Farm differentiation and intervention targeting in Mixed Farming Systems of Coastal and Inland Bangladesh

Powell Mponela[1], Sharif Ahmed[2],
Farah Deba Keya[1], Ishrat Jahanara[1],
Masud Rana[1], Santiago Lopez[1], Timothy J Krupnik[1]

Author affiliation [1]CIMMYT
[2]International Rice Research Institute

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The Sustainable Intensification of Mixed Farming Systems Initiative aims to provide equitable, transformative pathways for improved livelihoods of actors in mixed farming systems through sustainable intensification within target agroecologies and socio-economic settings.

Through action research and development partnerships, the Initiative improves smallholder farmers' resilience to weather-induced shocks, provide a more stable income and significant benefits in welfare, and enhance social justice and inclusion for 13 million people by 2030.

Activities are implemented in six focus countries globally representing diverse mixed farming systems as follows: Ghana (cereal–root crop mixed), Ethiopia (highland mixed), Malawi: (maize mixed), Bangladesh (rice mixed), Nepal (highland mixed), and Lao People's Democratic Republic (upland intensive mixed/ highland extensive mixed).

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Abbreviations and acronyms

ABC	Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT)
BARC	Bangladesh Agricultural Research Council
CIMMYT	International Maize and Wheat Improvement Center
GESI	Gender and Social Inclusion
ICARDA	International Center for Agricultural Research in the Dry Areas
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
IWMI	International Water Management Institute
SDG	Sustainable Development Goals
SI-MFS	Sustainable Intensification of Mixed Farming Systems Initiative
WP	Work Package

ABSTRACT

Multiple stakeholders use farm and farmer attributes such as land size and experience to select participants and beneficiaries for agricultural interventions. Such criterion often ensures project success and impact but potentially widens inequality if uncoordinated. In South Asia, despite the general improvement in farm productivity, not all farmers have benefited and wide variability in performance persist. Over past decades, vertical research-extension-farmer innovation transfer approaches have evolved to enable increased and direct interactions among researchers, extension, private sector and farmers. Horizontal participatory approaches have facilitated co-creation and co-design of interventions tailored to specific farmer segments. This study demonstrates how participatory workshops can be used to segment different farm typologies and design targeted strategies. Bangladesh is used as a cast study example for diverse intensification strategies due to regional variations in cropping systems driven by environmental and resource constraints. In the South, farmers are often limited to single-season rice cultivation due to flooding, salinity, irrigation, and land tenure challenges while in the North, diverse cropping patterns are enabled by better resource access and stronger markets. Using the approaches described in this report, organizations can design interventions to address specific regional challenges, such as soil quality issues in the North and salinity problems in the South. Economic conditions can dictate cropping intensity: limited finances may constrain farmers in southern Bangladesh, while those in the north can optimize crop choices for better returns. This study provides a methodological approach that can enhance innovation targeting given these differing circumstances by combining broad strategies for wide adoption with tailored approaches for specific farmer segments. While generalized strategies may enable mass adoption, they also have negatives, namely that they can overlook local variations and potentially worsen inequalities, highlighting the need for coordinated efforts to meet the diverse needs of farming communities

Keywords: Participatory Workshop, Agricultural Innovation targeting, Farmer Segmentation, Institutional bias. Farming Systems,

1 Background

To better tailor technologies to farm-specific conditions, classifications have evolved significantly over time. It began with the broad climate-based classifications of Köppen–Geiger (1884–1961), progressed to crop-animal-based farming systems (Dixon et al., 2001), and agro-ecological zones that incorporate local physiography, soils, land types, and agroclimatology (BARC, 1988). Later advancements included livelihood zones that account for human capacities (UN WOMEN, 2020) and now extend to local and hyperlocal targeting that considers the unique conditions of individual farmers and farms (Beg et al., 2024; Dobermann et al., 2002).

In Bangladesh, the development and deployment of innovations have undergone significant evolution over the past two decades. Despite the growing number of stakeholders in agricultural innovation, farmers often remain passive recipients of solutions determined by supporting institutions (Cook et al., 2021). To complement public investment in extension services, the involvement of the private sector and non-governmental organisations has been widely encouraged. However, the multi-stakeholder approach requires robust governance to ensure that it effectively addresses the needs of smallholder farmers (Kidd et al., 2000; Uddin and Qijie, 2013).

Unlike global and regional classifications, differentiation at local and hyperlocal levels demands a detailed understanding of farmers' attributes. Creating robust and relevant segments requires active engagement with multiple stakeholders at the grassroots level through participatory approaches, which adds complexity to the processes of development, validation, and implementation. Farm typology, the practice of stratifying agricultural holdings into mutually exclusive and relatively homogeneous groups, has gained significant attention in recent decades. This method enables tailoring interventions, technologies, and innovations to better align with the unique structure and functioning of individual farms (Kaur et al., 2021).

The farm typology are generally constructed based on farm structural components, resource endowments such as the gross cash farm income and functions (Hoppe and MacDonald, 2013; USDA, 2021). Domain experts often play a central role in both developing and validating typologies (Dossa et al., 2011), which ensures alignment with established understanding (Alvarez et al., 2018).

Engaging farmers in a participatory process enhances the accuracy and relevance of farm typologies by incorporating local knowledge (Kuivanen et al., 2016). To support domain-specific targeting, involving diverse actors, including farmers, in typology development, validation, and use is essential for creating practical and scalable solutions (Eshetae et al., 2024).

Access to innovations, strategies, and support for improving productivity, income, and resilience to shocks varies significantly across spatial and socio-economic profiles. Understanding these variations can help decision-makers and service providers tailor agronomic interventions and advisory services more effectively (Patel, 2013). Untargeted support risks exacerbating resource disparities, deepening inequality, and creating degradation hotspots within landscapes and communities.

This study aims to leverage farm typologies to develop targeted strategies for agricultural innovations. By engaging stakeholders through participatory discussions, the research seeks to ensure that these strategies address the diverse needs and conditions of different farming systems, promoting equitable resource distribution, productivity, and resilience.

2 Methodology

2.1 The study area

The study was carried out in two locations: the low-intensity cropping and multi-stress areas of the coastal Patuakhali district, and the moderate-intensity yet highly potential agricultural areas of Rangpur District.

2.2 Study approach

To develop targeted strategies for agricultural innovations, participatory multi-stakeholders' workshops with farmers, government extension and research, private sector and non-governmental organisations were conducted to elicit key factors used in differentiation and in reaching farmers with products and services.

Participatory workshops were conducted with farmers in Chalavanga, Patuakhali (south) and Rangpur Sadar, Rangpur (north) to gather insights and perspectives from practitioners on the major categorizations of farming systems. The workshops aimed to identify enablers and challenges to innovation adoption. Farmers were selected by community leaders to represent various farm types, ensuring a diverse range of farming contexts and practices. The workshops included gender-balanced groups of men and women who discussed differentiation in access to production resources, such as land and machinery, participation in markets, and development trajectories.

Stakeholder participants were drawn from a range of sectors including government, private sector, and NGOs organizations with core mandates from *awareness, implementation to policy plus enabling conditions such as gender*. To ensure coverage of key components of mixed farming systems, participants and innovations represented both crop and livestock sectors. A five point CGIAR scaling readiness stakeholder engagement guideline was used to ensure inclusivity of actor roles including those who ensure: (i) awareness, confidence and trust, capacity through information service or extension, (ii) availability, access to finance/affordability, (iii) compatibility with existing farming, market and business systems or business models, (iv) capacity and know-how including training and extension, and (v) gender equality and social inclusion, legal conditions and governance including partnership building.

Focus group discussions were conducted to compare perspectives among various stakeholders in multi-functional systems (MFS), ensuring balanced representation of men and women. At the district level, participants included government officers from research and extension, representatives from agriculture-focused non-governmental organizations (NGOs), and private sector actors. These discussions captured diverse approaches, stages of product development, and varying levels of spatial coverage.

The selection of participants was guided by key assumptions about their roles and strategies. Government extension departments were assumed to focus on broader communities, employing scaling strategies that span districts and regions. Research programs were seen as bridging research and extension through the demonstration of proven technologies in representative geographical domains. The private sector, including wholesalers, agrovet retailers, and small-scale service providers, was recognized for using market-oriented differentiation and product promotion strategies. NGOs were noted for implementing targeted projects aimed at addressing specific societal groups or localized challenges.

Each stakeholder group engages farmers in distinct learning processes tailored to different categories of adopters. Researchers primarily target innovators to test and refine new technologies. Extension services and the private sector focus on the early and late majority, facilitating broader adoption. NGOs, in turn, often work with laggards, aiming to include those who are typically left behind in the adoption of innovations.

2.3 The workshop

The guiding questions were developed (see table 1) to solicit information of how farmers perceive differences in structure and performance of farms within their communities. Depending on their roles and innovations implemented stakeholders were asked to specify how they select farmers, the kind of farmers engaged and farmers who self-select into programs.

2.4 Analysis and interpretation

The responses were grouped by region and for farmers, the farmers were characterised by major defining features. For crops, farmers agreed to categorise them by cropping intensity across the seasons and, additionally by crop diversity in the north. In the north farmers also categorised the livestock farms ownership by number. Although crops and livestock are mostly combined, farmers did not come up with joint crop-livestock classification.

3 Results

The results as agreed among stakeholders and farmers during discussions are presented on

Table 1, Table 2, Table 3, Figure 1, and Figure 2). These are group agreeable defining attributes and may not represent differing individual opinions. The results shows that farmers and stakeholders in North and Southern Bangladesh focus differentiation and targeting on land quality, size and accessibility, irrigation access, mechanisation, cropping system, livestock system, farmers' engagement and agency. Farmers rely on local knowledge and immediate environmental conditions to guide their differentiation while institutions implement more strategic, intervention-based approaches aimed at enhancing productivity, resilience, and economic stability.

3.1 Farm structural factors for differentiation and segmentation

3.1.1 Cropping system

Farmers distinguish their farming practices based on a three-season sequential cropping system: Kharif 1 (pre-monsoon, March-April to June-July), Kharif 2 (monsoon, July-August to November-December), and Rabi (spring, December to April/May). However, in the South, cropping intensity and the proportion of fallow land is a critical factor while in the North, crop diversity and livestock density stand out as a major factors distinguishing the cropping systems.

In the South, particularly in coastal regions (

Table 1), the number of times a household grows crops within a year serves as a key distinguishing factor. Around 50% of farmers grow only once during Kharif 2 (primarily aman rice), 30% manage to grow twice, including during Kharif 1, and a smaller portion, about 20%, grow three times, including the Rabi season. The reliance on a single cropping season by half the farmers often highlights the challenges posed by salinity, limited access to irrigation, and mechanization, making cropping intensity a key variable in the region.

On the other hand, farmers in the North identify five distinct cropping patterns based on the sequence of crops grown across the three seasons. A shared feature across all northern farmers is the cultivation of Aman rice during Kharif 2. However, the diversity of cropping choices during the Rabi and Kharif 1 seasons distinguishes farmers. In the Rabi season, some opt for Boro rice, while others grow maize or jute. During Kharif 1, a mix of crops like Aus rice, mustard, potato, maize, or tobacco is observed. The variety of cropping systems reflects the flexibility of northern farmers in adapting to different land categories, market demand, and input access.

Table 1 Farmer's differentiation of farming systems in southern and northern Bangladesh

Southern	Cropping systems		
variable	Single crop season (Karif II) 50%	Two crop seasons (Kharif II and Rabi) 30%	Three crop seasons (Kharif I, Khalif II and Rabi) 20%
Distance	>1km	0.5	Near home 100 m
Salinity	High	Medium	low
Elevation	low	medium	high
Investment	60%		Financial ability of farmers
Pro-active	5% of farmers are not proactive.		Active farmers and able to cultivate multiple crops
Mechanization	Available to all	Limited access	Very limited access
Irrigation	Depend on rainwater	Soil moisture plus irrigation	Access to irrigation (25%)

Northern	Cropping systems				
	Boro Rice Aman Rice Mustard	Maize Aman rice Mustard	Maize Aman rice Potato	Aus Rice Aman Rice Tobacco	Jute Aman Rice Mustard/ Tobacco/ Maize
Land category	Mid-high	High & Mid-high	Highland	Mid-high & sandy	Mid-high & sandy
Crop duration	90 days for mustard				
Crop Variety	Short duration Aman rice		Short duration Aman rice		
Irrigation	High irrigation	Low irrigation	Low irrigation	High irrigation	Low irrigation
Consumption Priority	Rice priority		Rice & potato priority		
Cattle feed	Rice priority (straw)	Maize fodder			
Labour		Low labour cost	Low labour cost		Low labour cost
Income		High return	High return	High return	
Fuel		Dry Maize straw	Dry Maize straw		
Production cost	High	Low	Medium		
Production rate	Low	High	High		
Market Demand	Low	High	High	High	

Northern	livestock systems		
	Less than 3 cattle	3 to 5 cattle	More than 5 cattle
Enough space for cattle	Not enough space	Enough space	Enough space
Availability of fodder/ straw	Not available	Available	Available
Rearing Cost	There is not enough money	Have enough money	Have enough money
Milk priority			High milk production priority
Organic fertilizer	Low priority for organic fertilizer	High priority for organic fertilizer	High priority for organic fertilizer
Veterinarian service	Available in locality	Available in locality	Available in locality
vaccine	Unavailable in locality	Unavailable in locality	Unavailable in locality
Improved breed	Unavailable	Unavailable	Unavailable

Farmers in the Northern region manage livestock differently based on the number of cattle they rear, with variations in resource access, priorities, and challenges. Those with fewer than three cattle face constraints such as limited space, insufficient fodder, and financial challenges, resulting in low emphasis on milk production and organic fertilizer use. Farmers with three to five cattle typically have adequate space, access to fodder, and the means to prioritize organic fertilizer use, but they still lack access to vaccines and improved breeds. Farmers with more than five cattle benefit from sufficient resources, enabling a high focus on milk production and organic fertilizer, yet they share similar challenges regarding vaccine and breed access. Despite these differences, veterinarian services are available across all groups, highlighting a common support system amidst varying capacities and priorities.

3.1.2 Land Size: Large vs. Small Farmers

In the North, land size is a key factor in selecting farmers for interventions. Institutions like BJRI, BINA, and BARI set clear thresholds for land size to target different types of farmers. BJRI's New Jute Variety intervention requires farmers to own at least 0.081 hectares (20 decimals). BINA's Rice Variety Bina Dhan 25 targets farmers with a minimum of 0.134 hectares (33 decimals), while BARI's Sunflower program in the North selects farmers with 0.134 to 0.201 hectares (1–1.5 bigha / 33–50 decimals) for risk diversification. DAE's Dissemination programs engage even smaller farmers, requiring as little as 3 decimals of land, particularly for information dissemination. In contrast, the South also emphasizes land size, particularly for large-scale interventions. For example, DAE's Crop Synchronization requires farmers to aggregate at least 20.23 hectares (50 acres) of land, highlighting the focus on large-scale farming to optimize productivity through synchronized planting. CORDAID segments farmers based on land size, distinguishing lead farmers with at least 0.0405 hectares (10 decimals) from commercial farmers who own at least 0.7 hectares (5 bigha).

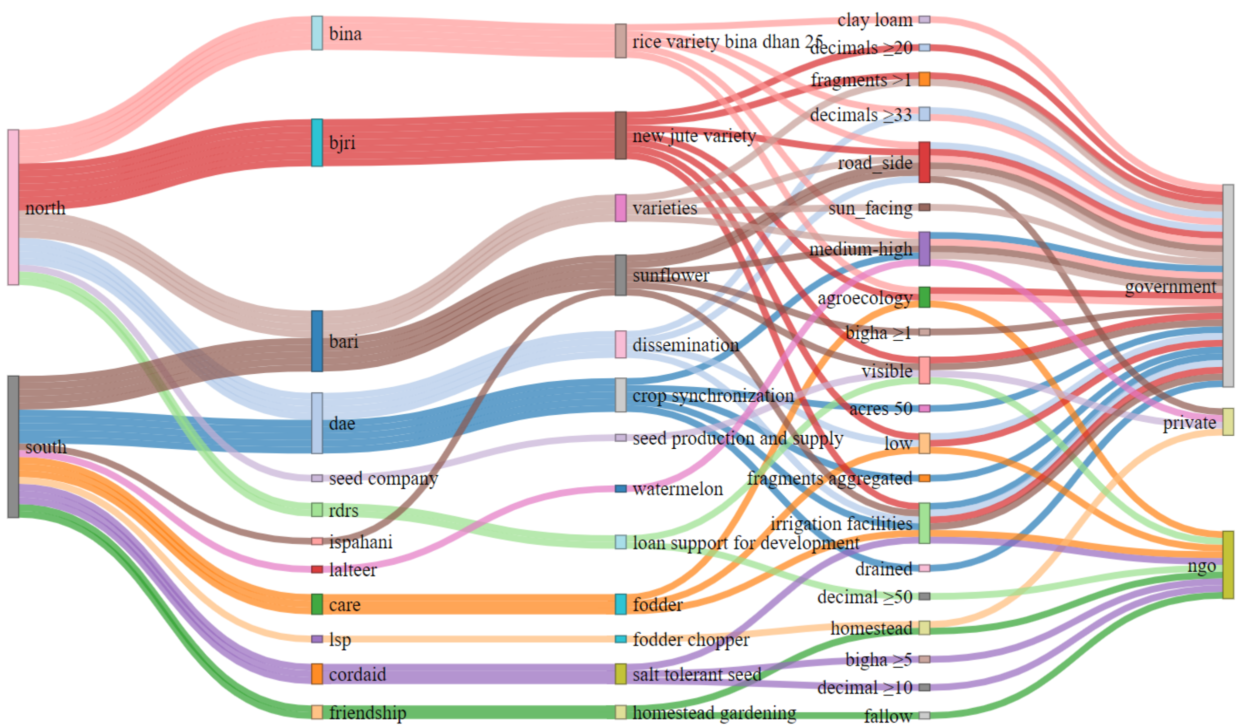

Figure 1 Land size, salinity, position, irrigation and vicinity factors stakeholders use in innovation targeting

3.1.3 Topographic position and salinity

Land size, a major farm attribute used in targeting, is not necessarily the primary determinant of cropping potential and farmer differentiation. Instead, land location and quality are pivotal factors that farmers use to classify and manage their cropping systems in both north and south. In the South, farmers differentiate farms based on proximity to the homestead and access to irrigation. Farms closer to the dwelling are more intensively cultivated, with farmers able to grow up to three crops a year due to easier management and better access to water from nearby ponds. On the other hand, farms that are further away or on saline soils are often left fallow during the Kharif 1 season, as these lands become productive only when salinity drops during Kharif 2. Farmers rely heavily on local knowledge to assess which crops can tolerate high salinity and adjust their cropping systems accordingly. District officials in the South, however, focus on land suitability for specific interventions, with an emphasis on targeting land based on topographic and environmental characteristics. Institutions like BARI and Private companies such as Ispahani Group select medium to high lands for cultivating crops like sunflowers, avoiding lowlands prone to waterlogging. Additionally, interventions like CORDAID's salt-tolerant seeds help farmers in saline-affected areas continue farming despite harsh conditions. The institutional approach is more strategic, aiming to mitigate environmental challenges by aligning crops with specific land conditions.

Table 2 Land suitability criterion used by institutions in targeting crop, variety and fodder innovations

Institution	Intervention	Land Suitability	Other Factors
BJRI	New Jute Variety	Lowland, Fragments >1	Irrigation, Roadside, Visible
BINA	Rice Variety Bina Dhan 25	Agroecological, Clay Loam	Irrigation, Roadside
BARI	Sunflower	Medium-High	Irrigation, Roadside, Visible
DAE	Dissemination, Crop Sync	Lowland, Aggregated Fragments	Irrigation, Drainage, Roadside
CARE	Fodder	Lowland	Irrigation
CORDAID	Salt Tolerant Seed	Medium-High	Irrigation facilities
FRIENDSHIP	Homestead Gardening	Not specified (small homestead)	Fallow land, Homestead
LSP	Fodder Chopper	Not specified (small homestead)	Homestead

BJRI (Bangladesh Jute Research Institute), BINA (Bangladesh Institute of Nuclear Agriculture), BARI (Bangladesh Agriculture Research Institute), DAE (Department of Agriculture Extension), CARE (CARE International), CORDAID (Catholic Organization for Relief and Development Aid), FRIENDSHIP NGO, LSP (Local Service Provider)

In the North, farmers categorize their land primarily by elevation and soil texture. Mid-highlands with sandy soils are suitable for crops like tobacco, jute, and maize, while highlands with more fertile soils support a mix of rice, maize, and mustard. This elevation-based classification system allows farmers to optimize land use by selecting crops that thrive in specific agro-ecological conditions. District officials in the North also focus on topography and soil quality, but their approach is more scientific. For instance, BINA promotes the cultivation of Bina Dhan 25 rice in areas with clay loam soils, which retain moisture and support rice growth. Similarly, BJRI targets lowland areas for cultivating new jute varieties, capitalizing on these areas' ability to retain water. The institutional approach is focused on selecting land based on its scientific suitability for specific crops, ensuring higher productivity and better resilience.

3.1.4 Location and Proximity: Visibility and Access

Location and proximity to roads are important considerations in both the North and South, particularly for demonstration plots and commercial crops. In the North, BARI and BJRI focus on targeting land close to roads for cultivating crops like jute and new varieties of rice. This ensures visibility for other farmers, allowing interventions to act as showcases of success and innovation. The proximity to roads also facilitates the use of machinery and access to external support services. In the South, similar strategies apply. BARI targets roadside land for sunflower cultivation, allowing for better promotion and visibility, especially for riskier crops like sunflower that require close monitoring and engagement from external stakeholders.

Proximity to the farm is another factor, particularly for homestead-based farming. FRIENDSHIP in the South focuses on homestead gardens by utilizing fallow land near farmers' homes. This proximity allows farmers to easily manage their gardens and ensure household food security. Similarly, the LSP's Papaya nursery targets small-scale farmers with homestead land, contributing to food security in the region.

3.1.5 Mechanization services

In the coastal south, despite the potential for multi-season cropping, a shortage of mechanization services during critical periods significantly hampers agricultural productivity. Farmers with the ability to grow multiple crops often find themselves restricted to growing only one crop, particularly in Kharif II, as tractors and other machinery are repurposed for transportation services, leaving fewer resources available for timely tillage and planting. This shortage is particularly problematic in the Rabi season, where timely field preparation is crucial for dry-season crops. Additionally, the mechanization shortage also affects the livestock sector, as delays in tilling for forage crops reduce the availability of straw and other essential feed, further compounding the challenges faced by farmers in the region.

3.1.6 Irrigation facilities

In the south, farmers' perspectives on irrigation access are highly variable and dependent on the proximity to water sources. Farmers growing multiple crops, particularly those cultivating three times a year, have better access to irrigation, often utilizing ponds near their homes. In contrast, those farming in more distant or saline-prone areas have minimal or no irrigation facilities. These farmers rely heavily on rainwater, especially during Kharif II, and as a result, many fields are left fallow during Kharif I due to insufficient water. The lack of irrigation for these farmers significantly restricts their cropping intensity and overall productivity. From the institutional perspective, irrigation facilities are recognized as crucial for sustaining agricultural productivity. Institutions like DAE prioritize land equipped with irrigation systems. For example, DAE's Crop Synchronization program in the South targets land with both irrigation and drainage systems, ensuring efficient water management. This institutional focus on systematic irrigation infrastructure contrasts with farmers' reliance on local water sources like ponds. Institutional interventions aim to create more reliable and sustainable water management systems to improve productivity across a broader range of farming contexts, especially in areas affected by salinity and water scarcity.

In the North, farmers experience greater variability in irrigation needs depending on cropping patterns and land types. For crops like Boro rice, which require significant water, high irrigation levels are essential, especially during the Rabi season. In contrast, cropping patterns like maize-rice-potato or maize-rice-mustard require low irrigation, allowing farmers to cultivate crops that are less water-intensive. Additionally, farmers with sandy soils, which offer natural drainage, often manage with low irrigation, especially for crops like jute and tobacco. From the institutional perspective, irrigation is equally critical. Institutions like BARI and BJRI focus on ensuring reliable irrigation systems for crops that need it, particularly rice and jute. These institutions emphasize the importance of water management during the dry season, recognizing that reliable irrigation is essential for maintaining crop performance and resilience. Institutional interventions in the North tend to be more structured and aim to support water-demanding crops, like Boro rice, through systematic irrigation strategies.

3.1.7 Livestock

Farmers in both regions classify themselves based on herd size, which directly correlates with their resource availability, including space, fodder, and financial capacity. In the South, farmers with fewer than three cows face significant limitations due to a lack of space and fodder, while those with three to five cows or more than five cows are better equipped to manage their herds. In the North, the classification is similar, with the smallest farmers facing resource constraints and struggling with limited access to veterinary care and vaccines, while larger-scale farmers are better positioned to focus on milk production and organic fertilizer use.

Institutions, on the other hand, generally target farmers who already have a minimum herd size. For example, in the South, the DLS improved breeds initiative targets farmers with at least two cows, while in the North, CARE supports farmers with at least three cows through fodder production interventions. This focus on farmers with a minimum threshold aligns with the middle and upper-tier farmers, who are already relatively better off in terms of resources and capacity. These interventions are designed to improve productivity and help farmers transition to more profitable livestock management. While institutional interventions in both the North and South aim to improve livestock productivity and economic stability, they primarily target larger herd owners who already have some capacity to manage their livestock. This focus leaves out smaller farmers who face the most significant constraints, creating a potential gap in equity and inclusive development. To ensure broader development benefits and sustainability, institutions need to expand their support to include smallholder farmers, helping them overcome resource limitations and providing them with the tools to transition from subsistence-level farming to sustainable and profitable livestock management.

3.2 Farmer attributes conditioning innovation targeting

3.2.1 Engagement and agency

The study has established that in Bangladesh, farmers' ability to engage in multiple cropping and adopt diverse farming practices is heavily influenced by their resource access, such as irrigation, mechanization, and financial stability. The comparison between the two perspectives reveals a shared understanding of the importance of farmer engagement and proactivity. Both farmers and institutions recognize that successful farming depends on the ability to adapt to new practices and manage multiple cropping systems. However, their approaches differ significantly in how agency is fostered and supported.

From the farmers' perspective, proactivity is largely determined by resource access. In the South, a lack of resources such as irrigation and mechanization constrain the majority of farmers to single-crop cultivation, limiting their engagement in more advanced farming practices. Only those with better access to these resources can take full advantage of their agency. Only about 5% of farmers are considered proactive, capable of cultivating two or three crops annually. These farmers tend to have better access to critical resources that enable them to overcome environmental constraints, like salinity and limited water availability. The majority, however, face significant barriers, with many restricted to growing a single crop, usually rice during Kharif 2, due to these limitations.

In the North, where resources are more readily available and market conditions are more favourable, farmers have greater flexibility and are more proactive in adopting diverse cropping systems. These farmers exhibit a generally higher level of proactivity and diversification in their cropping systems. The region's favourable market conditions and better access to inputs encourage farmers to engage in more complex cropping patterns, such as maize-rice-potato or jute-rice-mustard, which offer higher returns. This demonstrates that proactivity among farmers is not only a matter of individual effort but is deeply tied to the contextual resources available to them.

On the other hand, institutions such as BJRI, BINA, and BARI approach farmer engagement by targeting those who have already demonstrated a certain level of experience, proactivity, and capacity for innovation. These institutions often prioritize lead farmers or those with a proven track record of success in farming practices. For example, BINA introduces the Bina Dhan 25 rice variety to farmers who not only have experience in rice cultivation but also show a willingness to adopt new technologies. Similarly, BJRI focuses on delivering new jute varieties to lead farmers who are well-positioned to disseminate knowledge and practices within their communities. This strategy ensures that experienced and proactive farmers are at the forefront of adopting and scaling new agricultural innovations. Prioritizing experienced and proactive farmers who are well-established and capable of implementing innovations and advanced farming techniques risks excluding smaller, less-experienced farmers who may not yet have the resources or capacity to engage with new practices but could benefit significantly from such support. For example, programs like CORDAID's Salt Tolerant Seed Program and BARI's interventions focus primarily on lead farmers who have already demonstrated their ability to manage successful farms, leaving smaller farmers at risk of being left out of the innovation loop.

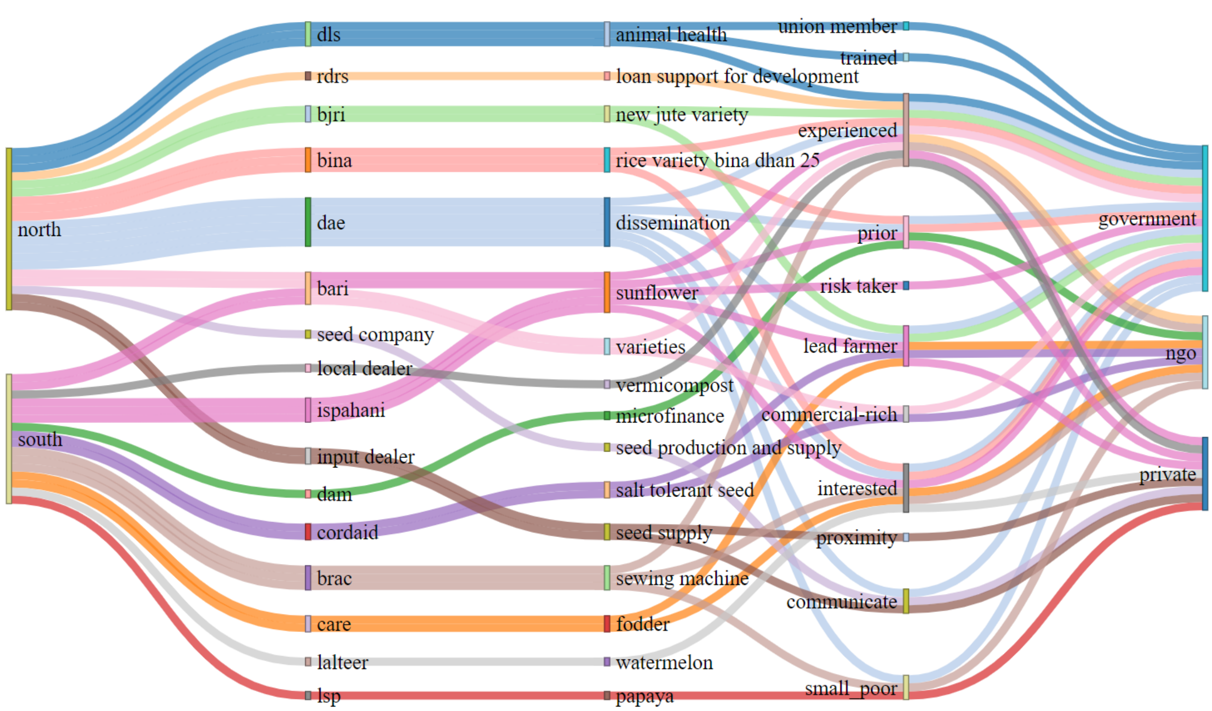

Figure 2 Engagement and agency factors influencing targeting decisions

In addition, BARI takes a slightly different approach when it comes to certain crops like sunflowers, where they specifically target risk-taking farmers who are willing to deal with the challenges associated with waterlogging and high investments. This reflects the institutional preference for working with farmers who not only have the technical capacity but are also willing to take calculated risks to implement more challenging farming practices. Moreover, DAE emphasizes collective engagement through programs like crop synchronization, where all farmers involved must fully commit to the intervention, demonstrating that institutional efforts require collaborative and proactive participation from farmers.

3.2.2 Gender considerations and inclusivity

DAE actively integrates gender inclusivity into its programs, ensuring that a substantial portion of participants (30%) are female as part of their innovation initiatives indicating the value placed on gender inclusivity but does not strive for gender parity. By including women in its programs, DAE promotes female involvement in the dissemination of agricultural innovations, aiming to empower them with knowledge and tools to participate in farming more effectively. CORDAID places a strong emphasis on gender equality, striving for an equal representation of both male and female farmers, with each gender making up 50% of the participants in their supported cohort. The goal of equal representation between male and female farmers suggests that CORDAID aims to ensure balanced participation in agricultural development, fostering inclusivity and equal opportunities for both genders.

Table 3 Gendered targeting of intervetions

Institution	Intervention	Gender Focus	Female Participation
DAE	Dissemination, Crop Synchronization	Moderate	30%
CORDAID	Salt Tolerant Seed	Gender Equality	50%
DAM	Microfinance	Full Female Focus	100%
BRAC	Sewing Machine Program	Women’s Empowerment	Primarily Female
FRIENDSHIP	Homestead Gardening	Strong Female Focus	80%
RDRS	Loan Support for Development	High Female Focus	88%
CARE	Fodder	No Gender Targeting	N/A

FRIENDSHIP prioritizes the engagement of 80% female farmers, focusing on those who own homestead land and are primarily responsible for household nutrition. The homestead gardening program engages women to use their available time and resources to grow gardens that contribute to both their household’s food and nutritional security, and the economic stability. In targeting females, FRIENDSHIP highlights its commitment to improving the livelihoods of women, particularly those who have limited access to other agricultural opportunities. DAM prioritizes female empowerment by targeting 100% female participation in their microfinance loan services, ensuring full engagement from women farmers in their financial initiative. This initiative not only enhances their skills but also fosters economic independence and self-sufficiency among female artisans. RDRS emphasizes the critical role of loan support in fostering agricultural development, with gender being a significant factor in the selection of participants. They aim for 88% female participation among farmers aged 18 to 50, promoting inclusivity and empowerment in both the northern and southern regions.

3.2.3 Perceived investment and outcome potential

Several key differences and similarities emerge in terms of financial capacity, labour costs, and market demand for the South and North. In the South, farmers segment themselves based on their financial capacity to invest in inputs, which directly affects their cropping intensity. 60% of farmers are unable to grow multiple crops due to financial constraints, limiting them to single season cropping. Conversely, those who grow three crops are typically more financially stable and able to afford necessary inputs such as seeds, fertilizers, and irrigation. The dataset used includes income as a proxy for financial capacity, underscoring that financial limitations affect all farmers, regardless of their ability to grow multiple crops.

In the North, financial constraints manifest differently. The cultivation of crops such as mustard and potato involves lower labour costs compared to crops like rice, making them more financially accessible. In cropping pattern 1 (Boro rice + Aman rice + mustard), farmers face high production costs for comparatively low yields and limited market demand. In contrast, cropping patterns 2 and 3 (e.g., maize-rice-potato) offer a more favourable balance of moderate to low production costs with high returns and substantial market demand, making them more profitable. Additionally, these cropping patterns benefit from more efficient use of resources and greater market opportunities, which contribute to their higher profitability. Thus, while in the South, the ability to grow multiple crops is largely determined by financial resources and access to inputs, in the North, the choice of crops and cropping patterns plays a more significant role in shaping production costs and returns. Both regions face economic limitations, but the strategies to overcome them differ—farmers in the South rely on investment in inputs to increase cropping intensity, whereas farmers in the North mitigate financial risks by selecting lower-cost, higher-return cropping systems.

In the South, farmers following a single or double cropping system prioritize rice for consumption, relying heavily on rainwater for irrigation, while those cultivating three crops rely on irrigation and have the financial capacity to invest in inputs. In the North, farmers who adopt the rice-rice-mustard cropping pattern also prioritize rice for consumption, but those following the maize-rice-potato pattern give equal importance to both rice and potato due to potato's high market demand and household use. For cattle feed, farmers in both regions value rice straw and, in the North, additionally rely on maize fodder, reflecting the dual utility of their cropping systems. Cropping patterns in the North, such as maize-rice-potato and jute-rice-mustard, offer higher returns on investment compared to the South, where financial limitations restrict cropping intensity. In the North, the ability to cultivate crops like maize and potato, which require less irrigation and labour, reduces costs while increasing yields. Additionally, dry maize straw is used as a source of fuel in the North, further adding value to the cropping system. Thus, while both regions prioritize rice, the North benefits from greater crop diversity, better market opportunities, and more efficient resource utilization.

4 Conclusion and recommendations

Farm typology or differentiation has been widely promoted to guide targeting. Its usage has been limited due to mismatch between data driven approaches and farmer conditions. In the south, cropping intensity is a key variable that differentiates farmers, with those who have better access to water and mechanization being able to cultivate more intensively. In the north, farmers distinguish themselves depending on ability to rotate and diversify crops, which reflects the region's better access to land categories, market demand, and inputs. This gives northern farmers more economic and agricultural resilience.

Land quality, topographic position, and suitability and not necessarily land size are key in differentiating farms for agricultural interventions. In the North, the focus is on factors like agroecology, soil quality, and the ability to retain water, while the South is more concerned with managing waterlogging and mitigating the effects of salinity. Across both regions, these considerations ensure that interventions are tailored to the specific environmental challenges and conditions that farmers face. It has been noted that irrigation in the north is more structured and adapted to specific cropping patterns. However, its availability in the south is more dependent on proximity to water sources and influenced by salinity and distance from the homestead.

In addition to land and cropping systems, both farmers and institutions place a strong emphasis on engagement and proactivity in farming. However, while farmers' agency is shaped by their access to resources and environmental factors, institutions tend to target farmers who have already demonstrated their capacity for innovation and success. This difference in approach creates a gap in support for less-resourced farmers, particularly in the South, where resource limitations prevent many from engaging in more diverse cropping systems. This discrepancy between farmer agency and institutional targeting can lead to potential inequities in agricultural development. Although institutions aim to enhance agricultural productivity, the focus on already proactive farmers can unintentionally deepen the divide between well-resourced and resource-poor farmers. While proactive and experienced farmers continue to receive support and thrive, those who are less resourced remain constrained by the same financial and infrastructural barriers that have limited their agency in the first place. To bridge this gap, institutions may need to adopt more inclusive strategies, ensuring that smaller, less proactive farmers are also empowered with the resources and support needed to enhance their agency and participate.

The insights on agricultural technology targeting highlights varied approaches by product and service providers, ranging from generalized strategies for broad outreach to differentiated strategies tailored to specific farmer segments. While generalized methods enable mass adoption, they may overlook local ecological and socio-economic variations, potentially exacerbating inequalities, whereas differentiated approaches, although more precise, risk excluding wider farmer populations. These reflections underscore the need for a balanced approach in agricultural targeting, one that combines the strengths of both generalized and differentiated strategies to address the diverse needs of the farming community effectively.

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