cultivating households in the past four seasons	0.21

10. Conclusion

We find that CGIAR-related innovations reached between 8.0 million households (lower bound) and 9.4 million households (upper bound) in Bangladesh in 2023/24. Rice varieties in the major Boro and Aman production seasons dominate the CGIAR contribution to these estimates, when looking across all CGIAR-related innovations. The newer stress-tolerant rice varieties are starting to be adopted at scale but have not yet displaced older releases. Aquaculture innovations, particularly the G3 Rohu strain, continue to grow in importance evidence during a period of consolidation of aquaculture operations, with fewer households operating larger ponds over time.

The panel nature of the survey data shows that agriculture's role in Bangladesh's economic development is dynamic and changing over the period 2011-2023/24. Households move in and out of agriculture, with a net movement out of agricultural production linked to Bangladesh's structural transformation towards middle-income status during this period. Looking ahead, a greater focus on non-household farms (i.e commercial operations) and on the pathways to impact via consumption and/or employment may be a necessary complement to the type of household data used in this report.

References

Alauddin, M., Sarker, M. A. R., Islam, Z., & Tisdell, C. (2020). Adoption of alternate wetting and drying (AWD) irrigation as a water-saving technology in Bangladesh: Economic and environmental considerations. *Land Use Policy*, *91*, 104430. https://doi.org/10.1016/j.landusepol.2019.104430.

Aziz, M. S. B., Hasan, N. A., Mondol, M. M. R., Alam, M. M., & Haque, M. M. (2021). Decline in fish species diversity due to climatic and anthropogenic factors in Hakaluki Haor, an ecologically critical wetland in northeast Bangladesh. *Heliyon*, *7*(1).

Barría, A., Trịnh, T. Q., Mahmuddin, M., Peñaloza, C., Papadopoulou, A., Gervais, O., Chadag, V. M., Benzie, J. A. H., & Houston, R. D. (2021). A major quantitative trait locus affecting resistance to Tilapia lake virus in farmed Nile tilapia (Oreochromis niloticus). *Heredity*, *127*(3), 334–343. https://doi.org/10.1038/s41437-021-00447-4.

Beyer, R. C. M. & Wacker, K. M. (2022).Good enough for outstanding growth: The experience of Bangladesh in comparative perspective. World Bank Policy Research Working Paper 10150. World Bank: Washington DC.

Chakravorty, U., Dar, M. H., & Emerick, K. (2023). Inefficient water pricing and incentives for conservation. *American Economic Journal: Applied Economics*, *15*(1), 319-350.

DoF. (2020). *Yearbook of Fisheries Statistics of Bangladesh, 2019-20* (p. 141). Department of Fisheries Bangladesh.

Emran, S., & Shilpi, F. (2018). Agricultural productivity, hired labor, wages, and poverty: Evidence from Bangladesh. *World Development, 109*, 470-482.

FAO, IFAD, UNICEF, WFP and WHO. 2024. *The State of Food Security and Nutrition in the World 2024 – Financing to end hunger, food insecurity and malnutrition in all its forms.* Rome. https://doi.org/10.4060/cd1254en.

FAO. (2020). *The State of World Fisheries and Aquaculture 2020. Sustainability in action.*

Gade, P., Alam, M. A., Barma, N. C. D., Majumder, R., Garapaty, R., Paranjape, V. D., Killian, A., Vijayaraghavan, K., Kabir, Md. R., Hakim, Md. A., Islam, Md. Z., Hossain, Md. M., Rahman, Md. M., Rahman, M., Khan, Md. A. A., Islam, Md. R., Hasan, Md. M., Amin, Md. F., & Acevedo, M. (2021). Assessment of wheat variety adoption in Bangladesh through DNA fingerprinting. *Crop Science, 61*(5), 3564–3577. https://doi.org/10.1002/csc2.20579.

Gautam, M., & Faruqee, R. (2016). *Dynamics of rural growth in Bangladesh: Sustaining poverty reduction.* World Bank Publications.

Gjedrem, T., & Rye, M. (2018). Genetic improvement of farmed fish and shellfish. *Nature Reviews Genetics, 19*(5), 278–291. https://doi.org/10.1046/j.1365-2109.2000.00389.x.

Hernandez, R., Belton, B., Reardon, T., Hu, C., Zhang, X., & Ahmed, A. (2018). The "quiet revolution" in the aquaculture value chain in Bangladesh. *Aquaculture, 493*, 456-468.

Hossain, M. A., Wahab, M. A., Shah, M. S., Barman, B. K., & Hoq, M. E. (2014). Habitat and fish diversity: Bangladesh perspective. In *Recent advances in fisheries of Bangladesh. Bangladesh Fisheries Research Forum, Dhaka* (pp. 1-26).

Houston, R. D. (2017). Future directions in breeding for disease resistance in aquaculture species. *Revista Brasileira de Zootecnia, 46*, 545–551. https://doi.org/10.1590/S1806-92902017000600010.

IRRI. (n.d.). *Bangladesh*. International Rice Research Institute. Retrieved February 5, 2025, from https://www.irri.org/where-we-work/countries/bangladesh.

Khan, M. A. G., Galib, S. M., Hasnath, M., Mia, M. R., & Kibria, R. (2022). Exotic fish and decreasing habitats vis-à-vis conservation of freshwater fish biodiversity of Bangladesh. *Journal of Fisheries, 10*(1), 101301-101301.

Kosmowski, F., Thanh, B. L., Chavez, S., Nguyen, H. T., Nguyen, P., Gimode, D., Biradavolu, M., Pelletier, J., Stevenson, J., & Visaria, S. (2024). *SPIA Viet Nam Report: Global Ambitions, Sustainable Pathways*. Standing Panel on Impact Assessment (SPIA).

Kretzschmar, T., Mbanjo, E. G. N., Magalit, G. A., Dwiyanti, M. S., Habib, M. A., Diaz, M. G., Hernandez, J., Huelgas, Z., Malabayabas, M. L., Das, S. K., & Yamano, T. (2018). DNA fingerprinting at farm level maps rice biodiversity across Bangladesh and reveals regional varietal preferences. *Scientific Reports, 8*(1), 14920. https://doi.org/10.1038/s41598-018-33080-z.

Kuerschner, E., Henschel, C., Hildebrandt, T., Jülich, E., Leineweber, M., & Paul, C. (2010). Water Saving in Rice Production– Dissemination, Adoption and Short-Term Impacts of Alternate Wetting and Drying (AWD) in Bangladesh. *Humboldt-Universitat Zu Berlin SLE Publication Series.*

Lojo, K. (n.d.). *Crop cafeterias facilitate the widespread dissemination and adoption of superior rice varieties across Bangladesh.* Retrieved February 13, 2025, from https://news.irri.org/2024/07/crop-cafeterias-facilitate-widespread.html.

Mainuddin, M., & Kirby, M. (2015). National food security in Bangladesh to 2050. *Food Security, 7*(3), 633–646. https://doi.org/10.1007/s12571-015-0465-6.

Moniruzzaman, S. (2015). Crop choice as climate change adaptation: Evidence from Bangladesh. *Ecological Economics, 118*, 90–98. https://doi.org/10.1016/j.ecolecon.2015.07.012.

Olesen, I., Bentsen, H. B., Phillips, M., & Ponzoni, R. W. (2015). Can the Global Adoption of Genetically Improved Farmed Fish Increase Beyond 10%, and How? *Journal of Marine Science and Engineering, 3*(2), 240–266. https://doi.org/10.3390/jmse3020240.

Rahman, M. S., & Sanger, B. O. (2017, January). *Application of Alternate Wetting and Drying (AWD) in Bangladesh Agriculture: Findings from case studies.* Application of Alternate Wetting and Drying (AWD) in Bangladesh Agriculture: Findings from case studies, Thailand.

Rossignoli, C. M., Shikuku, K. M., & Lam, R. D. (2021) Evaluating impacts of genetically improved farmed tilapia: Challenges and strategy. Presentation to SPIA webinar series, 17th February 2021.

Sen, B., Dorosh, P., & Ahmed, M. (2021). Moving out of agriculture in Bangladesh: The role of farm, non-farm and mixed households. World Development, 144: 105479.

Shah T. 2009. Climate change and groundwater: India's opportunities for mitigation and adaptation. Environmental Research Letters 4: 035005.

Stevenson, J., Vanlauwe, B., Macours, K., Johnson, N., Krishnan, L., Place, F., ... & Vlek, P. (2019). Farmer adoption of plot-and farm-level natural resource management practices: Between rhetoric and reality. *Global Food Security, 20*, 101-104.

Taleon, V., Hasan, Z., & Foley, J. (2024, May 1). *Research-backed policy to eliminate miniket rice in Bangladesh will improve nutrition.* IFPRI. https://www.ifpri.org/blog/research-backed-policy-eliminate-miniket-rice-bangladesh-will-improve-nutrition/.

Toufique, K. A., & Belton, B. (2014). Is aquaculture pro-poor? Empirical evidence of impacts on fish consumption in Bangladesh. *World development, 64*, 609-620.

Valera, H. G. A., Antonio, R. J., Habib, M. A., Puskur, R., Pede, V., & Yamano, T. (2025). High-zinc rice and randomized nutrition training among women farmers: A panel data analysis of long-term adoption in Bangladesh. *Q Open, 5*(1), qoaf001. https://doi.org/10.1093/qopen/qoaf001.

Yigezu, Y. A., Rahman, M. W., El-Shater, T., Alene, A. D., Sarker, A., Kumar, S., & Frija, A. (2022). Plot-level impacts of improved lentil varieties in Bangladesh. *PLOS ONE, 17*(1), e0262146. https://doi.org/10.1371/journal.pone.0262146.

A farmer pauses as she goes about her work in the village of Baikunthapur, Chirirbandar, Bangladesh. Credit: S. Mojumder/Drik/CIMMYT

A Bangladeshi woman cuts up feed for her family's livestock.
Credit: S. Mojumder/Drik/CIMMYT.

Appendices

Appendix A. Details of Survey Field Implementation

The survey team consisted of 125 enumerators, 25 supervisors and 12 monitors. The training period was around four weeks when our field implementation partner Data Analysis and Technical Assistance conducted the training with the assistance of SPIA consultants. A pilot was conducted in two upazilas in Dhaka division in January 2024, to familiarize enumerators with the questionnaire and refine the leaf sample collection protocol. The main survey was then implemented from 14 February-23 March 2024.

In order to assure the quality of the collected data, SPIA undertook extensive quality checks including high frequency check reports, audio audits, back-checking, etc. High frequency check reports focused on key variables of interest that would enable us to detect any systematic pattern of enumerator mistakes. Audio audits – where audio recording on the CAPI tablet was switched on at random for a portion of each interview – identified whether the enumerators were asking the questions correctly, or if they were skipping over questions to speed up in an unwarranted manner. Finally, a backcheck was conducted by phone to quantify the level of error in the main survey. Based on the findings from these quality control measures, SPIA was able to identify concerns with a fraction of the sample and negotiated for a re-survey of 730 households to uphold data quality standards. This re-survey was conducted from 5 July-3 August 2024. In the resurvey, 70 households that had previously been surveyed either refused, were not present, or had migrated. The eventual total sample size of the completed interviews for SPIA-BIHS 2024 after the resurvey stands at 5,554 households.

Appendix B. List of Rice Varietal Releases

Table 27: Rice varietal releases

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BR1	1970	Y	N	N	Y	N	N	N	N	IR532-1-176	
BR2	1971	Y	N	N	N	N	N	N	N	IR272-4-1-2	
BR-3	1973	Y	N	N	Y	N	N	N	N		IR506-1-133/ LATISAIL
BR-4	1975	Y	N	N	Y	N	N	N	N		IR20/IR5-114-3-1
Iratom 24	1975	N	Y	N	N	N	N	N	N		Mutant of IR 8
BR-5	1976	N	N	N	Y	N	N	N	N		
BR-6	1977	Y	N	N	Y	N	N	N	N	IR2061-214-3-8-2	
BR7	1977	Y	N	N	Y	N	N	N	N	IR2053-87-3-1	
BR-8	1978	Y	N	N	Y	N	N	N	N		IR272-4-1-2-J1/ IR305-3-17-1-3
BR9	1978	Y	N	N	Y	N	N	N	N		IR272-4-1-2J1/IR8
BR10	1980	Y	N	N	Y	N	N	N	N		IR20/IR5-114-3-1
BR11	1980	Y	N	N	Y	N	N	N	N		IR20/IR5-47-2
BR-12	1983	Y	N	N	Y	N	N	N	N		BR1/IR425-1-1-3-8-3
BR14	1983	Y	N	N	Y	N	N	N	N		IR5 (D)/BR3
BR 15	1983	N	Y	N	Y	N	N	N	N		IR 1561-228-1-2 / IR 1737 // CR 94-13
BR16	1983	Y	N	N	Y	N	N	N	N		IR 1416-131-5, IR 1364-37-3-1/IR 1544 A-E 666
BR17	1985	N	Y	N	Y	N	N	N	N		Jerak / IR 8
BR18	1985	N	Y	N	Y	N	N	N	N		Pelita 1-1 / IR 1108-2
BR19	1985	Y	N	N	Y	N	N	N	N		IR 2180-2 / IR 2178-1

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BR-20	1986	Y	N	N	N	N	N	N	N		IR272-4-1-2J1/IR5 (264)
BR21 (Niamot)	1986	N	N	Y	Y	N	N	N	N		C22/IET 1444
Binasail	1987	N	N	N	N	N	N	N	N		
BR22	1988	Y	N	N	Y	N	N	N	N		Nazirshail/BR 51-46-5 (IR20/IR5-114-3-1)
BR23	1988	N	Y	N	Y	N	N	N	N		DA 29 / BR 4
BR24	1992	Y	N	N	N	N	N	N	N		C 22 / IR 9752-136-2
BR-25	1992	Y	N	N	Y	N	N	N	N		PAJAM II/IR26
BR26	1993	Y	N	N	Y	N	N	N	N		IR18348-36-3-3/ IR25863-61-3-2// IR58
BRRI dhan27	1994	N	N	Y	Y	N	N	N	N		Kn-1B-361-1-8-6-9/ C168
BRRI dhan28	1994	Y	N	N	Y	N	N	N	N		IR28/PURBACHI
BRRI dhan29	1994	Y	N	N	Y	N	N	N	N		BG90-2/BR10 (a cross of IR20/IR5-114-3-1)
BRRI dhan30	1994	Y	N	N	Y	N	N	N	N		IR 2058-78-1-3-2-3/ BR 4
BRRI dhan31	1994	N	Y	N	Y	N	N	N	N		BR11/ARC10550
BRRI dhan32	1994	N	Y	N	Y	N	N	N	N		BR 4 / BR 2262
BRRI dhan33	1997	N	N	Y	Y	N	N	N	N	BG850-2	BG 388 / BG 367-4
BRRI dhan34	1997	N	N	N	Y	N	N	N	N		
BRRI dhan35	1998	N	Y	N	Y	N	N	N	N	BR4//BR26-7-4-1/ ARC14529	

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BRRI dhan36	1998	Y	N	N	Y	N	N	N	N	IR54791-19-2-3	IR 64 / IR 35293-125-3-2-3
BRRI dhan37	1998	N	N	N	Y	N	N	N	N		
BRRI dhan38	1998	N	N	N	Y	N	N	N	N		
BRRI dhan39	1999	N	N	N	Y	N	N	N	N		
Binadhan-4	1998	N	Y	N	N	N	N	N	N		BR 4 / Iratom 38
Binadhan-5	1998	N	Y	N	N	N	N	N	N		Iratom 24 / Dular
Binadhan-6	1998	N	Y	N	N	N	N	N	N		Iratom 24 / Dular
BRRI hybrid 1	2001	N	Y	N	N	N	N	N	N		IR 58025A / BR 827-35-2-1-1-1R
BRRI dhan40	2003	Y	N	N	Y	N	Y	N	N		IR4595-4-1-15/BR10
BRRI dhan41	2003	N	Y	N	Y	N	Y	N	N		BR 23 / BR 1185-2B-16-1
BRRI dhan42	2004	Y	N	N	Y	N	N	N	N		BR14/IR 25588-7-3-1
BRRI dhan 43	2004	N	Y	N	Y	N	N	Y	N		BR 14 / BR 21
BRRI dhan 44	2005	N	Y	N	Y	N	Y	N	N		BRRI dhan 30 / BRRI dhan 31
BRRI dhan45	2005	N	Y	N	Y	N	N	N	N		BR2/Tetep
BRRI dhan46	2007	N	Y	N	Y	N	N	N	N		BR11/Swarnalata// ARC14766A
BRRI dhan47	2007	Y	N	N	Y	N	Y	N	N	IR63307-4B-4-3	IR 51511-B-B-34-B / TCCP 266-2-49-B-B-3
Binadhan-7	2007	N	N	N	Y	N	Y	N	N		
BRRI dhan48	2008	N	Y	N	Y	N	N	N	N		BR 1543-9-2-1/IR 13249-49-3-2-2
BRRI dhan49	2008	N	Y	N	Y	N	N	N	N		BR 4962-12-4-1/IR 33380-7-2-1-3

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BRRI dhan50	2008	N	Y	N	Y	N	N	N	N		BR 30/IR 67684B
BRRI hybrid 2	2008	N	Y	N	N	N	N	N	N		BRRI 10A / BRRI 10R
BRRI hybrid 3	2009	N	Y	N	N	N	N	N	N		BRRI 11A / BRRI 15R
BRRI dhan51	2010	Y	N	N	N	Y	N	N	N		Swarna/IR 49830-7-1-2-3
BRRI dhan52	2010	Y	N	N	Y	Y	N	N	N		BR 11/IR 40931-33-1-3-2
BRRI dhan53	2010	N	Y	N	Y	N	Y	N	N		BR 10 / BR 23 // BR 847-76-1-1
BRRI dhan54	2010	N	N	N	Y	N	N	N	N		
BRRI hybrid 4	2010	N	Y	N	N	N	N	N	N		IR58025A/BR016-5-3-2-4R
Binadhan-8	2010	Y	N	N	Y	N	Y	N	N		IR 29/POKKALI B
BRRI dhan55	2011	Y	N	N	Y	N	Y	Y	N		IR64/Oryza rufipogon
BRRI dhan56	2011	Y	N	N	Y	N	N	Y	N		IR 55419-4/WAY PAREM
BRRI dhan57	2011	N	Y	N	Y	N	N	Y	N		BR11/CR146-7027-224
BRRI dhan58	2012	N	Y	N	Y	N	N	N	N		BRRI dhan29-SC3-28-16-4-HR2
Binadhan-9	2012	N	N	N	N	N	N	N	N		
Binadhan-10	2012	Y	N	N	Y	N	Y	N	N		IR 42598-B-B-B-B-12/NONA BOKRA
BRRI dhan59	2013	N	N	Y	Y	N	N	N	N	BW328	
BRRI dhan60	2013	N	N	N	Y	N	N	N	N		
BRRI dhan61	2013	N	Y	N	Y	N	Y	N	N		IR64419-3B-4-3/ BRRI dhan 29

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BRRI dhan62	2013	Y	N	N	Y	N	N	N	Y		
Binadhan-11	2013	Y	N	N	Y	Y	N	N	N		CIHERANG*2/IRRI 149
Binadhan-12	2013	Y	N	N	Y	Y	N	N	N		SAMBHA MAHSURI*4/IR 49830-7-1-2-3
Binadhan-13	2013	N	N	N	N	N	N	N	N		
Binadhan-14	2013	N	N	N	N	N	N	N	N		
BRRI dhan63	2014	N	Y	N	Y	N	N	N	N		Amol-3/BRRI Dhan-28
BRRI dhan64	2014	Y	Y	N	Y	N	N	N	Y		IR75382-32-2-3-3/ BR7166-4-5-3-2-5-5B1-92
BRRI dhan65	2014	Y	N	N	Y	N	N	N	N		OM606/IR44592-62-1-1-3
BRRI dhan66	2014	Y	N	N	Y	N	N	Y	N		IR78875-176-B-2/ IR78875-207-B-3
BRRI dhan67	2014	N	Y	N	Y	N	Y	Y	N		IR 61247-3B-8-2-1/ BRRI dhan 36
BRRI dhan68	2014	N	Y	N	Y	N	N	N	N		BRRI dhna29*2/ IR68144
BRRI dhan69	2014	Y	N	N	Y	N	N	N	N		WuShan YouZhan/ PI312777
Binadhan-15	2014	N	Y	N	Y	N	N	N	N		IR 2153-14-1-6-2/IR 2061-214-38 2/IR 2071-625-1-252
Binadhan-16	2014	N	Y	N	Y	N	N	N	N		Contains IRRI genetic material
BRRI dhan70	2015	N	Y	N	Y	N	N	N	N		IRR67423-208-6-2-3-3/IR65610-105-2-5-2-2-2
BRRI dhan71	2015	Y	N	N	Y	N	N	Y	N		IR55423-01 (NSIC RC 9)/IRRI 148
BRRI dhan72	2015	Y	N	N	Y	N	N	N	Y		

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BRRI dhan73	2015	Y	N	N	Y	N	Y	Y	N		BRRI dhan40/NSICRc 106 (IR61920-3B-22-2-1)
BRRI dhan74	2015	Y	Y	N	Y	N	N	N	Y		IR68144/BRRI dhan 29
Binadhan-17	2015	Y	N	N	Y	N	N	N	N		C418(ZHONG413)2// SH109/ (ZHONG413)2
BRRI dhan75	2016	Y	N	N	Y	N	N	N	N		Yuefengzhan/E-Zhong5
BRRI dhan76	2016	N	Y	N	Y	N	N	N	N		IR75862-208-8-B-B-H1/BR6110-10-1-2
BRRI dhan77	2016	N	Y	N	Y	N	N	N	N		IR 75862-208-8-B-B-HR1/BR 6110-10-1-2
BRRI dhan78	2016	Y	N	N	Y	Y	Y	N	N		IR84645/IR84649
BU Aromatic Dhan-2	2016	Y	N	N	N	N	N	N	Y		
BRRI hybrid 5	2016	N	N	N	N	N	N	N	N		
Binadhan-18	2016	N	N	N	N	N	N	N	N		
Binadhan-19	2017	N	N	N	N	N	N	N	N		
BRRI dhan79	2017	N	Y	N	Y	Y	N	N	N		Contains IRRI genetic material
BRRI dhan80	2017	N	Y	N	Y	N	N	N	N		IR 65610-105-2-5-2-2/IR 67423-208-6-2-3-3
BRRI dhan81	2017	N	Y	N	Y	N	N	N	N		Amol-3/BRRI Dhan-28
BRRI dhan 82	2017	N	N	N	Y	N	N	N	N		
BRRI dhan 83	2017	N	N	N	Y	N	N	N	N		
BRRI dhan84	2017	Y	Y	N	Y	N	N	N	Y		BR 29/IR68144// BRRI Dhan 28/// BR11

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BRRI dhan85	2017	N	Y	N	Y	N	N	N	N		BR4828-54-1-4-9/ IR50//BR4828-54-1-4-9/LU ZHONG ZAOI
BRRI dhan 86	2017	N	N	N	Y	N	N	N	N		
BRRI hybrid 6	2017	N	Y	N	N	N	N	N	N		IR79156A/ BRRI31R
BU Aromatic Hybrid Dhan-1	2017	Y	N	N	N	N	N	N	Y		
Binadhan-20	2017	Y	N	N	Y	N	N	N	Y		
BRRI dhan87	2018	N	Y	N	Y	N	N	N	N		BRRI dhan29*3/ Oryza rufipogon (IRGC103404)
BRRI dhan88	2018	N	Y	N	Y	N	N	N	N		BRRI dhan29-SC3-28-16-10-8-HR1(Com)
BRRI dhan89	2018	N	Y	N	Y	N	N	N	N		BRRI dhan29*3/ Oryza rufipogon (IRGC103404)
Binadhan-21	2018	N	N	N	N	N	N	N	N		
Binadhan-22	2019	N	N	N	N	N	N	N	N		
BRRI dhan 90	2019	N	N	N	Y	N	N	N	N		
BRRI dhan91	2019	N	Y	N	Y	N	N	N	N		BR10230-15-27-7B/ BRRI Dhan 41
BRRI dhan92	2019	Y	N	N	Y	N	N	N	N		Rice/Wheat(RI)/ BR319-1-HR2// DH(Mingolo/ Suweon290)/Panbira
BRRI dhan93	2019	N	N	N	Y	N	N	N	N		
BRRI dhan94	2019	N	N	N	Y	N	N	N	N		

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BRRI dhan95	2019	N	N	Y	Y	N	N	N	N		Swarna/Barisail/ PSBRC
BRRI dhan96	2020	N	Y	N	N	N	N	N	N		BRRI dhan28*3/ Oryza rufipogon (IRGC103404)
BRRI dhan97	2020	Y	N	N	Y	N	Y	N	N		IRRI113/BRRI dhan40
BRRI dhan98	2020	N	N	Y	Y	N	N	N	N		MLT-145-2/HR17512-11-2-3-1-4-2-3
BRRI dhan99	2020	Y	N	N	Y	N	Y	N	N		Huang-Hua-Zhan/ OM1723
BRRI hybrid 7	2020	N	Y	N	N	N	N	N	N		IR75608A/BRRI31R
Binadhan-23	2020	Y	N	N	Y	Y	Y	N	N		IRRI 149/IRRI 128
Binadhan-24	2020	N	N	N	N	N	N	N	N		
BRRI dhan100	2021	Y	Y	N	Y	N	N	N	Y		BR7166-5B-5/ BG305//BRRI dhan29
BRRI dhan101	2022	N	Y	N	Y	N	N	N	N		IRBB60/BRRI dhan29
BRRI dhan102	2022	Y	N	N	Y	N	N	N	Y		IR91153-AC117/ IR05F102//IR68144-2B-2-2-3-1-166/// IR66/4/NSIC RC158/ NEGRO//BRRI dhna29
BRRI Dhan 103	2022	N	Y	N	Y	N	N	N	N		BRRI Dhan 29/FL378
BRRI Dhan 104	2022	Y	N	N	Y	N	N	N	N		IR74052-217-3-3/ BR7150-11-7-4-2-16
Binadhan-25	2022	N	Y	N	N	N	N	N	N		BRRI Dhan 29
BRRI Dhan 105	2023	N	Y	N	N	N	N	N	N		BRRI Dhan 16/90060-TR1252-8-2-1

Variety	Year released	IRRI`s Direct Contribution	Indirect Contribution (IR line as one parent)	INGER entry	In our reference library	Sub1	Saline tolerance	Drought tolerance	Harvest plus	IRRI/ INGER listed (inbred and hybrid), released directly as varieties	IRRI/INGER entry used as parent(s)
BRRI Dhan 106	2023	Y	N	N	Y	N	N	N	N		MOROBEREKAN/ IR50/Ropa Aus 2007-08
Binadhan-26	2023	N	Y	N	Y	N	N	N	N		Contains Bacterial Leaf Blight resistant genes Xa4 and Xa5

Appendix C. Bioinformatic Analysis of the Genotyped Boro Rice Samples

Quality control was carried out on genotype data received from Agriplex Genomics. This entailed filtering genotypes by call rate (0.5), and SNPs by minor allele frequency (0.01),call rate (0.8) and removal of monomorphic markers. In addition, the polymorphism information content (PIC) of the markers, the heterozygosity, and the inbreeding coefficient of the genotypes were assessed, ensuring that only high-quality markers were used for downstream analysis. Thus, a total of 884 polymorphic SNPs were retained and used for assigning samples to Boro references. To approximate the level of purity of the samples relative to the references, calculation of pairwise comparisons between all samples and all references was done to determine the percentage similarity. This was followed by computation of genetic distance between all samples and references and generation of an identity by state (IBS) distance matrix. Samples were optimally matched to Boro references, with the lowest IBS distance and highest purity scores. The threshold for assignment was set at IBS distance of 5% or below.

Appendix D. Details of Wheat Varietal Releases

Table 28: Wheat varietal releases

Variety name	Year	Trait(s)	CGIAR-related?
Kheri	Landrace	Tall and susceptible to leaf rust and leaf blight diseases	No
Kalyansona	1974	Susceptible to leaf rust and leaf blight diseases	Yes
Sonora 64	1974	Susceptible to leaf rust and leaf blight diseases	Yes
Norteno 67	1974	Susceptible to leaf rust and leaf blight diseases	Yes
Inia 66	1974	Susceptible to leaf rust and leaf blight diseases	Yes
Sonalika	1974	Susceptible to leaf rust and leaf blight diseases	Yes
Tanori 71	1975	Susceptible to leaf rust and leaf blight diseases	Yes
Jupateco 73	1975	Susceptible to leaf rust and leaf blight diseases	Yes
Nuri 70	1975	Susceptible to leaf rust and leaf blight diseases	Yes
Balaka	1979	Susceptible to leaf rust and leaf blight diseases	Yes
Pavon 76	1979	Susceptible to leaf rust and leaf blight diseases	Yes
Doel	1979	Susceptible to leaf rust and leaf blight diseases	Yes
Akbar	1983	Susceptible to leaf rust and leaf blight diseases	Yes
Kanchan	1983	Susceptible to leaf rust and leaf blight diseases	Yes
Agrahani	1983	Susceptible to leaf rust and leaf blight diseases	Yes
Ananda	1983	Susceptible to leaf rust and leaf blight diseases and good for bread making	Yes
Barkat	1983	Susceptible to leaf rust and leaf blight diseases	Yes
Protiva	1993	Disease tolerant (Leaf rust and leaf blight tolerant)	Yes
BARI Gom 19 (Sourav)	1998	Lodging resistant. high yielding, disease resistant (Leaf rust and leaf blight resistant)	Yes
BARI Gom 20 (Gourab)	1998	Early maturing, heat tolerant, high yielding, disease resistant (Moderately tolerant to Bipolaris Leaf Blight and resistant to leaf rust)	Yes
BARI Gom 21 (Shatabdi)	2000	High biomass, late in maturity, high yielding, disease resistant (Moderately tolerant to Bipolaris Leaf Blight and resistant to leaf rust)	Yes
BARI Gom 22 (Sufi)	2005	Early maturing, high yielding, stress and disease tolerant (Heat and blast tolerant)	Yes
BARI Gom -23 (Bijoy)	2005	Stress (Heat) tolerant, high yieldin,g disease tolerant (Moderately tolerant Wheat Varities to Bipolaris Leaf Blight and leaf rust)	Yes
BARI Gom 24 (Prodip)	2005	Heat tolerant, high yielding, Stress and disease tolerant (Heat and blast tolerant) and good for bread making	Yes
BARI Gom 25	2010	Stress tolerant (Heat and salt tolerant), high yielding and resistant to LR and leaf blight disease	Yes
BARI Gom 26	2010	Stress tolerant (Heat and blast tolerant), suitable for late sowing, high yielding,	Yes
BARI Gom 27	2012	Disease tolerant (Ug99- tolerant), High yielding	Yes
BARI Gom 28	2012	Early maturing, heat tolerant, suitable for late sowing, high yielding, Disease tolerant (Moderately tolerant to Bipolaris Leaf Blight and leaf rust)	Yes
BARI Gom 29	2014	Short stature, tolerant to lodging, high yielding, disease tolerant (Ug99-tolerant and moderately tolerant to leaf blight)	Yes
BARI Gom 30	2014	Early maturing, stress-tolerant (Heat and blast tolerant), suitable for late sowing, high-yielding	Yes

Variety name	Year	Trait(s)	CGIAR-related?
Binagom 1	2016	Stress tolerant (salinity tolerant)	No
BARI Gom 31	2017	Early maturing, stress (heat) tolerant, Disease tolerant (Ug99-tolerant, resistant to LR, tolerant to spot blotch)	Yes
BARI Gom 32	2017	Early maturing, short stature, Stress tolerant (Heat and blast tolerant), disease tolerant (resistant to LR, tolerant to spot blotch)	Yes
BARI Gom 33	2017	Zinc rich, Resistant to wheat blast and leaf rust (LR), tolerant to leaf blight diseases	Yes

Appendix E. Details of Maize Varietal Releases

Table 29: Maize varietal releases

Variety name	Year	Trait(s)	CGIAR-related?
Shuvra	1986	Improved Hybrid	Yes
Khoibhutta	1986	Improved Hybrid	No
Barnali	1986	Improved Hybrid	Yes
Mohor	1990	High-yielding Improved Hybrid	No
BARI Maize 5	1998	High-yielding Improved Hybrid	Yes
BARI Maize 6	1998	High-yielding Improved Hybrid	Yes
BARI Maize 7	2002	High-yielding Improved Hybrid	Yes
BARI Sweet Maize 1	2002	Lodging resistant, Improved Hybrid	No
BARI Hybrid Maize 1	2000	Improved Hybrid	No
BARI Hybrid Maize 2	2002	Improved Hybrid	Yes
BARI Hybrid Maize 3	2002	High-yielding protein-enriched	Yes
BARI Hybrid Maize 4	2002	Improved Hybrid	Yes
BARI Hybrid Maize 5	2004	Protein enriched	Yes
BARI Hybrid Maize 6	2006	Improved Hybrid	Yes
BARI Hybrid Maize 7	2006	High-yielding Improved Hybrid	Yes
BARI Hybrid Maize 8	2007	Improved Hybrid	Yes
BARI Hybrid Maize 9	2007	Improved Hybrid	Yes
BARI Hybrid Maize 10	2008	Improved Hybrid	Yes
BARI Hybrid Maize 11	2008	Improved Hybrid	Yes
BARI Hybrid Maize 12	2016	Stress tolerant (Drought tolerant)	Yes
BARI Hybrid Maize 13	2016	Stress tolerant (Drought tolerant)	Yes
BARI Hybrid Maize 14	2017	Stress tolerant (Heat tolerant)	Yes
BARI Hybrid Maize 15	2017	Stress tolerant (Heat tolerant)	Yes
BARI Hybrid Maize 16	2016	Stress tolerant (Salt tolerant)	Yes
BARI Hybrid Maize 17	2019	Stress tolerant (Heat tolerant)	Yes

Appendix F. Details of Potato Varietal Releases

Table 30: Potato varietal releases

Variety name	Year	Trait(s)	CGIAR-related?
BARI Alu 1	1990	Stress tolerant, Early variety	Yes
BARI Alu 2	1990	Early variety	No
BARI Alu 3	1990	Table potato	No
BARI Alu 4	1993	Long lasting	No
BARI Alu 5	1993	Table potato, Early variety	No
BARI Alu 6	1993	Table potato, Early variety	No
BARI Alu 7	1993	Table potato	No
BARI Alu 8	1993	Table potato	No
BARI Alu 9	1993	Table potato	No
BARI Alu 10	1993	Table potato	No
BARI Alu 11	1993	Stress tolerant, Table potato	Yes
BARI Alu 12	1993	Stress (Heat) and disease tolerant, Table potato	Yes
BARI Alu 13	1994	Early variety and exportable	No
BARI Alu 14	1994	Table potato	No
BARI Alu 15	1994	Table potato	No
BARI TPS-1	1997	High-yielding, Table potato	Yes
BARI TPS-2	1997	High yielding, Table potato	Yes
BARI Alu 16	2000	Table potato	No
BARI Alu 17	2000	Table potato	No
BARI Alu 18	2003	Suitable for processing	No
BARI Alu 19	2003	Suitable for processing	No
BARI Alu 20	2003	Suitable for processing	No
BARI Alu 21	2004	Suitable for export	No
BARI Alu 22	2004	Stress (saline) tolerant	Yes
BARI Alu 23	2005	Suitable for processing and export	No
BARI Alu 24	2005	Suitable for processing and export	No
BARI Alu 25	2005	Suitable for processing	No
BARI Alu 26	2006	Suitable for processing	No
BARI Alu 27	2008	Suitable for processing	No
BARI Alu 28	2008	Suitable for processing	No
BARI Alu 29	2008	Suitable for processing	No
BARI Alu 30	2009	Suitable for processing	No
BARI Alu 31	2010	Table potato	No
BARI Alu 32	2010	Table potato	No
BARI Alu 33	2011	Suitable for processing	No
BARI Alu 34	2011	Suitable for processing	No
BARI Alu 35	2012	Suitable for processing, Table potato	No
BARI Alu 36	2012	Suitable for processing, Table potato	No
BARI Alu 37	2012	Suitable for processing, Table potato	No
BARI Alu 38	2012	Suitable for processing, Table potato	No
BARI Alu 39	2012	Suitable for processing, Table potato	No
BARI Alu 40	2012	Suitable for processing, Table potato	No

Variety name	Year	Trait(s)	CGIAR-related?
BARI Alu 41	2012	Suitable for processing, Table potato	No
BARI Alu 42	2012	Suitable for processing, Table potato	No
BARI Alu 43	2012	Suitable for processing and export. Table potato	No
BARI Alu 44	2012	Suitable for processing and export	No
BARI Alu 45	2012	Suitable for processing and export	No
BARI Alu 46	2013	Disease resistance, suitable for processing and export	Yes
BARI Alu 47	2014	Suitable for processing	No
BARI Alu 48	2014	Suitable for processing	No
BARI Alu 49	2014	Suitable for processing	No
BARI Alu 50	2014	Suitable for processing	No
BARI Alu 51	2014	Suitable for processing, early variety	No
BARI Alu 52	2014	Suitable for processing, table potato	No
BARI Alu 53	2014	Disease resistance, table potato	Yes
BARI Alu 54	2014	Suitable for processing and export	No
BARI Alu 55	2014	Suitable for processing, table potato	No
BARI Alu 56	2014	Table potato	No
BARI Alu 57	2014	Table potato, suitable for processing	No
BARI Alu 58	2014	Table potato, early variety	No
BARI Alu 59	2014	Table potato, suitable for processing	No
BARI Alu 60	2014	Table potato	No
BARI Alu 61	2014	Table potato	No
BARI Alu 62	2015	Table potato, preservable at room temperature, and suitable for export	No
BARI Alu 63	2015	Table potato	No
BARI Alu 64	2015	Table potato	No
BARI Alu 65	2015	Table potato	No
BARI Alu 66	2015	Table potato	No
BARI Alu 67	2015	Table potato	No
BARI Alu 68	2015	Suitable for processing	No
BARI Alu 69	2016	Table potato	No
BARI Alu 70	2016	Suitable for processing	No
BARI Alu 71	2016	Suitable for processing	No
BARI Alu 72	2016	Stress tolerant (heat and salinity tolerant),	Yes
BARI Alu 73	2016	Stress (heat) tolerant	Yes
BARI Alu 74	2017	Early variety	No
BARI Alu 75	2017	Early variety	No
BARI Alu 76	2017	Suitable for processing	No
BARI Alu 77	2017	Disease resistance, table potato	No
BARI Alu 78	2017	Table potato, salinity tolerant	Yes
BARI Alu 79	2017	Table potato, early variety	Yes
BARI Alu 80	2018	Table potato	No
BARI Alu 81	2019	Disease resistance, table potato	Yes
BARI Alu 82	2019	Table potato	No
BARI Alu 83	2019	Table potato, suitable for export	No
BARI Alu 84	2019	Table potato, early variety	No
BARI Alu 85	2019	Table potato	No

Variety name	Year	Trait(s)	CGIAR-related?
BARI Alu 86	2019	Table potato, suitable for export	No
BARI Alu 87	2019	Table Potato, suitable for export	Yes
BARI Alu 88	2019	Table Potato, suitable for export	Yes
BARI Alu 89	2019	Table potato, suitable for export	No
BARI Alu 90	2019	Disease resistance, suitable for export	No
BARI Alu 91	2019	Disease resistance, suitable for export	No

Appendix G. Details of Sweetpotato Varietal Releases

Table 31: Sweetpotato varietal releases

Variety name	Year	Trait(s)	CGIAR-related?
BARI SP-1	1985	Yellow-fleshed	No
BARI SP-2	1985	Orange-Fleshed	No
BARI SP-3	1988	White-fleshed	No
BARI SP-4	1988	White-fleshed	No
BARI SP-5	1994	White-fleshed	No
BARI SP-6	2004	Orange-Fleshed	Yes
BARI SP-7	2004	Orange-Fleshed	Yes
BARI SP-8	2008	Yellow-fleshed	Yes
BARI SP-9	2008	Yellow-fleshed	Yes
BARI SP-10	2013	Yellow-fleshed	Yes
BARI SP-11	2013	Yellow-fleshed	Yes
BARI SP-12	2013	Orange-Fleshed	Yes
BARI SP-13	2013	Orange-Fleshed	Yes
BARI SP-14	2017	Orange-Fleshed	Yes
BARI SP-15	2017	Orange-Fleshed	Yes

Appendix H. Details of Lentil Varietal Releases

Table 32: Lentil varietal releases

Variety name	Year	Trait(s)	CGIAR-related?
BARI Masur 1	1991	High yield and rust resistance; Tolerant to SB and root rot;	Yes
BARI Masur 2	1993	High yield and Disease resistant (Rust, foot and root rot resistant)	Yes
BARI Masur 3	1996	High yield and Disease resistant (Rust resistant)	No
BARI Masur 4	1996	Disease resistant (resistance to Stemphylium blight (SB) and rust); high iron, high yield	Yes
BINA Masur 1	2001	Disease resistant (resistance to Stemphylium blight (SB))	No
BINA Masur 2	2005	Early maturing, Protein enriched	No
BINA Masur 3	2005	Disease resistant (Rust, foot and root rot resistant); tolerant to mild water stress; late sowing potential	No
BARI Masur 5	2006	Disease resistant (resistance to Stemphylium blight (SB)), tolerant to foot rot, high yield	Yes
BARI Masur 6	2006	Disease resistant (resistance to Stemphylium blight (SB)), tolerant to foot rot, high yield, high in iron and zinc	Yes
BARI Masur 7	2011	Disease tolerant (tolerance to Stemphylium blight (SB) and rust); high yield; high crude protein	Yes
BINA Masur 4	2011	Disease resistant (Rust, foot and root rot resistant)	Yes
BINA Masur 5	2011	Disease tolerant (Rust and blight tolerant); good cooking quality crude protein	Yes
BINA Masur 6	2011	Disease tolerant (Rust and blight tolerant); good cooking quality crude protein	Yes
BINA Masur 7	2011	Disease tolerant (Rust and blight tolerant); High yield	Yes
BINA Masur 8	2014	High yield	No
BINA Masur 9	2014	High yield	No
BARI Masur 8	2015	Disease resistant (resistance to Stemphylium blight (SB))	Yes
BINA Masur 10	2016	Stress tolerant (Drought tolerant)	Yes
BARI Masur 9	2018	Early variety	No

Appendix I. Details of Groundnut Varietal Releases

Table 33: Groundnut varietal releases

Variety name	Year	Trait(s)	CGIAR-related?
Tridanabadam (DM-1)	1987	Suitable for cultivation as relay crop with maize and sugarcane	No
Zinga badam (ACC-12)	1988	Stress tolerant (drought tolerant)	No
BARI Chinabadam-5	1999	Protein enriched (Protein 25-27%), Oil content in seed 51-52%	No
BARI Chinabadam-6	1998	Short-duration, Oil content in seed 50-52%, Protein 25-26%	Yes
Binachinabadam-1	2000	Disease resistant (moderately resistant to collar rot, Cercospora leaf spot and rust diseases.), Seeds contain 47% oil and 28% protein.	No
Binachinabadam-2	2000	Disease resistant (moderately resistant to collar rot, Cercospora leaf spot and rust diseases.), Seeds contain 50% oil and 28% protein	No
Binachinabadam-3	2000	Disease resistant (moderately resistant to collar rot, Cercospora leaf spot and rust diseases.), Seed contain 25 oil and 29% protein.	No
BARI Chinabadam-7	2004	High-yielding, Leaf spot and rust disease are comparatively lower in this variety.	Yes
BARI Chinabadam-8	2006	Short duration	Yes
Binachinabadam-4	2008	Stress tolerant (tolerant to collar rot, Cercospora leaf spot, and rust disease)	No
BARI Chinabadam-9	2009	Short duration	Yes
Binachinabadam-5	2011	Stress (salinity) tolerant, Tolerant to collar rot and rust diseases, Seeds contain 49% oil and 25.72% protein	No
Binachinabadam-6	2011	Stress (salinity) tolerant, Tolerant to collar rot and rust diseases, Seeds contain 48.51% oil and 28.68% protein	No
BARI Chinabadam-10	2016	Short duration	Yes

Appendix J. Details of Chickpea Varietal Releases

Table 34: Chickpea varietal releases

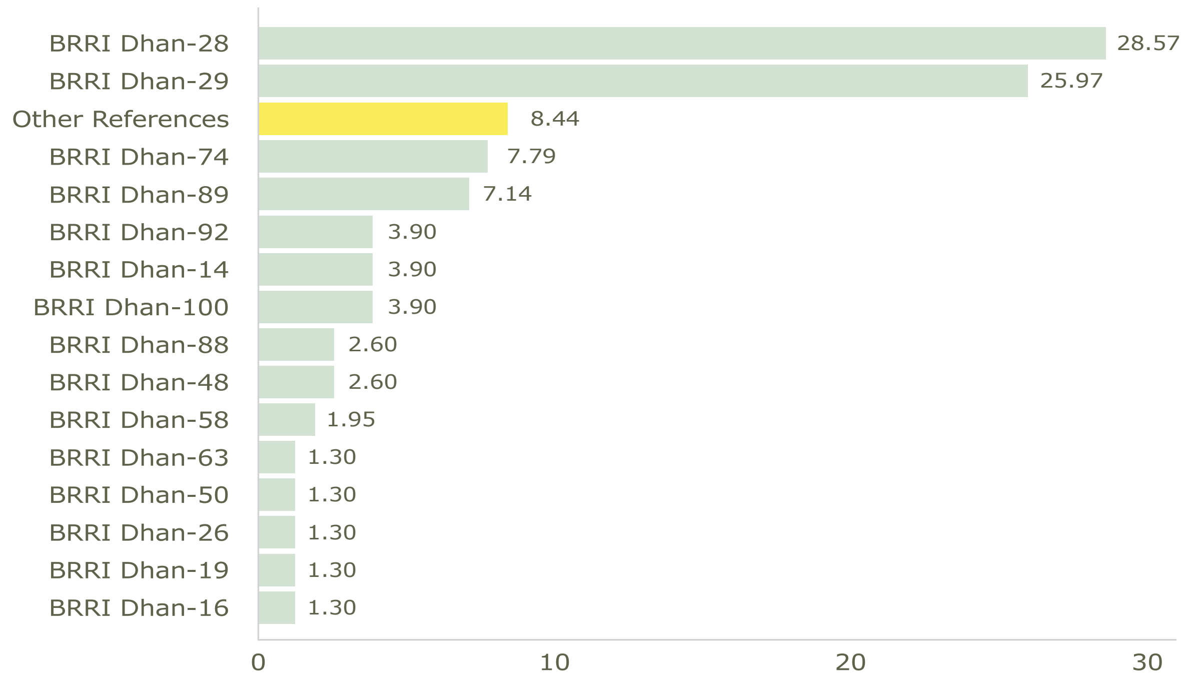
Variety name	Year	Trait(s)	CGIAR-related?
BARI Chola-1	1987	Improved	Yes
BARI Chola-2	1993	Disease tolerant or resistant (Wilt Disease tolerant) chickpea	Yes
BARI Chola-3	1993	Protein 23-26%	Yes
BARI Chola-4	1996	Disease tolerant or resistant (Fusarium Wilt Disease tolerant) chickpea	Yes
BARI Chola-5	1996	High yield	Yes
BARI Chola-6	1996	Disease tolerant or resistant (Wilt Disease resistant) chickpea	Yes
BARI Chola-7	1998	Disease tolerant or resistant (Fusarium Wilt Disease resistant)	Yes
BARI Chola-8	1998	Disease tolerant or resistant (Fusarium Wilt Disease resistant)	Yes
BARI Chola-9	1998	Disease tolerant or resistant (Fusarium Wilt Disease resistant)	Yes
BARI Chola-10	2017	Stress tolerant (Heat-tolerant)	Yes

Appendix K. Unassigned Samples from Rice DNA Fingerprinting and Their Characteristics

Among the total rice samples, 771 samples were not assigned to one of the varieties in the reference set. This could mean two things. First, it could indicate that some varieties used by farmers were not included in our set of references. Second, it could indicate systematic issues with matching samples to references.

Most evidence points to the first explanation. Of the "Not Assigned" samples, only 154 (20.6%) were self-reported by farmers as varieties included in the reference. The remaining 79.4% were listed as varieties that were not included in the reference set because reference material was unavailable.[28] In most cases, unmatched samples are from a traditional or hybrid variety, not within the sample, even though they are reported as improved varieties from BRRI and BINA. This is the breakdown of those 154. BRRI Dhan 22, 26, 33, 70, 79, 82, 90, 91, 103, 106, and Bina 23 were combined into Other References because they were less than 1% each (Figure 48).

Figure 48: Self-reports for 'Not-Assigned' samples (in reference list)



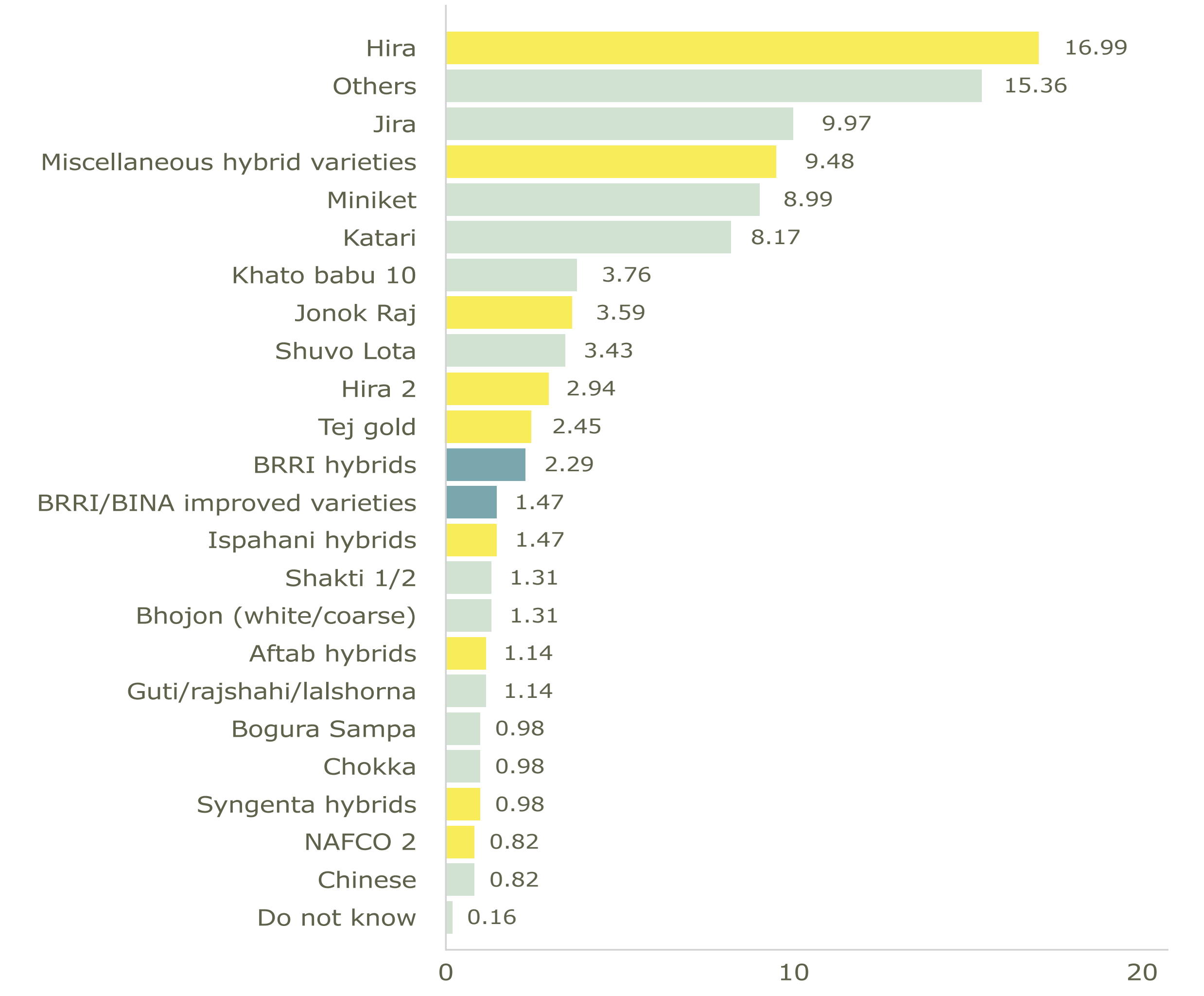
Note: Not assigned samples are the field samples that did not match with one of the reference materials from Bangladesh Rice Research Institute (BRRI) or Bangladesh Institute of Nuclear Agriculture (BINA). Samples =154 (20.6% of unmatched samples), all the varieties are CGIAR varieties. Other references include: BRRI Dhan 22, 26, 33, 70, 79, 76, 82, 90, 91, 103, 106, BINA 23, where BRRI Dhan 33, 79, 82, 90 are not CGIAR varieties

Out of the unassigned samples not within the reference list, 23 samples are from BRRI and BINA. These can be categorized as improved and hybrid varieties from self-reports. Thus, for

[28] Most of these are unavailable because they are local varieties or private company hybrids.

2.98% of the total unmatched samples, we are missing probable reference material, which may have provided a match if available. We categorize different varieties of hybrids together as miscellaneous hybrids due to the low number of observations of each variety in the graph below. The other notable hybrid varieties are highlighted within the graph. The Others bar contains varieties below 1% that are not confirmed as hybrids based on the information available from the Ministry of Agriculture documents (Figure 49).

Figure 49: Self-Reports for 'not assigned' samples (not in reference list) (%)



Note: Not assigned samples are the field samples that did not match with one of the reference materials from the Bangladesh Rice Research Institute (BRRI) or Bangladesh Institute of Nuclear Agriculture (BINA). Samples = 612 (79.4% of unmatched). Dark-blue: BRRI/BINA var. absent from the reference, blue: Hybrid, light-blue: Others

We drop the samples categorized as hybrids and BRRI/BINA improved varieties and BRRI hybrids and focus our analysis on the remaining samples to analyze the self-reported primary trait of a variety. 26.7% of the remaining samples are categorized as hybrids by respondents, which we drop for subsequent analysis. Approximately half of the respondents stated improved as the primary trait.

Appendix L. Farmer Self-Reported Data on Certainty of Responses and Reliability and Quality of Varieties Cultivated

Certainty regarding the accuracy of the self-reported main variety

Certainty Level	Percentage
Absolutely certain	84.16
Somewhat certain	15.29
Neither certain nor uncertain	0.22
Somewhat uncertain	0.11
Absolutely uncertain	0.22

Reliability of the main variety source

Quality Level	Percentage
Extremely reliable	81.56
Somewhat reliable	16.70
Neither reliable nor unreliable	0.65
Extremely unreliable	1.08

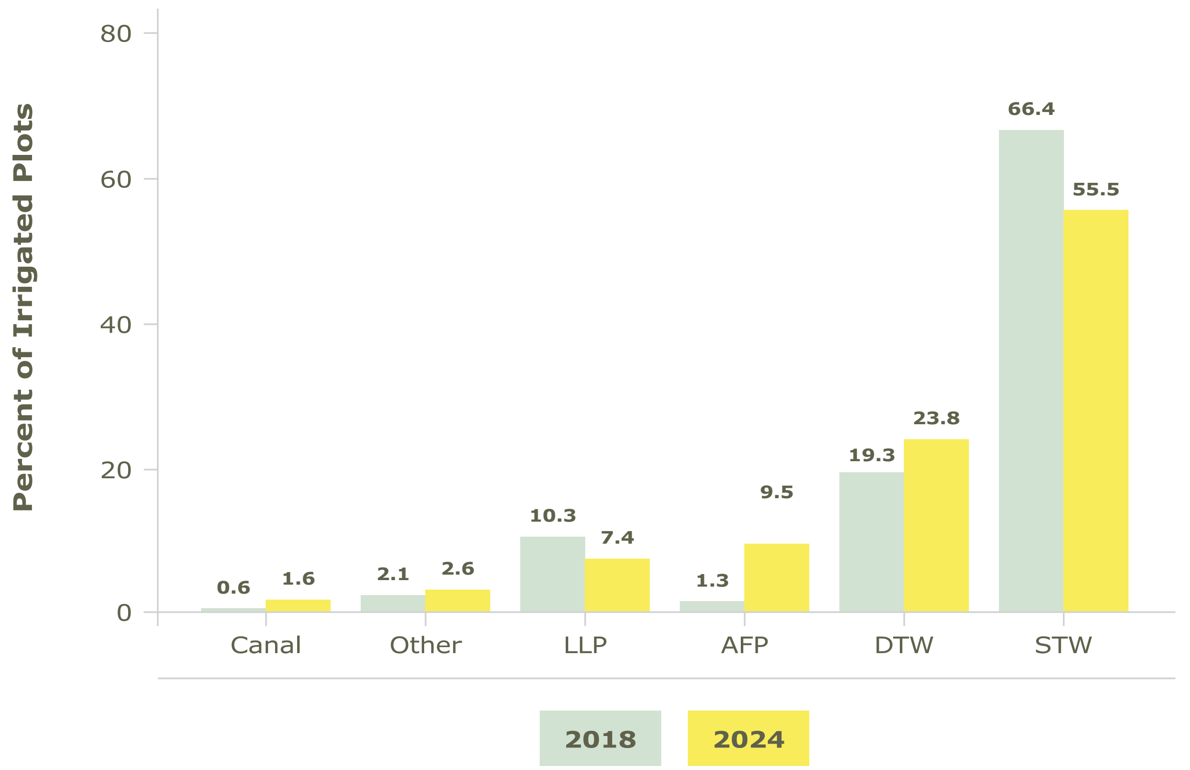
Quality of the main variety

Quality Level	Percentage
Very high quality	79.61
Somewhat high quality	18.87
Neither high neither poor quality	1.19
Somewhat poor quality	0.22
Very poor quality	0.11

Appendix M. Further Information on Irrigation Sources

There has been a notable decline of 10.9 percentage points in the use of shallow tube wells during the dry season when measured at the plot level, reflecting a shift in irrigation practices. This reduction has been partially offset by a 4.5 percentage point increase in the use of deep tube wells. More significantly, there has been an 8.2 percentage point rise in the proportion of irrigated plots using axial flow pumps, indicating a growing preference for this technology. These trends might suggest an ongoing transition towards sustainable irrigation methods, depending on surface water as groundwater continues to become scarcer and more expensive to pump.

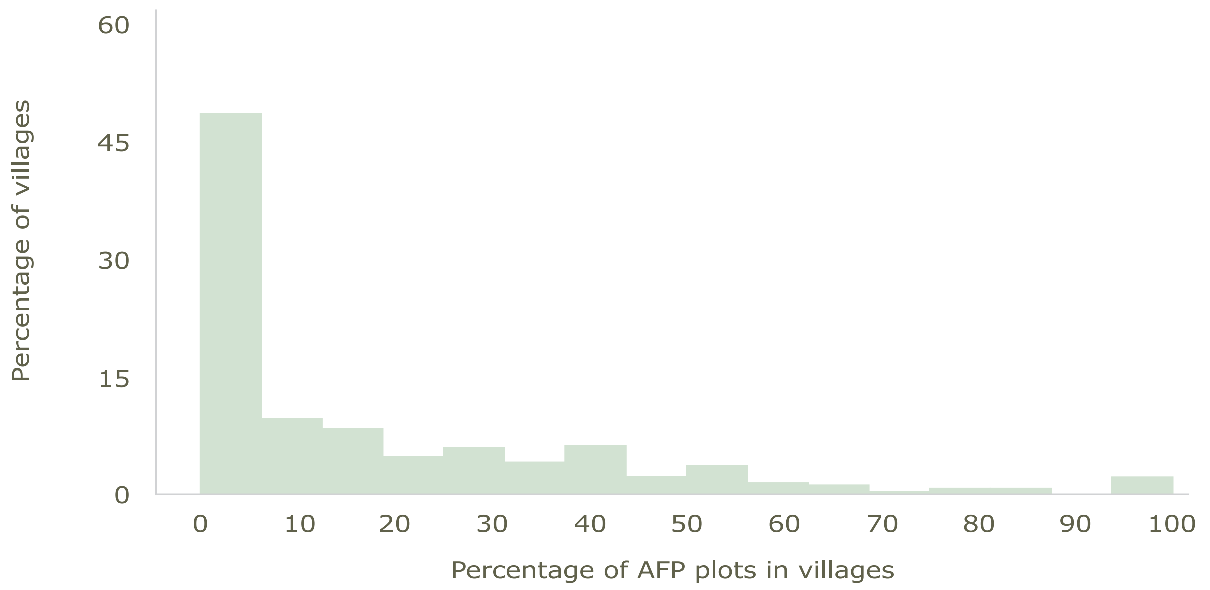
Figure 50: Primary pump type (% of agricultural households irrigating in the Boro season)



Note: Total agricultural households irrigating in the Boro season (2023/24) are 1,729 and 1,995 in 2018. A household can have multiple sources. LLP = Low lift pump, AFP = Axial flow pump, DTW = Deep tubewell, STW = Shallow tubewell.

We examine AFP adoption across villages to understand whether adoption tends to cluster within villages. The histogram in the figure below illustrates that, in the majority of villages, less than 30% of plots use AFPs. This pattern suggests that AFP adoption is not widespread at the village level and does not indicate village-wide group adoption facilitated through collective decisions. Instead, adoption may be driven by specific households within a village, likely influenced by access to surface water, financial capacity, or awareness of AFP benefits.

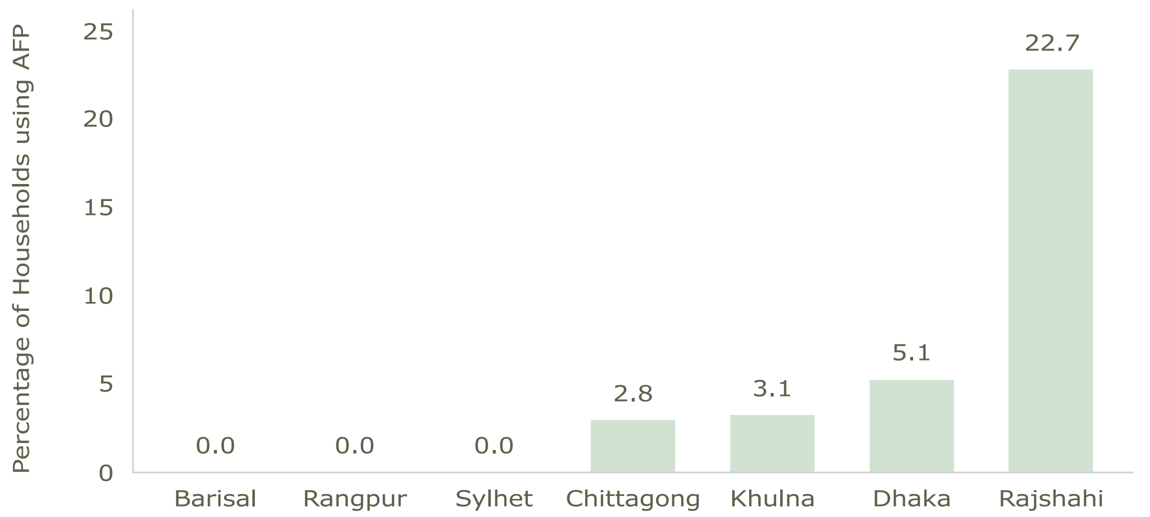
Figure 51: Histogram of plots using an axial flow pump in 2024 (share of plots on x axis, share of villages on y axis)



Note: This covers 270 villages in BIHS 2024.

The division-wise distribution of households using both axial flow pumps (AFPs) and Shallow Tube Wells (STWs) in 2024 is shown in Figure 52. It indicates a stark regional variation in the combined use of these irrigation technologies. Rajshahi leads significantly, with 22.7% of households utilizing both AFPs and STWs, while other divisions like Dhaka (5.1%) and Khulna (3.1%) show much lower adoption. This pattern suggests that in northern Bangladesh, particularly in Rajshahi, where groundwater availability may be limited or declining, households are supplementing their irrigation needs by combining AFPs with STWs.

Figure 52: Division-wise distribution of households using both axial flow pump and tubewells in 2024



Note: Total number of households using AFPs in 2024 is 358.

Appendix N. Definition of Variables Used in Analysis of Household Correlates of Adoption

Table 35: Definition of variables used in analysis of household correlates of adoption

Variable	Definition
b1plot_distance	Distance of the plot from the household [mts]
b2area	Area of the plot [hectare]
b5distance_pump	Distance from the pump/canal [mts]
b5additional_pipe	Plot has additional main/lateral pipe [0/1]
b5relative_height1	Relative Height: Upper [0/1]
b5relative_height2	Relative Height: Middle [0/1]
b5relative_height3	Relative Height: Lower [0/1]
b1soil_type1	Soil type: Clay [0/1]
b1soil_type2	Soil type: Loam [0/1]
b1soil_type3	Soil type: Sandy [0/1]
b1soil_type4	Soil type: Clay-loam [0/1]
b1soil_type5	Soil type: Sandy-loam [0/1]
total_b2area	Total area owned [hectare]
Number of lands	Total number of lands
a2hhroster_count	Household size
a2mem_age	Household Head: Age [0/1]
a2mem_gender	Household Head: Male [0/1]
a4employment_status	Household Head: Employed [0/1]
a2agri_decision_gender	Agricultural Head: Male [0/1]
a6_hh_savings	Annual Household Savings (Taka)
std_hh_asset_index	Household Asset Index (PCA)
pc_expm_	Monthly average consumption expenditure (Taka)
con bottom20	Household in bottom 20% by consumption [0/1]
religion_islam	Household Religion: Islam [0/1]
lit_can_read_write	Household Head: Can Read/Write [0/1]
b4machine_type_1	Use machine on the plot: Power tiller [0/1]
b4machine_type_2	Use machine on the plot: Tractor [0/1]
b4machine_type_3	Use machine on the plot: Plough [0/1]
b4machine_type_4	Use machine on the plot: Manual [0/1]

Appendix O. Covariates of Adoption for Additional Mechanization Innovations

2-wheel and 4-wheel tractors and shallow tubewells

Figure 53: Covariates of adoption for 2-wheel and 4 wheel power tillers

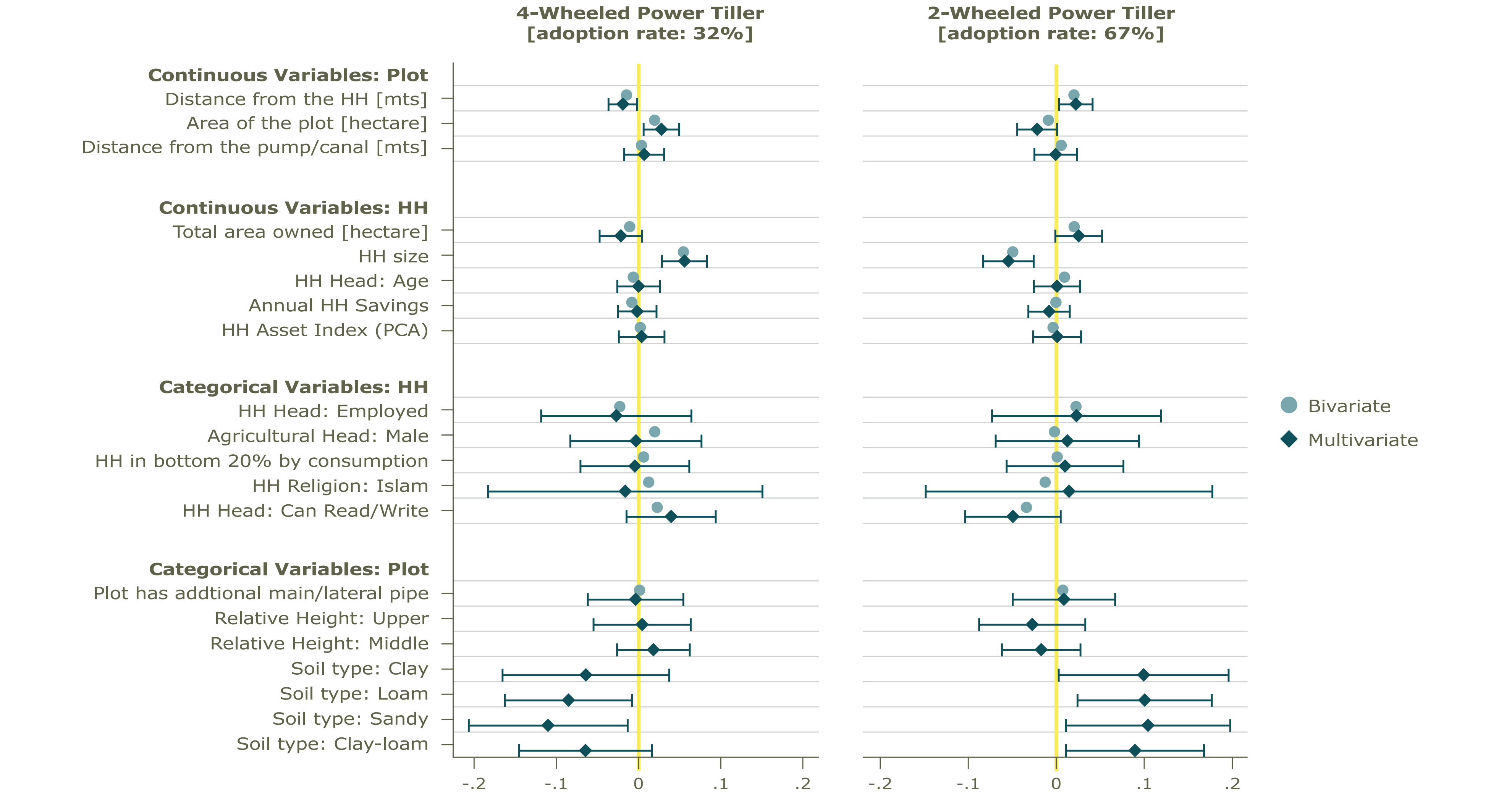
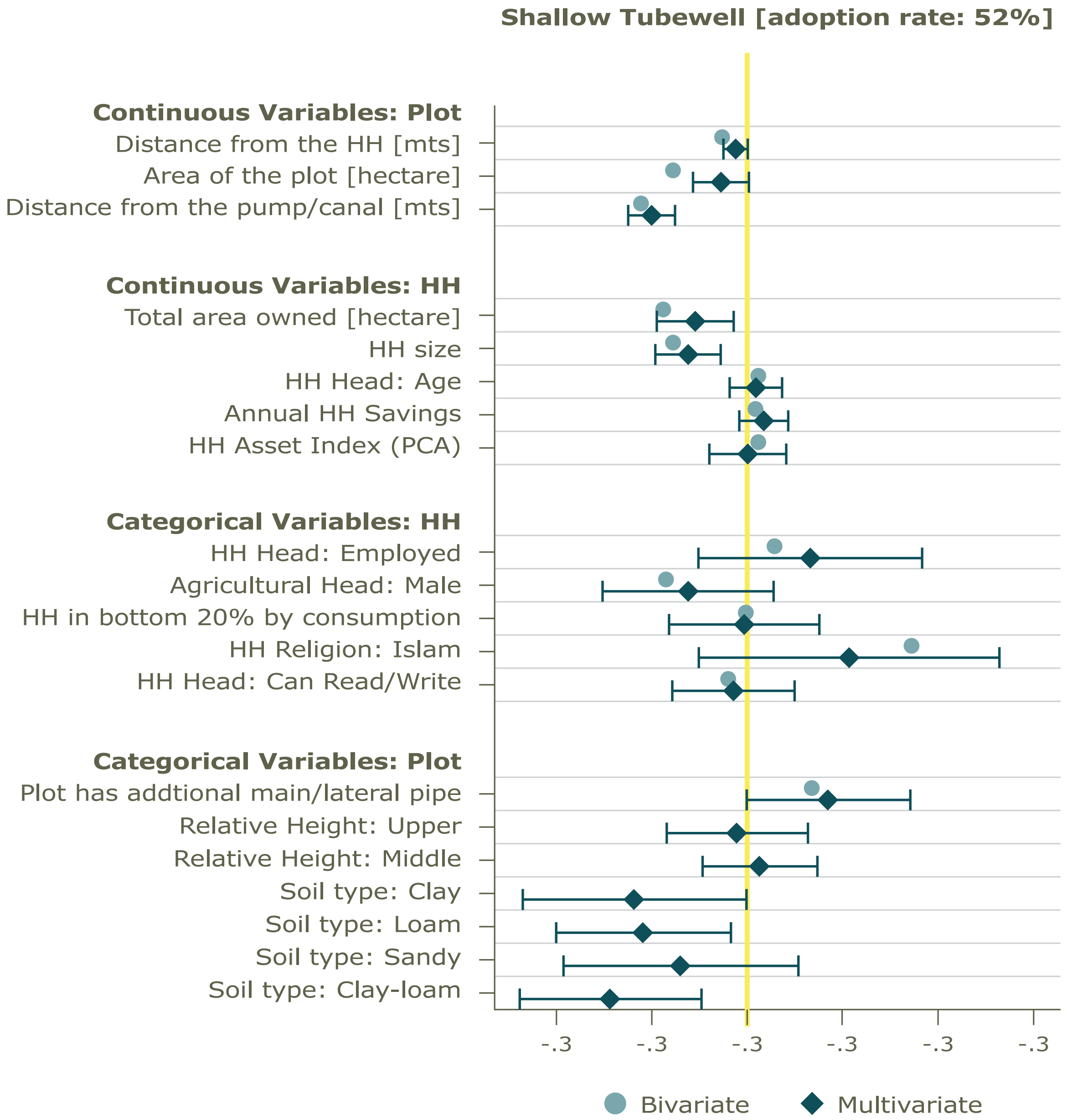


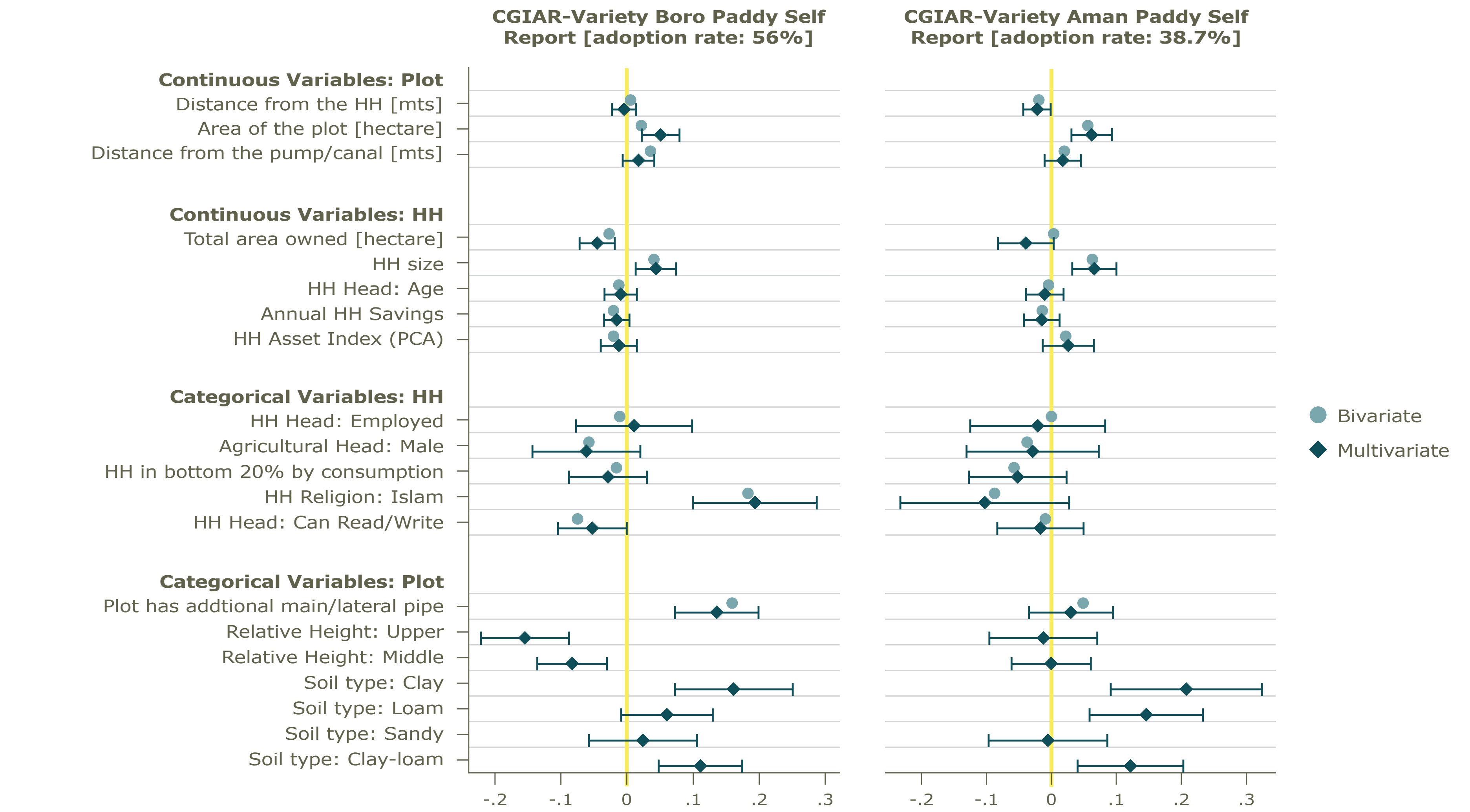
Figure 54: Covariates of adoption for shallow tubewells



Appendix P: Covariates of Adoption for Additional CGIAR Variety Innovations

Boro and Aman Paddy Self-Reports

Figure 55: Covariates of adoption for 2-wheel and 4 wheel power tillers



Note: For Boro paddy self-report adoption, we examine the 5,776 plots that had agricultural activity during the Boro 2024 season. The Aman paddy adoption is also based on self-reported information on CGIAR varieties.

CGIAR

Standing
Panel on
Impact
Assessment

CGIAR Advisory Services – SPIA
Alliance of Bioversity International and CIAT
Via di San Domenico,1
00153 Rome, Italy

spia@cgiar.org

https://cas.cgiar.org/spia