Seed systems in Bhutan:
A report on the current status and potential pathways for seed system development

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Design and Layout

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List of acronyms

AEO	Agricultural Extension Officer
ARDC	Agricultural Research and Development Centre
ARDSC	Agricultural Research and Development Sub-Centre
ASSR	Agricultural Sales and Services Representative
BAFRA	Bhutan Agriculture and Food Regulatory Authority
BAS	Bhutan Alpine Seed
BFDA	Bhutan Food and Drug Authority
CBSPG	Community-based seed production group
CNR	College of Natural Resources
CSB	Community seed bank
CSM	Cost-sharing mechanism
DAO	District Agricultural Officer
EGS	Early generation seed
FGD	Focus group discussion
IRRI	International Rice Research Institute
MoAL	Ministry of Agriculture and Livestock
NBC	National Biodiversity Centre
NCOA	National Centre for Organic Agriculture
NMBU	Norwegian University of Life Sciences
NSC	National Seed Centre
PGRFA	Plant Genetic Resources for Food and Agriculture
PoP	Packages of Practices
PVP	Plant Variety Protection
RNR	Renewable natural resources
RSG	Registered Seed Growers
VRC	Variety Release Committee

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Finally, we thank Ana Catarina Mendes Leite for preparing the map of the study areas, and Natalia Rodriguez for graphic design and technical editing which improved the presentation and quality of the report.

Executive summary

This report presents an assessment of Bhutan's seed systems. The assessment has two analytical entry points. First, we characterize Bhutan's national seed system by mapping and assessing the roles and activities of seed system actors across three seed system functions: variety management, seed production, and seed dissemination. Second, we examine the seed security outcomes in selected districts by assessing farmers' perspectives on varietal suitability, seed availability, quality, and access. Finally, we present recommendations by function to address the system and security challenges identified.

1. Seed system functions in Bhutan

1.1 Variety management

Farmers' Seed Management: The bulk of seeds planted by farmers in Bhutan are farm-saved and farmers are the most significant actors in managing the country's crop diversity. Based on focus group discussions with farmers across the country we estimate that a majority (>70%) of the varieties cultivated are farmers' varieties (landraces) while the rest are improved varieties introduced by the formal seed system. Crops play an important cultural role. For example, the Dru-na-gu, the Nine Fundamental Crops (rice, wheat, barley, peas, sweet and bitter buckwheat, millet (several species), mustard, soybeans and sometimes maize), are important in various religious rituals. At the same time, changes in food habits have led to decreased consumption of traditional crops like millets and buckwheats. However, some government programs have countered this trend by promoting the cultivation of culturally significant crops. In the following, we focus on the formal seed system and its interaction with the seed systems farmers use.

Conservation: The National Biodiversity Centre (NBC) is responsible for the conservation and governance of Plant Genetic Resources for Food and Agriculture in Bhutan. NBC manages the national genebank and collaborates with Agricultural Research and Development Centres (ARDCs) and NGOs on various projects. NBC also provides training and germplasms for research at the College of Natural Resources (CNR).

Variety development, evaluation, and release: The ARDCs under the Ministry of Agriculture and Livestock (MoAL) focus on public variety development and evaluation, with mandates for different crops across agroecological zones. Between 1988 and 2023, 310 crop varieties have been released.

Seed system governance: The Variety Release Committee (VRC) oversees the registration of new varieties, with the National Seed Board granting final approval. The Seed Act (2000) and the National Seed Rules and Regulations (2018), provide regulatory frameworks.

Farmer Involvement in the Formal System: Farmers play a significant role in variety evaluation, particularly in crops like rice, potato, and maize. The participatory approach extends to projects linking conservation and breeding activities.

International and Regional Cooperation: ARDCs source new lines/varieties from CGIAR centres (CIMMYT, IRRI, ICRISAT, CIP) and national programs in other countries (e.g. Nepal, India, Japan). Bhutan participates in the Seeds without Borders initiative and the South Asian Association for Regional Cooperation Seed Bank agreement, which both aim to streamline transnational movement of crop varieties and seeds.

Challenges:

Limited Plant Breeding Capacity: There has been a decline in plant breeding activities at ARDCs and a lack of specialized education at CNR, impacting the sector's ability to innovate.

Regulatory and Market Constraints: The seed value chain faces practical, economic, and logistical challenges, limiting the public system's responsiveness to farmers' needs.

1.2 Seed production

Farmers' Seed Production: For staple crops like rice, maize, and potatoes most seeds are farm-saved, often stored using traditional methods. Farm-saving of seed is thus the backbone of farmers' seed supply, but there are challenges with seed viability loss during storage. Seed replacement rates vary significantly; vegetables have high rates while cereals have much lower rates.

Formal System Seed Production: ARDCs are responsible for breeder seed production. The National Seed Centre (NSC) produces foundation seed and truthfully labelled seed disseminated to farmers. NSC produces seed on their own farms as well as through outgrowers, called Registered Seed Growers (RSGs). Bhutan Alpine Seed (BAS) is the only private seed company producing seeds independently, using contract growers.

Community-based seed producer groups (CBSPGs) and community seed banks (CSBs) are two types of intermediary actors in seed production in Bhutan.

The Bhutan Food and Drug Authority (BFDA) does not monitor early generation seed (EGS) production but inspects certified seed production, although capacity issues are noted.

Governance of Seed Production: MoAL is responsible for the overall governance of seed production, with protocols and standards outlined in the Manual on Breeder, Foundation and Certified Seed production (2021).

New agricultural laws will clarify responsibilities between foundation and certified seed production, with ARDCs maintaining breeder seed.

Challenges:

Maintaining quality in on-farm seed storage is difficult due to pest attacks and environmental conditions.

Wildlife damage to crops, such as from wild boars, affects both public and private seed producers.

CSBs face issues with humidity and temperature control in storage facilities.

Coordination between ARDCs and NSC regarding access to foundation seeds is a challenge, though there have been significant improvements.

There are concerns about BFDA capacity to follow up its seed quality assurance mandate following its transition to the Ministry of Health.

1.3 Seed Dissemination

Most of the seed used by farmers in Bhutan is farm-saved. The farm-saved seed is both of local varieties and improved ones that are recycled. The share of farm-saved seeds is higher for self-pollinating crops than for outcrossing crops.

The volume of seeds produced and distributed by NSC is not sufficient to meet the annual demand for seed for farmers in Bhutan. Considering for example rice, the annual seed distribution is only sufficient to cover about 4% of the seed requirement. For vegetables, the situation is different with NSC covering about 80% of the annual seed requirement.

The main off-farm seed source is NSC, covering about 90% of the formal seed system supply overall. Two private companies, Bhutan Alpine Seed and Reva Seed, focus on vegetable seeds. Bhutan Alpine Seed produces and sells seeds domestically and internationally, while Reva Seed imports seeds from multinational companies and sells them directly to select farmers. The private sector supplies 10-20% of formal hybrid vegetable seeds in Bhutan. There is also a considerable private nursery sector in the country supplying fruit seedlings.

Most of the NSC seeds are distributed to farmers via local government/agricultural extension services. In addition, private Agricultural Sales and Services Representatives (ASSR) traders can sell seeds against a 10% commission. NSC seeds are distributed at affordable, uniform prices countrywide, with transport costs and the ASSR commission covered by the government. Demand for seeds is collected by agricultural extension officers (AEOs) and distributed to farmers either free or at subsidized rates, depending on their economic status.

In addition to the NSC and private sector seed dissemination, some seeds are distributed by the public research organization and a small number of NGOs. The ARDCs distribute seeds directly to farmers, especially those near research stations. This includes distributing small quantities of cereal seeds

and engaging with CBSPGs. ARDCs also collaborate with international organizations and NGOs on seed projects.

Two NGOs, Tarayana and Samdrup Jongkhar Initiative (SJI) engage in intermediary seed system activities, including CSBs providing seed loans and some small-scale sale.

Governance of Seed Dissemination: The Seed Rules and Regulations of Bhutan (2018) govern seed systems, allowing for the coexistence of formal and informal systems. Traditional and new varieties can be released or notified, and small-scale exchange and local sale of traditional varieties are permitted. Seed policy is covered by the Biodiversity Act (2022) and the Food and Nutrition Security Policy (2023).

Challenges

Limited Seed System Research: There is a lack of comprehensive studies quantifying the importance and reasons for farmers' use of different seed sources in Bhutan.

Insufficient Seed Supply: NSC produces and distributes a limited volume of seeds, meeting only a small percentage of the total annual demand for staple crops like rice, maize, and vegetables.

Economic Sustainability and Social Mandate: NSC faces challenges in balancing its dual mandate of being economically sustainable while providing affordable seeds nationwide. According to several informants, this limits NSCs ability to innovate and increase production.

Private Sector Involvement: The current policy environment is not considered conducive to greater private sector involvement in the seed market. Private companies struggle to compete with subsidized seed prices from NSC.

Rigid Public System: The public seed distribution system is rigid, with challenges in forecasting and meeting changing demand. Low varietal turnover and low seed replacement rates indicate inefficiencies.

Geographic and Logistical Issues: Farmers in remote areas face difficulties accessing seeds due to long travel distances to pick-up points for certified seed.

2. Seed security in Bhutan

This study examines the seed security situation in 10 municipalities (gewogs) in five agroecological zones by assessing farmers' perspectives on varietal suitability, seed availability, quality, and access. The findings, based on focus group discussions with 111 men and women farmers, provide insights into how well the local seed system meets farmers' needs and preferences. While not representative of all farming communities and environments in the country, the results offer a snapshot of the diversity in these selected areas.

2.1 Varietal suitability

Varietal suitability refers to how well crop varieties are adapted to farmers' growing conditions and meet their agronomic, culinary, market, cultural, and other preferences. This assessment was conducted using Four-Cell Analysis, where focus group discussion (FGD) participants listed and categorized crop varieties grown in their gewog based on the number of households cultivating them and the land area dedicated to each variety. The analysis identified 111 varieties for 16 key crops, with rice, maize, and chili having the most varieties, followed by potato, finger millet, and wheat. An estimated 73% of these are farmers' varieties (landraces). Some improved varieties circulate within the informal seed system, saved and exchanged among farmers, and some appear to be from adaptation trials conducted by extension services.

2.2 Availability

Generally, farmers' own saved seeds were rated as "always available" across all crop types, as farmers carefully save enough seeds for the next planting season. However, some crops experienced shortages due to diseases or other issues, such as wilt affecting cardamom seedlings in Sombaykha and poor seedling growth in areca nut nurseries in Senggye. Similar shortages were noted for buckwheat in Sombaykha and orange seedlings in Wangphu due to production challenges.

Seeds from other sources were deemed less reliable. Seeds from neighbors were often rated as "sometimes available" because they only share or sell surplus seeds. For crops like oranges in Wangphu and staple crops in Phuntshothang, neighbors rarely

had sufficient quantities, especially after wild animal attacks or extreme weather.

Seeds from research centers, extension agents, and ASSRs were rated as "sometimes" or "rarely" available, often due to formal system bottlenecks. For instance, in Singgye, farmers did not always submit seed requirements, and in Kabijsa, seeds did not arrive on time or in sufficient quantity. Farmers in Mendrelgang faced similar issues with vegetable and mandarin seeds.

An example of limited availability was the improved potato variety Yusi maap in Samar, initially provided in small amounts by extension officers and later multiplied by farmers. The process of accessing and maintaining sufficient seed took years, highlighting the need for more extensive initial distribution. Farmers also noted that certain varieties, such as local potato varieties and the improved wheat variety Sonalika, have become scarce due to shifting preferences and susceptibility to diseases.

2.3 Access

Generally, FGD participants indicated that members of their communities do not have difficulty accessing seeds, as they rely on their own stocks or their social networks. The primary source of seeds is farmers' own stock. FGD participants said seeds are also often accessed from neighbors or relatives through various transaction types, including cash payments, seed exchanges, labor exchanges, loans, and bartering. Although gifts were mentioned, the primary method of obtaining seeds involves some kind of exchange of cash or goods.

Farmers also noted that these social exchanges not only provide seeds but also introduce new varieties. For example, the Yusi maap potato variety spread through social networks in Samar Gewog, and in Bumdeling, the rice variety Machum was introduced by a relative from another dzongkhag in exchange for local rice.

Seeds from ASSRs, commission agents, and other commercial actors like nurseries and local seed dealers are typically purchased. However, seeds from government sources, such as extension agents and research centers, are often provided for free or at subsidized rates. The one NGO identified in this study that distributes seeds does so for free. In Wangphu, farmers considered government distribution more equitable than access through social networks because it ensures balanced and equal distribution. However, some participants noted that traveling to the extension office to obtain seeds can be difficult, especially for those living far away.

Farmers also shared several local customs and beliefs that influence their seed use. Specific days are considered auspicious for sowing, drying, or storing seeds, as well as for giving, acquiring, or purchasing seeds. Certain crops are also believed to bring bad luck if planted near homes. For example, jackfruit trees are considered bad omens because their roots spreading in front of a house is thought to bring misfortune. Similarly, papaya and mango trees are also considered inauspicious for different reasons.

Providing or sharing seeds on specific days, such as Tuesdays and Fridays, is prohibited due to cultural beliefs about these being "lucky" or "good merit" days. Insect days, on the 3rd, 9th, and 19th days of the Bhutanese lunar calendar, are also avoided for sowing or cultivation to prevent pest and disease outbreaks.

These customs and beliefs have been passed down through generations, but they are gradually fading due to modern education and technological advancements. The evolving perspectives of younger generations are contributing to the slow decline of these traditional practices.

2.4 Quality

Farmers generally rate their own saved seeds as excellent due to their personal selection processes, which they trust more than seeds from other sources. Seeds obtained from neighbors are often seen as lower quality. Opinions about seeds from formal systems, such as government and NGO sources, vary, with some farmers appreciating the quality while others prefer their own seeds due to specific varietal preferences.

Challenges in seed production and storage are significant, with issues such as pests, diseases, weather patterns, and inadequate storage facilities affecting seed quality. Farmers rely on traditional storage methods, which are often inadequate in humid and

subtropical regions, leading to pest infestations and spoilage. While these challenges do not diminish the perceived quality of their own saved seeds, they do impact seed availability.

Farmers express a need for improved knowledge and skills in seed selection and production, particularly for maize and vegetable seeds. Resource constraints, such as land availability, also limit seed production. Farmers note that climate change is exacerbating storage issues, necessitating new knowledge and solutions. Despite these challenges, farmers continue to rely on their own seeds, underscoring the importance of enhancing seed management practices.

3. Recommendations

3.1 Variety development and management

Increase varietal diversity in staple crops available from the formal system and hence enhance farmers' possibility for varietal turnover and diversification.

Enhance farmer participation: Continue and expand participatory approaches in variety evaluation to ensure that new varieties meet the practical needs and preferences of farmers.

Purify breeder seed of deteriorated varieties.

Simplify and expedite variety release procedures, including for farmer varieties, to foster timely access to new varieties for farmers.

Strengthen specialized education in plant science and breeding at CNR to ensure sustained innovation and development in the formal system.

3.2. Seed production

Improve production and storage, on-farm and among other local seed producers by enhancing traditional storage methods and providing technical support to mitigate pest and environmental impacts on seed quality.

Develop better forecasting and communication strategies to match NSC seed production with actual demand, minimizing waste.

Increase production of high-quality seeds and seedlings as per demand by enhancing capacity of RSGs and CBSPGs.

Invest in building BFDA technical expertise and infrastructure to ensure effective regulation and quality assurance in seed production.

3.3 Seed dissemination

Undertake comprehensive studies of farmers' seed systems to quantify the importance of different seed sources to better understand farmers' seed systems in Bhutan.

Increase seed production and distribution from NSC by increasing seed and seedling production capacity of RSGs and NSC farms, DoA approved nurseries.

Enhance technical capacity of RSGs, Farmers, CSB, CBSPGs, Private seed companies and technical staff (NSC, extension agents, and ARDCs) in seed purification and maintenance in line with the new manual to be developed on crop specific seed production and maintenance.

Conduct a National Seed Fair annually to display varietal diversity from NBC and ARDCs.

Encourage private companies to present investment plans and take on greater role, in particular in the fruit and vegetable seed market.

Reform the public seed distribution system to be more flexible and demand-oriented, improving forecasting and responsiveness to farmers' needs.

Address geographic and logistical barriers. Develop strategies to improve seed access for farmers in remote areas, potentially through decentralized distribution points or mobile extension services.

Rice terraces in Tsirang, Bhutan. Photo: NMBU

1 INTRODUCTION

This report presents an assessment of Bhutan's seed systems. The study was undertaken as part of the project Biodiversity for Opportunities, Livelihoods and Development (BOLD). The objective of BOLD is to strengthen food and nutrition security worldwide by supporting the conservation and use of crop diversity. This report focuses on how the link between conservation and use of crop diversity in seed systems can be strengthened in Bhutan.

1.1 Study objectives

The objective of this study is to identify pathways to enhance farmers' access to quality seeds and planting material of a diversity of preferred varieties. The research presented in this report consists of the following three parts:

First, we characterize Bhutan's national seed system by mapping and assessing the roles and activities of seed system actors across seed system functions. We identify the strengths and weaknesses in the existing seed systems and describe the current dynamics of seed governance in Bhutan.

Second, we characterize farmers' seed systems in selected study sites by mapping the diversity of major crops, examining the sources of seeds used by farmers, and identifying seed security challenges. Seed security is assessed in the context of cultural, political, climatic, market, and other factors that influence farmers' preferences and needs.

Finally, we conceptualize pathways to improve seed system outcomes through strengthening linkages between seed system functions at national and local level. The research findings and suggested pathways were validated during a roundtable workshop in October 2024 and will inform the design of a project to enhance seed systems functions and coordination among seed system actors.

1.2 Conceptual framework: Seed systems and seed security

Seed systems are understood as the institutional arrangements, roles, and activities of actors involved in crop diversity management, breeding and selection, seed production, and dissemination (Almekinders et al., 1994; Louwaars and de Boef, 2012). In short, they are the systems that make seeds available to farmers.

Although it has generally been common to distinguish between different types of seed systems such as informal or formal seed systems, there are many linkages and interdependencies between these and farmers often source seed originating from both (Almekinders and Louwaars, 2002). Furthermore, the terms themselves are imprecise and can reinforce misconceptions. For instance, the term "informal" can misleadingly imply that such seed systems are not rule-governed, while "local" suggests that seed only circulates at limited geographic scales, while there is ample evidence to the contrary (Coomes et al., 2015). Recent literature (Christinck et al., 2018) suggests that seed system characterization based on their functions can help design more need-based seed system development programs.

Based on this understanding, we have identified ***five factors to characterize seed systems.*** These include three "functions" representing the core activities performed by actors in the seed system, and two "contextual factors" that enhance or constrain the functioning of seed systems due to their influence on actors' roles and activities (Figure 1).

Our characterization of seed systems at local and national levels refers to the ***scale of the analysis*** rather than the type of seed system. In the ***national seed system characterization***, we examine the functioning of the seed system operating at the national scale, be they "formal" or "informal". In some countries, policies, regulatory frameworks and institutions may

have greater focus on supporting functions within the formal seed system. However, by structuring our analysis using the five factors described above, we will aim to integrate analysis of all types of seed systems. Similarly, the ***local seed system characterization*** is aimed to zoom in to assess how seed systems are functioning in specific localities, e.g., the strengths and weaknesses of seed production by different producers both in the formal and informal seed systems.

Figure 1. Conceptual framework identifying five factors to describe seed systems. The three in light green are the basic "functions" that seed system actors are engaged with. The two in dark green (seed governance and food system drivers) are broader contextual factors that influence how the seed system functions (Westengen et al. 2023).

In theory, a well-functioning seed system will ensure ***seed security*** for all farmers, i.e., that "men and women within the household have sufficient access to adequate quantities of good quality seed and planting materials of preferred crop varieties at all times in both good and bad cropping seasons" (FAO, 2016). In reality, this is rarely the case and seed systems can be disrupted both by acute stresses such as conflicts and disasters, and chronic problems relating to social inequalities, inefficiencies or lack of coordination between actors, or inappropriate policies etc. (Bentley et al., 2018; Madin et al., 2022; McGuire and Sperling, 2016; Mulesa et al., 2021). Thus, it is important to recognize that seed systems – and by extension – farmers' seed security, are influenced by the broader context in which they operate. In this regard, seed systems can be understood to be embedded within the broader food system, and their functioning influenced by a number of drivers (i.e., sociocultural, economic, political, institutional, biophysical, technological, infrastructure, etc.) (HLPE, 2020; Mausch et al., 2021). From the perspective of food sovereignty (i.e., seed sovereignty), questions are also raised about who has political and economic control over seeds (Bezner Kerr, 2013; Hernández et al., 2020). We operate with two categories of contextual factors: Seed Governance and Food System Context. We understand governance in the broad sense as the IPCC: "The structures, processes and actions through which private and public actors interact to address societal goals. This includes formal and informal institutions and the associated norms, rules, laws and procedures for deciding, managing, implementing and monitoring policies and measures at any geographic or political scale, from global to local." (IPCC 2022).

Seed security experienced by farmers can be understood as an ***outcome of the seed system*** (Puskur et al., 2021). In this regard, a well-functioning seed system should contribute to seed security for farmers. On the other hand, seed insecurity can reflect shortcomings in the functioning of the seed system (Bentley et al., 2018), including dynamics related to any of the contextual factors. Figure 2 illustrates the conceptual framework linking seed system actors, functions and seed security outcomes. In summary, we use the five seed system factors to structure the characterization of seed systems at both national and local levels. In addition, the seed security framework will be used to explore how well seed systems meet farmers' needs and preferences at local level.

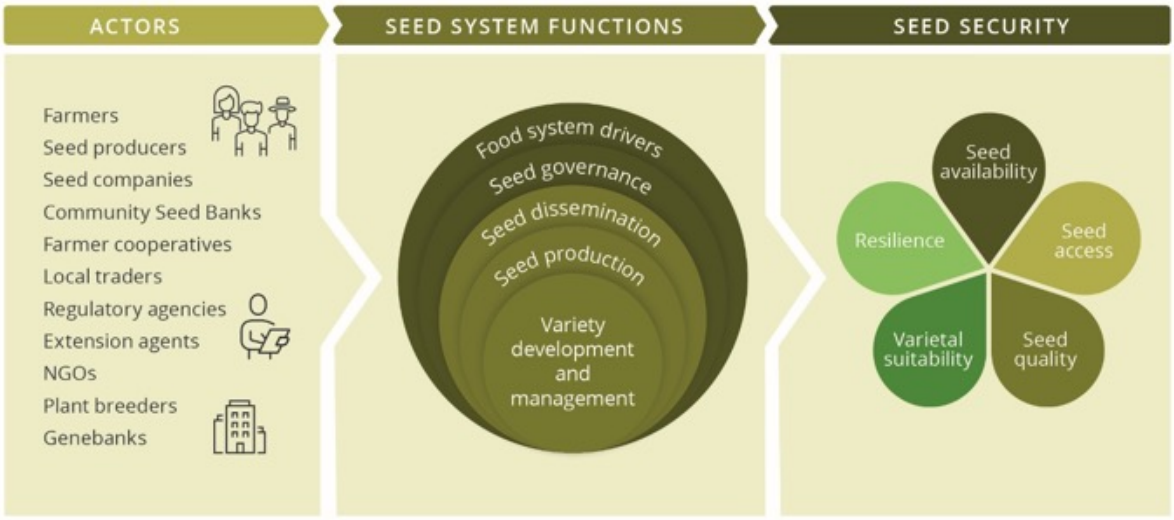

Figure 2. The framework used to analyze seed system actors' contribution to seed system functions and their seed security outcomes for farmers.

2 METHODS AND TOOLS

In this section, we provide an overview of the approach for the national and local seed system characterizations and describe the data collection methods used.

2.1 National seed system characterization

The main steps in the national seed system characterization are outlined in Figure 3. Methods include key informant interviews, workshop discussions and document review.

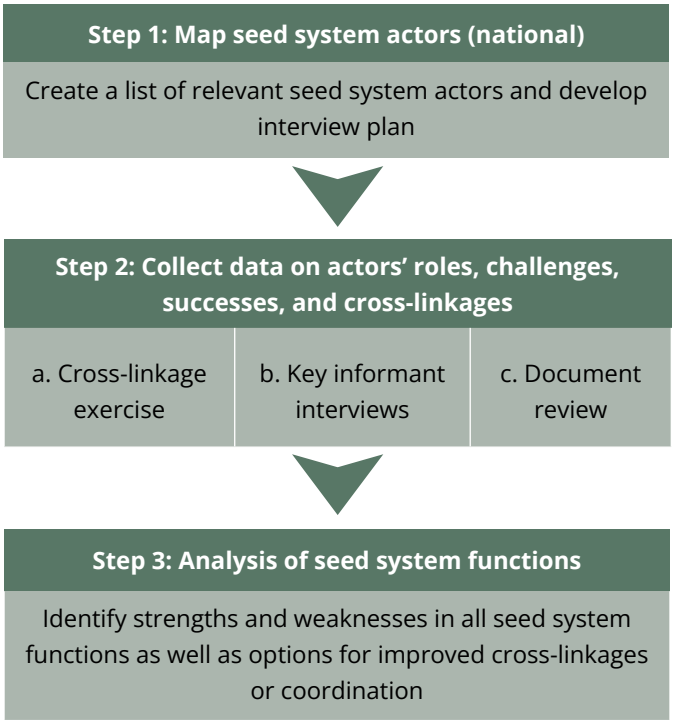

Figure 3. Steps in the national seed system assessment.

Following the initial document review, a launch workshop was organized in Tsirang, Bhutan in October 2022. The launch workshop was attended by about 25 participants representing key stakeholder organizations in Bhutan's seed system.

A total of 36 key Informant Interviews were carried out between March and December 2023 (Annex 1). Based on a review of the relevant policy documents, research and grey literature, the key documents are included in Table 1.

2.2 Local seed system characterization

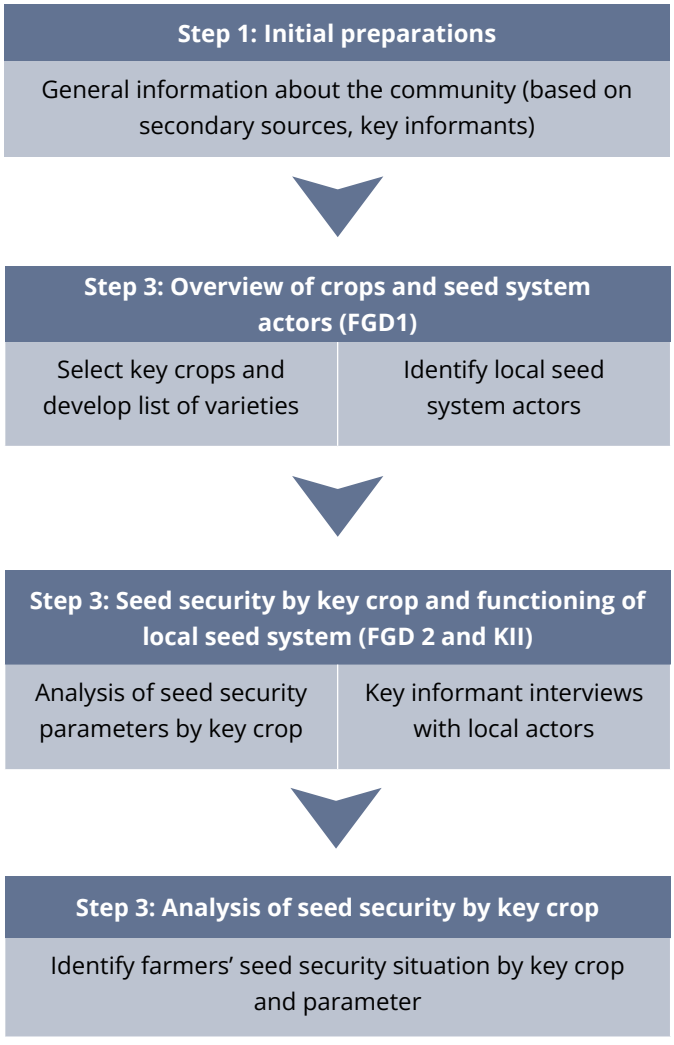

Figure 4. Steps in the local seed system assessments.

Table 1. Key seed systems documents Bhutan.

Title	Institution and year	Theme
Food and nutrition Security policy of Bhutan	Ministry of Agriculture and Livestock Royal Government of Bhutan (2023)	Overall policy for the agri-food system development in Bhutan
National food system pathway of Bhutan	Ministry of Agriculture and Forests* (2021)	The Bhutanese national pathway submitted to the UN Food System Summit and its follow-up process
Biodiversity Act of Bhutan	Parliament of Bhutan (2022)	The law governing biodiversity, including agrobiodiversity in Bhutan
Seed act	Parliament of Bhutan (2000)	The law governing seed in Bhutan
Seed Rules and Regulations of Bhutan	Department of Agriculture Ministry of Agriculture and Forests (2018)	The rules and regulations of the seed law
Seed Sector Development Strategy 2021-2028	Department of Agriculture Ministry of Agriculture & Forests* (2021)	Overall seed sector development strategy/policy
Minimum seed standards of Bhutan	Royal Government of Bhutan Ministry of Agriculture and Forests* (2019)	Minimum seed standards for all seed classes of all crops
Agriculture Research Strategy 2018-2028	Department Of Agriculture Ministry of Agriculture & Forests (2019)	Overall strategy for agricultural research in Bhutan
Guidelines on Cost-Sharing Mechanism for The RNR Sector	Ministry of Agriculture and Forests May 2021	Document specifying types of input subsidies in the renewable natural resources (RNR) sector
Seeds without borders: regional cooperation for seed sharing	Ministry of Agriculture & Forests & International Rice Research Institute IRRI (2018)	The agreement between Bhutan and the six other countries in the region that are party to the Seeds without Borders agreement (India, Bangladesh, Cambodia, Myanmar, Nepal and Sri Lanka)

*The Ministry of Agriculture and Forestry was reorganized and renamed in 2022 and is now the Ministry of Agriculture and Livestock.

The main steps in the local seed system characterization are outlined in Figure 4. The main methods include focus group discussions (FGDs) with farmers and key informant interviews with local seed system actors.

The FGDs were conducted in ten gewogs selected to represent different agroecological zones, ethnolinguistic groups, and regions in Bhutan (Table 2 and Figure 5). In doing so, we aimed to account for social and geographical factors influencing farmers' crop preferences. The selection is not meant to be statistically representative of all farming environments and communities in the country, but rather to display the diversity. A total of 111 farmers participated in the FGDs, with a range of 10 to 32 participants per gewog. In each site, Gewog Agriculture Extension and Gewog Administrations were instructed to invite farmers based on the following criteria: participants must be farmers involved in cultivating crops and represent a balance in terms of gender, age, and different chiwogs within the gewog. While this was generally achieved, in a few cases relatively few women participated (Table 2).

The research phase was concluded by a Roundtable Meeting (RTM) at Tsirang in October 2024 attended by 38 participants representing the same range of stakeholders as during the launch workshop two years earlier. During the RTM the draft seed system research report (an earlier version of this report) was presented and participants 1) validated the content and filled in remaining knowledge gaps and 2) co-developed an evidence based seed system intervention project to address seed system development needs in Bhutan.

Table 2. Overview of the ten study sites selected for the local seed system characterization and number of FGD participants per gewog.

Agroecological zone	Gewog (Municipality)	Dzongkhag (District)	Ethnolinguistic groups*						# FGD participants (% female)
			B	K	L	N	S	Y	
Wet Subtropical	Phuntshothang	Samdrup Jongkhar		X	X	X	X		32 (66%)
	Senggye	Sarpang			X		X		13 (46%)
Humid Subtropical	Mendrelgang	Tsirang	X	X	X	X	X		11 (36%)
Dry Subtropical	Bongo	Chukha				X			11 (55%)
	Kabjisa	Punakha				X			17 (59%)
Warm temperate	Orong	Samdrup Jongkhar					X		20 (60%)
	Sombaykha	Haa			X	X			10 (20%)
	Wangphu	Samdrupjongkhar					X		23 (9%)
	Bumdeling	Trashiyangtse						X	30 (50%)
Cool Temperate	Samar	Haa				X			19 (63%)

*Ethnolinguistic groups: B=Brokpa, K=Khengpa, L=Lotsampa, N=Ngalop, S=Sharchop, Y=Yangtsepa (Zalakha dialect).

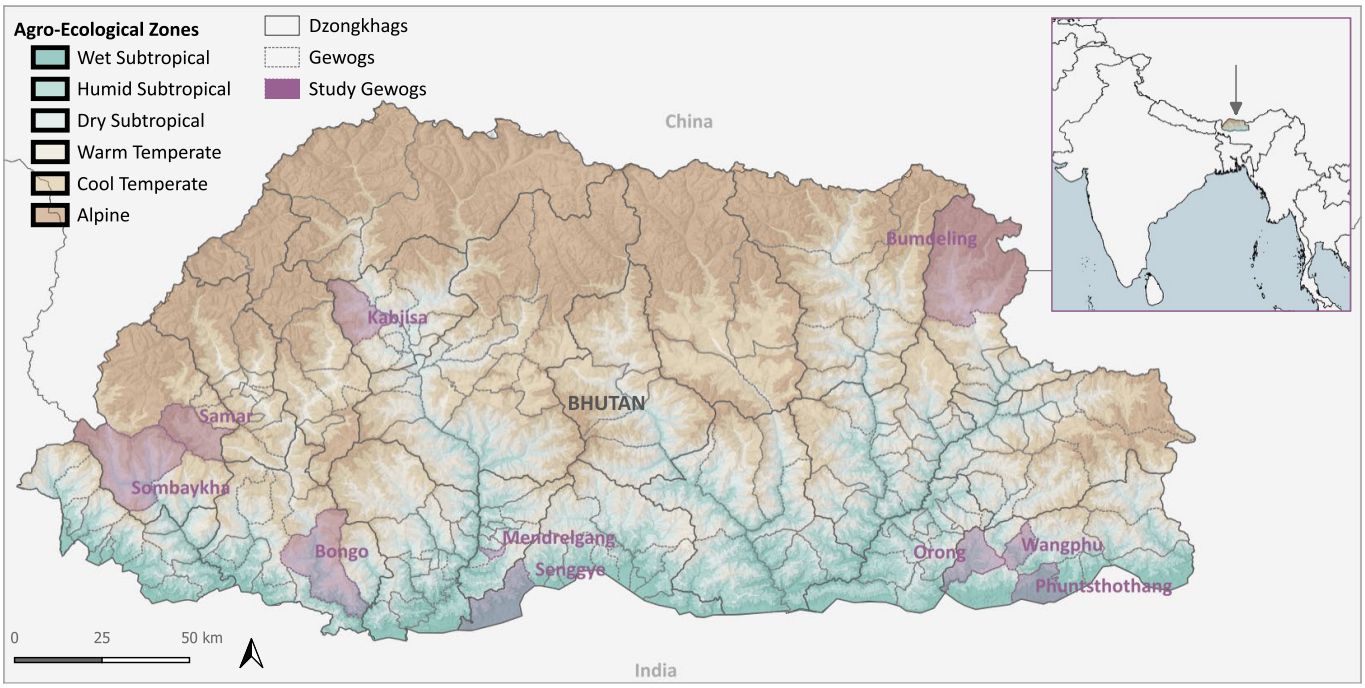

Figure 5. Map of study gewogs and agroecological zones.

Discussions during roundtable workshop, Tsirang, Bhutan. Photo: NMBU

3 FUNCTIONING OF THE SEED SYSTEM

3.1 Bhutan's seed system in a nutshell

Farmers in Bhutan source seeds from various sources. The country has a formal public system with organizations with mandates covering all the main seed system functions from the conservation of PGRFA to dissemination (Table 3). In addition to the public system, there are two private seed companies and a number of private nurseries involved in seed production and dissemination in the country.

While many of the varieties grown by farmers in Bhutan originate from this formal system, the bulk of the seeds farmers plant every year are farm-saved. Quantitative data on seed use and sources in Bhutan are limited, but Gyeltshen (2022) reported that 98% of the cereal seeds used are sourced from informal channels, primarily farm-saved. The same study reported that the situation is different for vegetables where the public formal system is the largest source of seeds (~50%), in addition, a small share (~5%) is sourced from the commercial formal system (Gyeltshen, 2022).

3.2 Overview of formal system actors and institutions

Table 3 provides an overview of the actors and policies/ legal frameworks in the Bhutanese seed system by function.

3.3 Variety development and management

The variety development and management function encompass conservation and management of plant genetic resources as well as breeding and evaluation of new varieties.

The National Biodiversity Centre (NBC) has the national responsibility for conservation and governance of PGRFA. NBC is located in Thimphu and manages the national genebank. NBC actively collects PGRFA in annual collection missions and also receives accessions of breeder seeds from the Agricultural Research and Development Centres (ARDCs) for long-term conservation. The safety duplicate collection is maintained at the National Duplicate Genebank at ARDC Wengkhar. NBC also collaborates with ARDCs, the NGOs Tarayana and SJI on community seed bank (CSB) projects involving management of PGRFA, for example by collecting among the farming communities involved and by providing long-term storage of accessions of the varieties conserved and developed in these projects. NBC also collaborates with the College of Natural Resources (CNR), providing training and lectures to students on PGRFA management, thus contributing to long-term capacity building. Further, NBC also provides germplasms for students' research activities according to due processes and under the conditions of a Material Transfer Agreement.

The ARDCs under Department of Agriculture (DoA) in the Ministry of Agriculture and Livestock (MoAL), are responsible for public variety development and evaluation. The four ARDCs and three ARDSCs (sub-regional centres) have mandates for different crops for different agroecological zones.

As of June 2023, a total of 310 varieties have been released in Bhutan since 1988, excluding forages (ARID, 2023). The crop type with the largest number of notified improved varieties are vegetables with 128 varieties. The current seed rules and regulations provide for both "notification" and "release" of varieties. The new lines/varieties are typically sourced from the CGIAR and other international sources of new lines/varieties and the variety research at the ARDCs is focused on characterizing and evaluating these lines. The CGIAR centres mentioned as variety sources are CIMMYT, IRRI, ICRISAT, CIP. Other international sources mentioned by respondents are World Vegetable Centre and the national agricultural research programs in Nepal and the Japanese International Cooperation Agency (JICA).

Table 3. The formal seed system in Bhutan by function

Function	Actors	Policies and legal frameworks
Conservation and management of crop diversity	The National Biodiversity Centre (NBC) has the national mandate for the conservation and management of PGRFA.	Biodiversity Act (2022) The act is compliant with the Convention on Biological Diversity and the International Treaty on Plant Genetic Resources.
Breeding and variety release	The Agricultural Research and Development Centres (ARDCs) and Agricultural Research and Development Sub-Centres (ARDSC) are responsible for public crop research, including variety development/evaluation and release. Variety release is the responsibility of the Variety Release Committee and the National Seed Board under the Ministry of Agriculture and Livestock.	Variety release: Currently, governed by the Seed Act (2000) and the National Seed Rules and Regulations (2018) (new version published in 2025). Plant Variety Protection (PVP): According to the Biodiversity Act (2022), NBC shall be responsible for variety registration and sui generis PVP regulation (including both Farmers' and Breeders' Rights).
Seed production	The National Seed Centre (NSC) is a public seed company doing the bulk of the formal seed production at four NSC regional centres and through about 500 Registered Seed Growers (RSGs) (groups or individual farmers). The private seed company Bhutan Alpine Seed produces seed for sale in Bhutan and abroad. Bhutan Seedlings and a number of smaller nurseries produce seedlings in Bhutan. Seed certification is done by Bhutan Food and Drug Authority (BFDA). Community-based seed production groups (CBSPGs) produce seed of local varieties and some improved OPVs. They use foundation seed provided by ARDCs rather than NSC. The CBSPGs are pending formal registration.	Seed production and certification: Currently governed by the Seed Act (2003) and the National Seed Rules and Regulations (2018).

Function	Actors	Policies and legal frameworks
Seed dissemination	District Agricultural Officer (DAO) (Gewog Agriculture Office) distributes seed from NSC through the Gewog Agriculture Extension Officers at the local level. The price is set by the government and is the same in the entire country. When seeds are promoted in particular projects a cost-sharing mechanism is activated, providing seeds free of charge or at subsidized rates. Agricultural Sales and Service Representatives (ASSRs) distribute seed from NSC (against 10% commission which is covered by the government). Two private seed companies sell directly to farmers: • Bhutan Alpine Seed (vegetables) • Reva Seed Enterprise (commissioned sale of Syngenta and Bayer vegetable seeds) There are also a number of private nurseries The NSC regional centres distribute seeds directly to farmers (minor, project-based route). ARDC also does some direct distribution to farmers, often in connection with on farm trials. A few NGOs are involved in seed dissemination. Most notably *Tarayana* and the *Samdrup Jongkhar Initiative* (*SJI).*	Certification of seeds and seed sellers. Currently, governed by the Seed Act (2003) and the National Seed Rules and Regulations (2018). Seed providers and seed companies must be registered and can only sell registered varieties. But the Seed Rules and Regulations and the Biodiversity Act protect farmers' rights to "small-scale exchange and local sale" of uncertified seeds of unregistered varieties.
Overall	Ministry of Agriculture and Livestock	Food and Nutrition Security Policy (2023) Bhutan Food System Pathway (2021) (Submission to the UN Food System Summit 2021).

Not only new improved varieties can be released/ notified but also traditional varieties. A notable historical example is the variety released under the name Khangma Maap by ARDC Wengkhar in 1999, a farmer variety with the original name Chhomrong Dhan introduced from Nepal where it had been released in 1991. The Chhomrong rice is originally a cold-tolerant high elevation landrace collected and purified at the Lumle Agricultural Research Station of the National Agricultural Research Centre in Nepal. According to the scientists doing the pure-line selection, the origin of the Chhomrong landrace before it was introduced by a farmer in the Chhomrong villages is "an unknown location in India" (Sthapit et al., 1998). There are also other examples of farmer varieties in the national catalogue in Bhutan and recently a farmer variety was released under the name Zangthi 1 (ARID, 2023).

The ARDCs had active breeding programs in the past. In the late 80s, ARDC Bajo developed and released a number of rice varieties. In recent years, international programmes such as Seeds without Borders have made variety import from abroad easier and has allowed for more efficient evaluation of a larger number of lines. Some of the ARDC informants referred to their work with CGIAR varieties as "adaptation", others as "characterization and evaluation". The latter seems most appropriate as there is currently no active crossing or selection within segregating populations involved in the process. There is currently a CIMMYT project on hybrid maize seed production in the Lingmethang sub-centre of Wengkhar ARDC. The ARDCs are responsible for maintaining the breeder seeds and foundation seeds distributed to National Seed Centre (NSC).

The private seed company Bhutan Alpine Seed was in 2023 experimenting with hybrid seed production for some vegetables (parents supplied from a Japanese seed company) and is considering shifting to these varieties if the results are promising.

In addition to the farmer varieties of local origin in Bhutan and the varieties on the official variety list, it was also reported from informants that new varieties are entering the country over the borders with India. The revised Seed Rules and Regulations 2025 specifies provisions for legal import of notified and non-notified varieties (the latter for research purposes).

Farmer involvement in variety evaluation

Farmers are involved in the variety evaluation of several crops (rice in Bajo, potato in Yusipang, hybrid maize in Lingmethang, minor cereals in Wengkhar). In vegetables, it seems there is little or no farmer involvement apart from regular field trials in the variety release process (in Value for Cultivation and Use tests).

The ARDC Wengkhar was for a long time involved in the Biodiversity Use and Conservation in Asia Programme (BUCAP) coordinated by the Development Fund Norway and experiences and lessons from that project are used in current evaluation studies. From the second year, evaluation takes place in parallel on-station and on-farm. In the third year, they already move to farmer-to-farmer distribution of seeds.

The ARDCs are also involved in current projects linking conservation activities with breeding activities. A prominent example is the IFAD-funded Evolutionary Plant Breeding project organized through ARDC Tsirang, coordinated by NBC. In addition, there are several other projects where ARDCs evaluate NBC material such as ARDC projects and CSBs.

"When we get germplasm from outside, we evaluate hundreds of lines, for 3-4 years at our station, take promising lines to the Farmers' field for 2 to 3 years, and conduct field days, if farmers accept the varieties, we propose for release." (KII ARDC Bajo).

"Whenever a new crop is introduced, we do an on-station trial over a season. If it is found to be fine, we do close observation in the field with the farmers-where we provide the seeds and farmers grow." (KII ARDC Wengkhar).

Governance of variety management

The current main rule is that varieties must be registered before they can be sold (but see chapters 3.1.1 about the exemption for traditional varieties in the National Seed Rules and Regulations). Registration of varieties is the responsibility of the Variety Release Committee (VRC). The MoAL organizes the annual VRC meeting in May or June. But frequency may also depend on number of proposals received.

Breeders submit proposals for variety release based on a format that is different for each crop. The VRC is headed by the Director of DoA. The VRC has 10 members, including the private sector and 2 farmers. If a proposal is accepted the application is sent to the National Seed Board for approval. The Board is headed by the Secretary. For research purposes, MoAL can grant permits to test varieties without first going through an official release process.

A relatively new policy element with potential large consequences for variety and seed availability in Bhutan is the country's participation in the Seeds without Borders Regional cooperation for variety and seed sharing since November 2022. The objective of this agreement is harmonization for transnational movement of both varieties and seeds between the countries India, Nepal, Bangladesh, Vietnam, Sri Lanka, Cambodia, Philippines, Bhutan. The agreement was initiated by the International Rice Research Institute (IRRI). For seeds from a member country to be sold in Bhutan, the variety must be registered in another country party to the agreement. Similarly, Bhutan is party to the South Asian Association for Regional Cooperation Seed Bank agreement which also has provision of movement of varieties and seeds across borders in the region (Food and Nutrition Security Policy, 2023). But so far there has been very limited cross-border transactions of seeds under the two policies. One reason might be that there are still strict phytosanitary requirements that must be adhered to when importing seed. It was therefore expressed by some actors that the most likely use of especially the latter Seed Bank arrangement would be in emergency situations (NSC KII).

The Biodiversity Act (2022) governs the work NBC does on conservation, use, and ABS of PGRFA. According to the Biodiversity Act, NBC shall also be responsible for Plant Variety Protection (PVP).

Discussion

There are good working relations between all actors involved in variety development and management (NBC, ARDCs and CNR). NBC is a strong and well-connected genebank. NBC is involved in a number of direct distribution and research projects involving farmers in collaboration with ARDCs and other actors. NBC and ARDC have long experience with involving farmers in variety evaluation of both genebank material and new improved lines. NBC staff also play an important role as delegates of the Bhutanese government in international biodiversity forums such as the Convention on Biological Diversity and the International Treaty on PGRFA, influencing the international governance frameworks as well as the domestication and operationalization of these. ARDC is well connected with international actors such as the CGIAR for access to new breeding lines/varieties.

There is very limited plant breeding capacity in the ARDCs currently. This is a concern for the Ministry: *"We used to do some plant breeding, but now people are losing interest in research like plant breeding. A lot of people are leaving the system. If we say this is the office of plant breeding-we do not have it, we just have empty chairs."* (KII DoA, MOAL). There is also no specialized education in plant breeding at CNR. The CNR informants expressed in the KII that they have limited capacity to teach several fields and topics – from plant breeding to agricultural economics. The professor currently teaching the basics of plant breeding has retired and works on contract-basis.

While the ARDCs and NBC have many projects involving farmers in research and varietal evaluation, the formal public system's ability to meet farmers' needs is limited by practical, economic and logistical factors in the seed value chain. This point was raised by NSC Paro in KII when asked about how they respond to challenges posed by climate change: *"The market is very regulated and since NSC cannot generate a revenue this means there is no opportunity for research into demands for other varieties than those from ARDCs and selected for bulk seed production and dissemination".*

Private sector informants consider the variety release process to be unnecessarily bureaucratic and slow. Also, ARDC informants mentioned that the registration process is too slow and difficult. One problem is that the VRC typically has met once a year but the Seed Rules and Regulations provides for more frequent meetings if need be: "Convene VRC meetings annually or as and when required».

The private seed company Bhutan Alpine Seed (BAS) made an interesting point about VRC and BSB making

decisions to de-notify varieties without consulting them: *"BAS –broccoli –Magic Green was doing very well. Last year, they said, another variety came and Magic Green was de-notified without consulting BAS stating that both are similar varieties. Farmers should be given the choice."* This seems to be a case where the public formal legal institutions narrow the variety choice available to growers.

The private sector informant, as well as ARDC informants, make the point that there could be a more explicit and formalized division of responsibility for different crops, with the private sector being responsible for vegetables (and perhaps some other selected crops with commercial potential) and the public system being primarily responsible for staple crops.

The low seed replacement rate in cereals has negative consequences for variety management as the farm-saved seed gets mixed up with other varieties, resulting in geneflow in outcrossing species and potentially lower varietal purity/quality.

3.4 Seed production

The seed production function covers the production of all the seed classes. Early generation seed (EGS) production encompasses production of breeder seeds and foundation seeds (also called basic seed). The seeds disseminated to farmers in the formal system are either fully certified or truthfully labelled.

Seed production in farmers' seed systems

The bulk of the seeds farmers in Bhutan plant to produce staple crops like rice, maize, potato etc. are farm-saved. The farm-saved seeds are stored on farm, typically dried outside (on rooftops or hanging under roofs) (Figure 6). Using such storage techniques, the physical seed quality can be compromised by pests and diseases. There have been some projects to support improved on-farm seed storage by the NGO Tarayana as well as in some DoA projects, distributing storage containers for seeds. There are also some CSB projects organized by NGOs, in some cases in collaboration with NBC[1].

In many crops, a substantial share of the farm-saved seeds is of varieties originally released by the formal system. It is therefore important to consider the "seed replacement rate" for different crop types. For vegetables, the seed replacement rate is high, with farmers sourcing fresh seeds from NSC or national or foreign private seed companies every season, while for cereals like rice, maize and wheat the seed replacement rate is considerably lower (Gyelthsen 2022). We return to estimates of the seed replacement rate for different crops in section 3.5.

Figure 6. Drying of chili for conservation. Photo credit: Wangdi Agriculture extension officer.

Formal system seed production

EGS production: As described in chapter 3.1.4 about variety management, the ARDCs are responsible for maintaining breeders' seed. The volumes of EGS produced and supplied by the ARDCs are reported in table 4. The Bhutan Food and Drug Authority (BFDA) does not monitor the production of EGS.

The major actor in certified seed production in Bhutan is the public National Seed Centre (NSC). NSC produces seed based on demands reported from the District Agricultural Officers (DAOs)/Agriculture Extension officers (AEOs) in the gewogs. NSC has seven stations

1 There are several CSBs in the country: Gomdar CSB, Phuntshothang CSB and Bumthang CSBs supported by NBC, Dewathang CSB supported by SJI and Lumang CSB supported by Tarayana Foundation.

in different agroecological zones dedicated to seed production. In addition, NSC organizes more than 500 Registered Seed Growers (RSG). RSGs are farmers or farmer groups certified for seed production by BFDA. RSGs are provided training on different aspects of quality seed production for specific crops. The volumes of seed produced and supplied by NSC is reported in table 5.

Comparing the number of varieties in tables 4 and 5, the number of varieties for which certified seed is produced broadly corresponds to the number of varieties for which EGS seed is produced in most crops. But there are exceptions and in the case of rice for example, EGS is produced for 20 varieties (out of 31 released/notified varieties) while NSC only produces seeds of 8 of these varieties. The paddy varieties for which NSC and their outgrowers, RSGs, produce seeds are all old. The most recently released paddy variety for which seeds are produced is from 2010 (Bhur Kamja-1) and the oldest ones were released in 1988 (including the IRRI "mega-rice" variety IR64).

In the KII with the RSG in Bumthang, we learned that BFDA closely monitored seed potato production, while the monitoring of vegetable seed production was perceived as more relaxed. The RSGs draw on traditional practices as well as the formal RSG training they have received. For example, when storing the seeds they use a Kotai, a traditional granary made of bamboo, and keep the seeds there for 1-3 months with intermittent drying before they are collected by the AEO (KII Bumthang).

Table 4. EGS production in select ARDCs in 2022 and 2023. Source: The ARDCs

Crop	Volume	No of varieties	Centres
Rice (paddy) (2022)	6024,5 Kg	20	Bajo, Samteling, Wengkhar, Lingmethang, Khangma
Potato (2023)	5500 Kg	2	NCOA Yusipang
Wheat (2023)	1140 Kg	4	Bajo
Beans (2023)	34 Kg	3	Tsirang, Lingmethang, Khangma
Maize (2023)	57 Kg	2	Wengkhar, Lingmethang
Radish (2023)	55 Kg	2	Tsirang, Wengkhar
Cauliflower (2023)	10,7 Kg	1	Tsirang, Wengkhar
Broccoli (2023)	25,4 Kg	2	Tsirang, Wengkhar
Carrot (2023)	38 Kg	2	Tsirang
Spinach (2023)	16,6 Kg	2	Tsirang, Wengkhar
Tomato (2023)	3,8 Kg	3	Tsirang, Samteling. Wengkhar, Lingmethang, Khangma
Brinjal (2023)	0,6 Kg	1	Tsirang
Watermelon	2,2 Kg	3	Tsirang
Bunching onion	1 Kg	1	Tsirang
Okra (2023)	3,7 Kg	1	Tsirang
Zucchini (2023)	2,6 Kg	2	Tsirang, Lingmethang
Azuki bean	10 Kg	1	Tsirang
Chili	0,5 Kg	1	Tsirang and Samteling
Soyabean	33,5 Kg	2	Lingmethang and Khangma
Mustard	60 Kg	1	Khangma
Peas	61 Kg	2	Wengkhar, Khangma
Pumpkin	3 Kg	1	Lingmethang
Lettuce	0,1	1	Lingmethang
Mustard green	3	1	Khangma

Table 5. Seed production by NSC on station and with Registered Seed Growers (RSGs). Data: NSC

Crop	2022 production	2023 production	Unit	# varieties	Station/RSG groups
Rice (Paddy)	42730	37760	kg	8	Station + RSG (Bajo and Chundudingkha)
Maize	47050	109350	kg	2	Station+RSG Yangtse
Wheat	34906	43400	kg	2	Station + RSG Bajo
Sweet buckwheat	2500	3780	kg	1	RSG Yangtse
Bitter Buckwheat	320	500	kg	1	RSG Nangsiphel
Quinoa	800	1200	kg	1	RSG Yangtse
Potato	256300	278000	kg	5	Station + RSG (Yangtse, Phobjikha and Nangsiphel)
Radish	713	370	kg	3	Station + RSG Nangsiphel
Cucumber	42,7	23,2	kg	1	Station + RSG Bondey
Squash	15	39	kg	1	Station
Pea	676,5	1283	kg	2	Station + RSG (Bondey and Bajo)
Onion	41,4	63,5	kg	2	Station
Beans	7768,5	7737,3	kg	4	station + RSG (Yangtse, Bondey and Bajo)
Okra	53	45	kg	1	Station
Mustard Green	304,5	151	kg	1	Station + RSG (Bondey and Bajo)
Spinach	46	60	kg	2	Station
Chili	482,5	307,6	kg	1	RSG (Bajo and Bondey)
Tomato	4,6	34	kg	2	Station
Cabbage	16,5	6	kg	1	Station + RSG Yangtse
Broccoli	10,4	280	kg	1	RSG Nangsiphel
Cauliflower	130	365,5	kg	1	RSG Nangsiphel
Japanese Green	86	50	kg	2	Station + RSG Bondey
Mustard	385	267	kg	3	Station + RSG (Nangsiphel and Bajo)
Sag	11,53	12,6	kg	1	RSG Yangtse
Coriander	8,5	8	kg	1	RSG (Yangtse, Bondey and Nangsiphel)
Ginger	3900		nos	1	RSG Samtenling
Turmeric	3000		nos	1	RSG Samtenling
Tea	4000		nos	1	RSG Samtenling
Apple	8540	6181	nos	4	Station
Pear	8359	6169	nos	4	Station
Persimmon	3649	3882	nos	3	Station
Almond	810	522	nos	1	Station
Apricot	1938	624	nos	1	Station
Cherry	195	300	nos	1	Station
Chestnut	743	202	nos	1	Station
Peach	4976	4820	nos	2	Station
Plum	1402	896	nos	1	Station
Prune		208	nos	1	Station
Strawberry	2721	4260	nos	2	Station
Walnut	582	3279	nos	1	Station + RSG Bajo

Crop	2022 production	2023 production	Unit	# varieties	Station/RSG groups
Avocado	11260	19070	nos		Station
Mango graft	8520	6228	nos		Station
Areca nut	7444	6075	nos		Station
Banana	9500	5173	nos		Station
Dragon Fruits	7413	19951	nos		Station
Guava	598	500	nos		Station
Papaya Bhr-I	1699	2940	nos		Station
Pine apple	7860	500	nos		Station
Pomegranate	1012	1212	nos		Station
Cardamom	0	2370	nos		Station
Litchi	2042	7028	nos		Station
Jack Fruits	7	100	nos		Station
Passion fruit	7100	1500	nos		Station
Citrus	67594	37606	nos		Station
Asparagus	100000	6600	nos	1	Station + RSG Bondey

In addition to certified seed production, NSC is responsible for producing foundation seed of its registered varieties for private seed companies, but part of its mandate is sometimes difficult to fulfil because of NSC's own production needs. Bhutan Alpine Seed is currently the only private seed company in Bhutan that produces their own seed. BAS produces seed on their land in Paro as well as with farmers working as contract seed producers. They produce substantial volumes of seeds of a number of vegetables and in some crops like cabbage and spices such as coriander, BAS is a larger supplier than NSC.

Governance of seed production

MoAL has the overarching governance responsibility for seed production. MoAL's Manual on breeder, foundation and certified seed production for field crops and horticulture crops (2021) specifies protocols and standards which all seed producers must adhere to.

Quality assurance of the different seed classes is done by BFDA. BFDA was established in 2022 and was the result of a merger of Bhutan Agriculture and Food Regulatory Authority (BAFRA) and Bhutan Narcotics Control Authority and Drug Regulatory Authority. While BAFRA previously sorted under MoAL, BFDA is under the Ministry of Health. BFDA's seed certification is done according to the applicable provisions laid out in the Plant Quarantine Act of Bhutan 1993, Seed Act of Bhutan 2000 and Pesticides Act of Bhutan 2000, and the rules thereunder (KII BFDA).

BFDA reports that they inspect certified seed production at NSCs farms and among the RSGs, as well as among the registered outgrowers of the private company BAS. BAS described the modality of the latter this way: *"We do monitoring three times a year. BFDA also comes for monitoring when they are available. We visit the field together with the farmers. In our Tsirang seed production site, we invite Tsirang BFDA. Similarly, Paro BFDA for our farm here."* (KII BAS)

Discussion

NSC is a strong public organization with a social mandate to produce and make seed available according to demand. There is a clear line of communication and responsibility between the DAO/AEO and NSC. NSC has a national network of offices/farms and affiliated RSGs.

Challenges in seed production in Bhutan can be categorized in terms of policy challenges and technical challenges.

Policy challenges: NSC Paro described the situation in the 2022 season when they had produced large volumes of wheat seed (70-80 tons) responding to

EAs demand forecast (and policy signal to increase wheat seed production), but when the season came the demand was much lower and they had to discard a large share (KII NSC Paro). A similar "mismatch" between supply and demand is reflected in this information from the farmer seed producer group in Bumthang: *"DAO wanted about 10 million worth of tomato seeds, and NSC imported from outside, but later, DAO did not take it. So there is a mismatch…Dzongkhag wanted mustard in 2022, but we did not have this in stock. They did not submit demand last year. So, they bought from local farmers directly and supplied to other farmers. There was poor germination."*

The working relationship between ARDCs and NSC is good, but according to NSC, there are sometimes problems with timely access to sufficient foundation seeds. This problem is also acknowledged by ARDCs in KIIs but according to NSC, this has improved in later years (KII NSC Paro).

MoAL informants expressed concern about BFDA's capacity in seed quality assurance. This was said to be a concern that had increased with the move of BFDA from the ministry of agriculture to the ministry of health: *"BFDA plays a crucial role in implementing seed laws, including seed inspection and certification. However, there is a capacity gap in BFDA, suggesting the need to build stronger technical expertise for effective regulation of the seed system."* (KII MoAL legal division). The MoAL informant expressed concerns about the impact of the move of BFDA on the coordination and implementation of sector laws. However, the informant also acknowledged the purpose of this move, which is to separate the responsibility for quality assurance from the ministry responsible for seed production. In the forthcoming agricultural input law, there will be a clear segregation between foundation seeds and certified seeds, which should make the division of mandate and authority easier. The maintenance of breeder seeds will still be the responsibility of the ARDCs. The MoAL informant emphasized the need for MoAL, ARDCs and BFDA to work closely together to ensure successful implementation of the new law.

Technical challenges: A major challenge in on-farm seed production is to maintain good drying and storage conditions and avoid degradation caused by pest attacks during storage. This is also a challenge for "intermediate" seed system efforts such as CSBs and efforts to support on-farm storage of seeds. The informants from the NGO SJI said they have faced "technical problems" related to humidity and temperature control in the storage facilities in the CSBs they support. Similarly, the informants from the NGO Tarayana said farmers still face challenges caused by temperature and humidity swings when using the seed storage bags they had distributed. Other technical challenges are experienced during the actual seed growing. Damages to crops in the field by wild boars and other wild animals were reported both by public and private seed producers (KII BAS Paro, ARDC Tsirang, FGD RSGs).

3.5 Seed dissemination

Seed dissemination is the seed system function that makes seeds available to farmers. As noted above, the bulk of the seeds for Bhutan's staple crops are farm-saved, but over the long run, all farmers rely on obtaining seeds from off-farm sources. There are, however, few studies of farmers' seed systems in Bhutan that quantify the importance of different seed sources. In this section, we mainly focus on seed dissemination from public and private formal sources and "intermediate sources" like community based organisations like CSBs and community-based seed producer groups (CBSPGs).

Formal system seed dissemination

The National Seed Centre (NSC) in collaboration with the local government are the big players in formal system seed dissemination in Bhutan. NSC covers about 90% of the formal supply overall and a bit less in vegetables. The certified seeds produced are disseminated through two routes: 1) Direct distribution through local government/extension and 2) Sale through private Agricultural Sales and Services Representatives (ASSR) traders. Earlier, there was a third modality for seed distribution called one-stop farmers shop, but these are no longer operational. The total volumes of certified seed distributed to farmers in Bhutan through the different routes are reported in table 6.

NSC has both a commercial and a social mandate. Being a seed company, their operation must be economically

sustainable. The social mandate of NSC is reflected in its policy to provide seeds at an affordable price at the same level in the entire country. Transport costs are covered by the government and for seeds supplied through ASSRs. The 10% commission the ASSRs charge on seed sales is also covered by the government.

Farmers' demand for seeds from the formal system is solicited by the AEOs and reported upwards in the system through the DAOs. Prior to the onset of the season, the seeds are received by the AEOs and distributed to farmers either free of charge or at subsidized rates. Whether the farmers must pay a share or not depends on their economic status. The "Guidelines on Cost-Sharing Mechanism (CSM) for the RNR Sector 2021" aims to streamline practices of support provisions for various renewable natural resources (RNR) related activities. The CSM outlines various types of support packages depending on the category of farmer (subsistence, semi-commercial, commercial). The 2021 CSM stated that for rice seed, the cost coverage should be 100% across all categories of farmers, while for vegetables it should be 100% coverage for subsistence farmers and 70:30 cost sharing for semi-commercial and 50:50 for commercial farmers. The implementation of this CSM has been restricted to projects and specific promotion activities. The policy and planning division in the ministry is currently revising the cost-sharing mechanism. Additional subsidies is used to maintain uniform prices around the country as transport costs and other transaction costs are covered by the government.

NSC is mostly able to meet pre-defined demand, but demand has sometimes changed when the growing season starts (KII NSC Paro). The NSC has received external project support (most notably from IFAD) for seed packaging equipment in the Trashiyangtse station and this station can now package and supply seeds directly without first transporting the seeds in bulk to Paro (Figure 7). The Trashiyangtse station can today transport seeds in bulk to dzongkhags and gewogs all over the country (KII NSC Trashiyangtse).

Not all of the seeds distributed in the formal seed system reported in table 4 is certified by BFDA, most is rather "truthfully labelled", a quality assurance from NSC itself (NSC KII).

Gyeltshen (2022) cites the following statistics on seed replacement rate: "seed replacement rates for rice, maize and wheat stood at 8.59%, 13.48% and 25.62% respectively (DoA, 2021), failing to meet the minimum standard for seed replacement of 33% and 50% for self-pollinated and cross-pollinated crops respectively (Jayara & Pandey, 2021)." For vegetables the situation is different: the replacement rate is reported to be 74% annually (Gyeltshen 2022).

Figure 7. Seed cleaning and packaging equipment in the NSC Trashiyangtse station. Photo: NMBU

Table 6. Seed production volume of NSC seeds distributed to farmers in 2022 and 2023. Data: MoAL

Crop	2021/2022 volume (kg)	2022/2023 volume (Kg)	No of varieties
Staple crops			
Maize	70,336	103,168	4
Rice (paddy)	57,480	40,096	10
Wheat	28,866	34,245	3
Potato	362,050	274,385	4
Vegetables			
Common beans	3,632	2,958	5
Beetroot DDR	72	151	1
Bitter Gourd	33	40	1
Bottle Gourd	43	23	1
Brinjal PP Long	117	69	1
Broccoli	671	608	2
Bunching Onion	44	33	1
Cabbage	704	734	5
Carrot	608	1073	2
Cauliflower	579	539	6
Chili	442	241	4
Chinese cabbage	1	1	1
Coriander	229	164	1
Cucumber	90	83	3
Japanese Green	25	75	2
Lettuce	42	46	1
Mustard	126	153	1
Okra	75	32	1
Onion	1584	839	3
Pea	2358	1234	3
Radish	513	460	3
Spinach	69	47	2
Zucchini (Squash)	13	18	1
Tomato	132	109	5
Turnip	35	24	1
Watermelon	55	0	1
Oil seeds and pulses			
Mustard	4,710	15,377	1
Soybean	1,705	-	1
Yusi peka	84	9	1
Organic production seed			
Beans	778	703	2
Chili	2	1,082	2
Quinoa	48	1017	1
Buckwheat – sweet	4758	3272	1
Buckwheat - bitter	568	320	1
Ginger local	9488	1500	1
Turmeric local	2000	500	1

Table 7. Seedlings distributed in the Million Fruit Tree Plantation (MFTP) project in 2022 and 2023. Data: MoAL

Fruit type		Quantity (# plants)	
	Subtropical Fruit Plants	2021-2022	2022-2023
1	Areca nut Bhur S-1	0	0
2	Avocado seedlings	109063	190843
3	Avocado grafted	4243	0
4	Banana G-Naine	60575	4256
5	Dragon Fruit Gewaringpa-1	103589	75974
6	Guava Bebsew Shakha	11553	458
7	Seedless lime	0	143813
8	Litchi	38559	6083
9	Mango Grafted	123139	25007
10	Mango Grafted Irwin	0	70055
11	Soursop	0	31500
12	Papaya Bhur S-1	5990	2127
13	Passion Fruit	25181	2800
14	Pomegranate Bedana	9961	800
15	Macadamia seedlings	0	8881
16	Citrus (Malta/Mikam/sanh)	0	186993
17	Citrus Seedlings	57380	7886
	Sub-Total	**549233**	**757476**
	Temperate Fruit plants		
1	Apple	51775	14872
2	Almond Kagzi	54680	103144
3	Apricot Shakapara	9755	4214
4	Cherry Seneca	4810	97
5	Chestnut Jewphu-1	2665	565
6	Peach	52635	20530
7	Pear	86465	35543
8	Persimmon	69833	23223
9	Plum	41946	18095
11	Walnut Kagzi grafted	10258	3946
12	Walnut seedlings	37928	109625
14	Pecan nut	12300	17618
15	Kiwi	27662	73988
	Sub-Total	**462712**	**425460**

In addition to the regular distribution of seeds and planting material, an extraordinary fruit tree seedling distribution effort has been carried out during the last three seasons (2021 to 2024). The Million Fruit Tree Plantation project was established upon the Royal Command of His Majesty the King and the objective of the project is to enhance the income of rural households and increase nutritional intake from fruits.

As the project name implies, every season about a million seedlings are distributed[2] (Table 7). A substantial share of these seedlings are produced in Bhutan by both public and private seedling producers.

Direct distribution from research centres: As mentioned in the variety management section, the ARDCs are also involved in direct seed distribution to farmers. ARDCs direct seed distribution is project driven and the geographic scope is commonly the vicinity of the research station. ARDC Bajo distributes different cereal seeds to farmers (small bags, 6-10 kg) and follow-up with visits/monitoring of the performance. ARDC Wengkhar mentions both work with Community-Based Seed Producer Groups and *"in general, we give seeds to anyone interested, especially farmers"* (ARDC Wengkhar KII). This small-scale direct seed distribution from ARDCs is a strategy to reduce the distance between research and farmers' fields. There are also examples of projects in which ARDCs work as development partners with INGOs and IOs (IFAD, FAO, CGIAR) and engage in seed production and distribution. A notable example of this is ARDC Yusipang's distribution of seed potato directly to farmers in continuation of a Helvetas-supported project.

There are two private seed companies in Bhutan focusing on vegetable seeds (Bhutan Alpine Seed and Reva Seeds) and several focusing on fruit tree seedlings (e.g. Bhutan Seedlings). Bhutan Alpine Seed is the oldest and largest company and has a full operation of seed production and sale. Their seeds are disseminated through various market channels. They give some seeds to the extension service to promote locally, and they sell through shops and market vendors around the country. The NGO Tarayana is among the companies' customers. According to the BAS informant, the company relies mostly on word of mouth to reach new customers. BAS also has some export sales of seeds, most notably to Japan. Reva Seed, on the other hand, does not produce the seed they sell, but imports seed from the multinationals Syngenta and Bayer. Reva Seed is thus an agent for imported seed. They sell directly to a limited number of farmers and are currently only operating in pockets of the country. The NSC estimates that the private sector supplies about 10-20% of formal hybrid vegetable seed used in Bhutan.

Another modality of seed and planting material distribution about to become important in Bhutan is contract farming in which farmers are provided seedlings under an agreement for a guaranteed market for the products. For example, the fruit processing company Bhutan Agro processors has started establishing a contract farming scheme for the kind of fruiting varieties they need for their products.

Intermediary system dissemination

The NGOs Tarayana and SJI are both involved in activities that can be labeled intermediary seed system activities. The CSB coordinated by SJI are reportedly involved in some sale of vegetable seeds but mainly distributes seeds on a seed loan basis. According to the NGO informant: *"1 phueta of rice is returned with 2 phuetas*[3]" (KII CSB SJI). And as mentioned above, ARDC Wengkhar work with Community-Based Seed Producer Groups.

2 Bhutan begins third mega plantation programme. Kuensel 06.02.2024. https://kuenselonline.com/bhutan-begins-third-mega-plantation-programme/

3 Phueta is a volume unit and the weight varies from crop to crop. E.g. for sweet buckwheat one phueta is 300 gram, while for rice and sweet buckwheat it is 250 grams.

Governance of seed dissemination

The most important existing legislation for seed system development is the Seed Rules and Regulations of Bhutan (2018). While the regulation does not explicitly use the term, this legal framework has several provisions for an integrated approach to seed system development, meaning that it allows for the co-existence of formal and informal seed systems. For example, under article 13 of the regulation, both traditional varieties grown on commercial scale and new varieties proposed for release by the VRC can be notified (and thus released). In addition: "Any farmer shall be allowed to engage in small-scale exchange and local sale of their traditional varieties, if the varieties for exchange or sale are not covered under article 13." Bhutan does not have and is not planning to develop an overall Seed Policy.

Discussion

The volume of seeds produced and distributed by NSC (tables 3 and 4) is not sufficient to meet the annual demand for seed for farmers in Bhutan. Considering for example rice, the total area harvested in 2022 was 9179 hectares (Statistical yearbook 2023). Assuming a seed need of 100 kg per hectare this requires >900 thousand kgs of paddy seed, while the supply from NSC the same year was about 40 thousand kg, thus only about 4% of the total need. This discrepancy can be explained by a high share of farm-saved seed for crops like rice in Bhutan. The farm-saved seeds are both of local varieties and improved ones that are recycled. The share of farm-saved seeds is higher for self-pollinating crops than for outcrossing crops. NSC itself estimates that they meet 5% of annual seed requirement for rice, 20% for maize and 80% for vegetables.

Seed dissemination is largely a public sector affair in Bhutan. The NSC is today a public company and there are no plans for privatization at this point. The NSC was for some years "corporatized" under the name Druk Seeds Corporation (DSC), but this was not a commercial success and the government resumed ownership and responsibility of NSC again in March 2010. The dual mandate of NSC requires it to be both a commercially viable seed company and to supply seeds according to demand and at affordable prices all over the country. There is widespread agreement that need-based price subsidy for seeds is an important social protection policy in Bhutan. At the same time, all actors agree that it is a constant challenge to strike a balance between the commercial and the social mandate of NSC. This is a challenge for NSC itself as their economic room of maneuver (for innovating and expanding for example) is very limited. And it is also seen as an obstacle to a larger involvement of the private sector in the seed market in Bhutan.

The private seed companies are critical to the way the current seed market functions and expressed hope for a more private sector-friendly system under the 13th five-year plan: *"The overall policy for private company involvement in the seed system is not good: NSC sells seed at subsidised rates, even vegetable seeds, so it is very difficult for a private company to find a market. In the new (13th five-year plan) this company has applied for vegetable and temperate fruit market shares."* (KII BAS).

It is important to note that none of the informants, neither from the private or the public sector, suggested that NSC should be entirely privatized or that all seed subsidies should be ended. It is commonly agreed that for the staple crops, especially the cereals, there is general agreement that there is a very limited potential for a fully commercial market, while for vegetable seeds and fruit plants larger involvement of the private sector is desirable: *"The NSC has a social mandate and therefore also a cereal mandate. The private sector has expressed their wish to take the vegetable market and that will also be the policy. DoA also says fruits can be done by the private sector. But at the same time, it is clear that NSC does some vegetables and that ARDC Wengkhar has a fruit mandate so this leaves the question if practice follows policy on this."* (KII DoA, MoAL). This tension in the question of sharing of responsibility between the public and private sector is further explained by the MoAL Legal division: *"Currently, the government centrally decides seed prices, but there's a debate on whether this should continue or if prices should be determined by demand and supply."* The MoAL informants noted that they have had hearings and consultations with the private sector to discuss how to achieve more efficient sharing of responsibilities and markets.

For the private sector to take over a crop group currently managed by the public sector they will have to present an investment plan.

The informants in MoAL expressed that it is important to retain flexibility in the law to find a balance between subsidies for affordable inputs on the one hand and maintaining functional markets for the private sector on the other hand. The informants suggested that these decisions should be policy-based rather than law-based to allow for flexible governance also in the future. It was also mentioned that there is substantial collaboration between the public and private sector already today. For example, NSC and BFDA have supported the private sector with seed testing at the regional lab in Bajo.

Different reasons are given for why the private sector should be granted more responsibility for the vegetable and fruit seed market. At one level, this is a political question. As one private sector informant put it, he *"believes in free market and competition"*. In this perspective, the private sector is better able to offer a diversity of seed choices and respond to farmers' demands. Another informant from the private sector indicated that the public seed dissemination modality is rather inaccessible to farmers unless they are on the list of the AEOs for all crops he/she need: *the farmer will have to go to gewog in formal dress. It should be in a shop that is easy for them to go and buy where they can also get other tools and pesticides etc."* Also, one of the NGO informants formulated a critique of the way the government distributes seeds - both in terms of who they reach (and don't reach) and with what quality seed and at what time. The private sector informant expressed that he considers it a "farmers' right" to have easier access to a larger diversity of varieties than what is currently the case for most farmers in Bhutan. More in line with the international definition of farmers' rights is the same informant's view on seed saving: *"Some seeds they can save themselves, but others are difficult to produce and they need public or private seed companies to develop and produce seed for them."* (KII BAS). Basically, none of the informants from the public or the private sector indicated that farmers' use, saving, exchange or even sale of seeds should be restricted.

Both ARDC and NSC informants acknowledge that there are challenges with their seed distribution. The public systems to solicit and forecast seed demand is quite rigid and several informants express a need for creating a more flexible and demand-oriented system. The low varietal turnover and the low seed replacement rate indicate a need to look at ways to reform the current system. Capacity and know-how is an issue also when it comes to seed dissemination. The CNR informant said that due to lack of teaching capacity, the college is no longer able to offer courses in agricultural economics and related fields that could help in this reform.

In summary, the main modality for seed dissemination will according to the MoAL continue as it is also in the 13th five-year plan, but with more space for the private sector in vegetable seed and fruit planting material.

Landrace of black rice and yardlong bean in Chirang, Bhutan. Photo: NMBU

4 SEED SYSTEM OUTCOMES: THE VIEW FROM THE GROUND

Here we present findings from the local seed system characterization, with the aim to examine farmers' seed security situation in selected gewogs. Considering farmers' perspectives on the suitability of the varieties they cultivate, as well as the availability, quality and access to seed provides a measure of how well the seed system analyzed in the previous chapter is meeting farmers' needs and preferences. Results presented here are based on FGDs with 111 men and women farmers. It is not a representative sample of all farming communities and environments in the country, but a snapshot of the diversity in selected areas.

In the sections that follow we first describe some key features of the cropping system (e.g., crops considered most important, changes in crops cultivated, and main agricultural problems), and then present finding about the local seed systems, including varietal suitability, seed quality, seed availability and seed access.

4.1 Crop diversity and production

To explore the significance and use of crop diversity in the local communities, FGD participants were asked to identify the 10 most important crops in their gewog and select 2-3 "key crops" for seed security analysis. A total of 34 crops were identified across the 10 FGDs, including a range of staple crops (11), legumes (9), vegetables (7), fruits (4) and spices/stimulants (3). Staple crops such as maize, rice, potato, sweet buckwheat, and finger millet, as well as chili, cole crops and other vegetables were among the most frequently cited crops (Table 7).

Most of the staple crops are appreciated for multiple uses, playing key roles in food security, for cultural or ritual purposes, and as feed or fiber. The most frequently cited staples (maize, rice, potato, and sweet buckwheat) are also sold for income generation in some localities. Special dishes like "cheurra" (beaten rice) and "torm" (ritual cakes made from wheat and barley) are used in different rituals. In some FGDs, farmers spoke of the cultural and ritual significance of crops like rice and sweet barley as part of the "Dru-na-gu", the Nine Fundamental Crops. The Dru-na-gu usually consists of rice, wheat, barley, peas, sweet and bitter buckwheat, millet (several species), mustard, and soybeans (Dorji, Tamang and Vernoy, 2015). Maize is also commonly included in the Dru-na-gu and used in various rituals and ceremonies. These crops have vital significance in Bhutanese culture and tradition, playing an integral part in various religious rituals like Rimdro, a ritualistic action that is practiced for purposes such as adverting negative forces and eliminating various adversaries, healing illness, prolonging life span, bringing well-being to individuals, families, society, country, and all sentient beings, etc.

Crops in the remaining categories (legumes, vegetables, fruits, spices, and stimulants) were mainly cited due to their value for household consumption, fodder, and, depending on the locality, for income generation, but some also bear cultural significance. For example, chili was the most frequently cited crop, being valued for its rich culinary practice as a vegetable and spice as well as being an important source of income in some gewogs. In Bumdeling, farmers explained that they plant it "for the happiness, if we do not have chili in our diet, we do not feel happy". Other crops like ginger, turnip and perilla, have important ritual, medicinal or cultural uses (Table 7). For instance, the dried green leaves of turnip, called "lom", are associated with the highlanders and form an integral part of their crop-culture-cuisine, being used together with sweet buckwheat to prepare a special dish called "hyontyo". Legumes were mentioned in gewogs like Orong, Singye, Mendrelgang, and Samar, for their values in household consumption and fodder, and in some cases for income generation. In Singye, farmers also highlighted the long storage life of beans and black gram, as well as the use of soybean, one of the Nine Fundamental Crops, in the preparation of fermented products called "kinama". Despite these values, no legume was selected as a key crop in the FGDs, with participants focusing instead on crops that provide

an important source of income like chili, ginger, cole crops, orange, mandarin, areca nut, and cardamom.

When asked about gender differences in the importance of crops, responses were varied. In Bongo Gewog, participants felt that crops such as maize, sweet buckwheat and millets being equally important for both genders, due to their values in preparing different culturally important dishes, which was echoed in several other FGDs. In many gewogs, however, participants pointed out characteristics of certain crops that were particularly valued by women or men, often related to gendered division of labour. For example, the FGDs often emphasized men's roles as providing for the family and identified cash crops like citrus, areca nut, chile and ginger being of particular importance to them for their economic importance. Women on the other hand often highlighted the important role they play in food preparation, noting the certain crops like potato and spinach as being quick and easy to prepare, which is important in managing busy schedules, as well as certain foods being like potato and peas being preferred by children. Nonetheless, this general trend did not always hold. For example, in Bumdeling, participants noted that men appreciate chili since they are responsible for preparing food for rituals during mass gatherings. Some groups also considered certain cash crops to be equally important to men and women, such as orange in Wangphu, the sale of which "meets one year's expenditure". Some FGDs noted that women are responsible for marketing certain crops or products like vegetables and local wine brewed from finger millet. In one gewog, participants explained that men are "shy" to sell vegetables and are more involved in marketing crops like potato that provide larger sums at one time, whereas women focus more on "sustainability" of income throughout the year.

4.1.1 Drivers of change in crop diversity

To understand some of the factors driving crop choice, farmers were asked to identify crops in their gewog whose cultivation had increased or decreased in the last ten years and discuss reasons behind these changes.

Market forces and government programs were among the most common factors driving increased cultivation area of certain crops. For example, crops like ginger, areca nut, avocado, and vegetables have increased in many gewogs, driven mostly by their market value which is higher per unit compared to other crops. Vegetable crops have also been promoted through government programs, and over 128 vegetable varieties have been released in the last decades in Bhutan (see 3.1.4). The impact of this can be observed in the increase in cultivation area under vegetable crops in almost all the studied sites. Furthermore, nearly all FGDs mentioned the new introduction of high-value fruit trees, that have been promoted by government programmes, most notably the Million Fruit Tree Plantation Programme (see 3.1.6). Other new crops identified in certain gewogs are quinoa and dragon fruit, both of which have been promoted by government initiatives in recent years, with new varieties of both crops released in 2018 and 2017 respectively (ARID, 2023). While government programs make these varieties available, some FGD participants also point to farmers' own self-interest and inquisitiveness leading to the adoption of these new crops.

Table 8. Crops identified as most important by participants of the 10 FGDs.

Crop		Frequency *	Importance rating §										Key crop ¤	Reasons considered important by farmers
			1	2	3	4	5	6	7	8	9	10		
Staples	Maize	8	4	2	2								5	Household consumption, special dishes (sip/flattened bread), rituals, animal feed, and sale/income generation.
	Rice	7	6		1								7	Household consumption, special dishes like "churra" (beaten rice), rituals. Straw used as forage for animals and weaving mats. Source of income.
	Potato	6	1	4		1							3	Household consumption and/or income generation, depending on the gewog
	Sweet buckwheat	6	2		2	2							1	A "food and traditional security" crop, used for some special dishes like putta, khuley, hyontyo, and in rituals. Also used as cattle feed and for income generation in some gewog.
	Finger millet	4	3								1		2	Food security crop with uses as pancake, brewing local wine. Cultivated at higher elevation where there are no rice fields, also due to lower pest incidence. But in some localities such as Bongo, cultivation is declining as other foods are more available.
	Barley	3	1		1	1								Torm making, kaapchi, local beverages, cattle feed
	Bitter buckwheat	3	1	1	1								**	Khuli and consumption
	Wheat	3	1	1	1								1	Torm making, kaapchi, local beverages, cattle feed
	Foxtail millet	1	1										1	Only mentioned in Bongo, where use has declined due to availability of other foods.
	Quinoa	1			1									Cash crop (Kabisa)
	Sorghum	1					1							Snacks (Bongo)

Crop		Frequency *	Importance rating §										Key crop ¤	Reasons considered important by farmers
			1	2	3	4	5	6	7	8	9	10		
Legumes	Beans	3		1		2								Household consumption/fodder (Orong) and in Singye for income generation. Long storage life
	Black gram	2				1	1							Household consumption/fodder (Orong) and in Singye for income generation. Long storage life
	Kidney bean	2		1		1								Household/fodder (Orong) and in Mendrelgang main source of income.
	Mung bean	2		1		1								Household/fodder (Orong) and in Mendrelgang also for sale
	Soybean	2				1				1				Household consumption, preparation fermented producted (kinama), fodder
	Cowpea	1				1								Household consumption, fodder (Orong)
	Pea	1				1								Household consumption, fodder (Orong)
	Pigeon pea	1				1								Household consumption, fodder (Orong)
	Rice bean	1				1								Household consumption, fodder (Orong)
Vegetable & oil crops	Chili	8	2	3	2	1							2	Household consumption, and culinary uses; in some gewogs it is an important or main source of income.
	Mustard	5	2				2					1		Household consumption (greens) and for oil extraction
	Vegetable crops	5		2	1	1			1					Household consumption and in many places for income generation. Considered an easy cash earner in case of emergency
	Cole crops (broccoli, cabbage, cauliflower)	4	2		1		1						1	Cash crop, also used for household consumption
	Radish	2		1	1									Household use and sold on the local market (Kabjisa)
	Turnip	2	1		1								1	Household use and sold on the local market (Kabjisa). Used in Samar for hyontyo (with sweet buckwheat), important as livestock feed
Fruits	Bananas	2						1		1				Household consumption and/or income generation
	Guava	1									1			Household consumption
	Mandarin	1	1					2					1	Cash crop. In Bongo it had died out but slowly coming back

Crop		Frequency *	Importance rating §										Key crop ¤	Reasons considered important by farmers
			1	2	3	4	5	6	7	8	9	10		
Spices & stimulants	Ginger	3	1			1	1						1	Cash crop, for export. Also has culinary, medicinal and ritual uses, being one of the most required items in times of performing Pawo (local ritual/spiritual practices)
	Areca nut	2	1	1									2	Cash crop, low labour demand. Also used for household consumption
	Large cardamom	1							1				1	Cash crop in Sangbay and Bongo, but in the latter gewog has declined in importance.
	Perilla	1				1								Ritual, nutrition security

*The number of FGDs mentioning the key crop as one of the 10 most important crops in their gewog.
§The number of FGDs assigning the importance rating to the crop, where 1=most important and 10=least important.
¤Number of FGDs that selected the crop as a key crop for seed system analysis.
**Bitter buckwheat was not selected as a key crop for seed security analysis but in Bongo the FGD participants decided to conduct the four-cell analysis for this crop (see section 4.3 on varietal suitability).

Generally, we observe a trend of increasing cultivation of economically valuable crops at the expense of culturally important food crops as expressed in this quote "The open grain market with India has been accompanied with a shift in diets away from some traditional crops towards rice. The new diet is 90% rice. This means national self-sufficiency in this crop has decreased to 47% from earlier full self-sufficiency.» (NCR KII). Farmers from gewogs such as Orong, Kabjisa, Senggye and Wangphu explain that the shift towards crops like cole and chili has adversely affected the cultivation of local varieties of a range of food crops including maize, rice, foxtail millet, barley, chile, and peach. In all study sites farmers report that cereal crops have decreased in cultivation area, including culturally important crops such as rice, millets, buckwheats, maize, barley, and wheat, and a few also mention declines in legumes, oil crops, and some vegetables like radish and turnip. Farmers in many FGDs attribute the declines in these crops to factors such as depredation of crops by wild animals, labour shortages, bans on shifting cultivation, and lack of irrigation water for paddy that discourage production of these crops. In addition, economic factors like the lack of value addition and market development for cereal crops, the availability of cheaper imports of rice and oil from India, or the conversion of land to other crops like areca nut and cole also play a role, as do changes in food habits which have led to reduced consumption of millets and buckwheats in some areas. As described in the previous section, many crops are valued for their cultural significance, and in some FGDs farmers mentioned specific varieties of potato, wheat and rice that have increased in recent years due to cultural preferences and market demand (see 4.2.4). In Sombaykha Gewog, for example, changes in food habits have led to increased cultivation of some rice varieties. There are also some government programs helping to counter the trend of declining cultivation of culturally important crops. For example, in Bongo Gewog, farmers note that maize, sweet buckwheat, and foxtail millet have increased in cultivation area in certain parts of the gewog (Zamsa). Although they explain this based on their importance as staple crops, this also appears to be due to the efforts of an initiative to reintroduce foxtail millet in this gewog through NUS project. Similarly, an initiative of National Centre for Organic Agriculture (NCOA) has resulted in increase in cultivation area of adzuki beans in Samar Gewog.

Adverse effects of climate change was cited by many communities as causing losses in crop production and driving changes in cropping patterns. For example, in 2021 hailstorms and heavy rain affected harvested paddy and resulted in the loss of many tons of rice. Erratic weather patterns, dry spells, delayed rainfall, and shortage of irrigation for rice and other crops. This is especially the case in Phuntshothang where windstorms, erratic rainfall and pests and diseases have led to declines in both rainfed and irrigated paddy. As a response to changing and unpredictable climatic conditions, farmers of Wangphu Gewog have increased the area under cultivation for upland paddy, a strategy that the Bhutanese government has been promoting since upland rice requires minimal water. Higher pest and disease incidence is also commonly cited as negatively affecting a number of crops. In Sombaykha, for example, cardamom wilt and citrus greening are serious problems leading to major declines in these tree crops, while new pests such as fall army worm are affecting maize. Depredation of crops by wild animals such as wild boars, bears, monkeys, porcupines, birds, golden langurs, and rodents-squirrels is another biophysical driver of crop change. FGD farmers reported that seed potatoes are dug by wild boars, rice is eaten by rodents before harvest, squirrels attack immature areca nuts.

Overall, change in crop diversity in Bhutan is driven by both push and pull factors, including economic opportunities and government programs that encourage cultivation of certain crops, combined with socio-economic (e.g. labour shortages, food habits), environmental policies (e.g. ban on shifting cultivation), and biophysical factors (human-wildlife conflicts, climate change, pests and diseases).

4.2 Seed security for key crops

In this section we examine the seed sources used by farmers, as well as their assessment of the quality, availability and accessibility of these sources (pillars of seed security). We then examine varietal suitability. In the FGDs, the analysis focused on seed sources used for key crops selected in each FGD (Table 7), although

in some gewogs seed sources were discussed without specifying the key crop.

4.2.1 Seed sources used by farmers

In the FGDs, the most commonly identified seed sources included their own saved seeds, farmer to farmer seed exchange, seeds supplied by the Gewog Agriculture Extension officers and through the ASSRs. Some of the communities also received seeds through various programmes under the ARDCs, NCOA and from the national programme like Million Fruit Tree Plantation Programme, while in Samdrup Jongkhar farmers indicated that they sometimes accessed seeds through Samdrup Jongkhar Initiative (SJI), a non-governmental organization (NGO). In a few instances other sources were mentioned, such as local seed dealers (farmers who produce and sell seed in the local market) as well as seed obtained from other gewogs or dzongkhags.

Overall, farmers generally rated their own saved seed as the most important source for most crops, except vegetables. Reasons for using farm-saved seed varied from trust in seed that farmers select themselves and preference for local varieties (e.g., local wheat in Samar Gewog which farmers there in general find more reliable, adapted to the local conditions and better tasting). Farmers also noted the lack of alternative seed sources for some seeds (e.g., sweet buckwheat in Sombaykha and areca nut in Singgye), whereas in other cases, problems with the availability of seed from government sources were noted (see 4.2.3 further below).

Despite this general trend, several other seed sources are used and appreciated, especially for cash crops like cole and potato where improved varieties are cultivated. When variety preferences shift, also sources tend to shift. For example, in Kabijsa, farmers listed ASSRs as the most important source for hybrid seed of cole crops, whereas in Bumdeling farmers rely primarily on ARDSC-Kangma as a source of high-yielding potato varieties. Farmers in these two communities noted that they have shifted seed sources for these two crops, driven by changing varietal preferences. These appear to be driven especially by campaigns run by government and NGO programs. In Kabijsa farmers have begun to plant hybrid seed for cole crops instead of the open-pollinated varieties they cultivated in the past, citing superior quality and size, which fetches a better price in the market. Similarly, farmers of Phuntshothang Gewog have begun using hybrid vegetable seeds, promoted by the NGO SJI. Similar shifts in varietal preferences are seen in potato, where local cultivars have been replaced by the popular Yusi maap variety since its release in 2017 by the National Potato Program based at NCOA. The seed potatoes are distributed by the extension agents as well as by the Research Centres as a part of promotional program. In both gewogs farmers indicated that they tried producing the seed of these improved varieties themselves. In the case of potato, many farmers are now maintaining the tubers themselves, although they only obtain higher yields the first year, whereas for cole crops farmers in Kabijsa continue to rely on seed purchased from ASSRs as it is not possible to produce their own seed as the varieties are hybrids.

Apart from these two major commodities, only a few other crops have seen a slight change in seed sources. For instance, since 2013 farmers in Wangphu have accessed orange seedlings from ARDC-Wengkhar whereas finger millet seeds have been obtained by farmers in Bumdeling from trials run by ARDSC-Khangma as part of a project on neglected and underutilized crops, and from NCOA Yusipang by farmers in Bongo. However, own saved seed continues to be the major source for these crops.

These findings are generally consistent with national trends reported in Gyelthsen's 2022 survey, which found that the majority of households rely on own saved seed for cereal crops whereas extension agents, and ASSRs or other market sources are more commonly used to for vegetables and oil crops (Figure 7).

4.2.2 Seed quality

Here we discuss farmers' assessment of the quality of seeds obtained from different sources. In most FGDs, farmers rated their own saved seeds as excellent quality and preferred this seed over other sources. A common explanation was "because we ourselves do the selection". Some farmers explained specific practices to ensure good quality, for instance in Bongo farmers explained that it was important to select seed in the field, with one participant adding: "I will keep

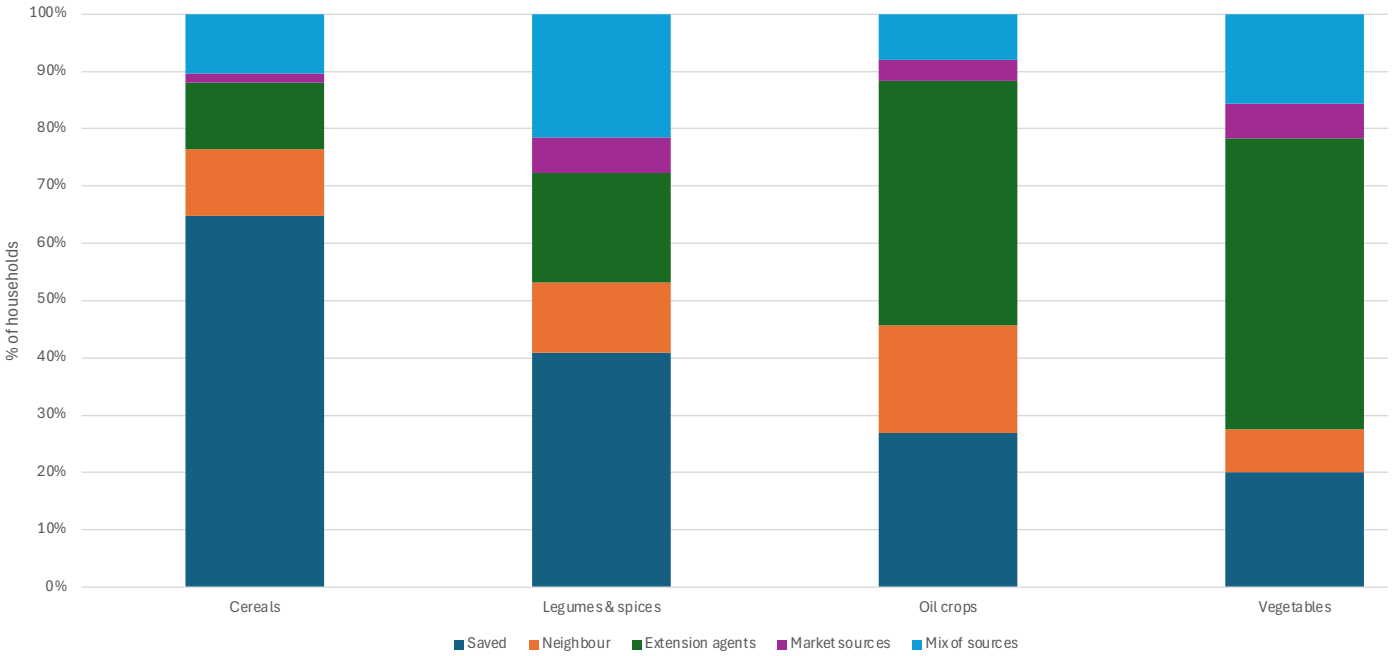

Figure 8. Seed sources used by Bhutanese farming households by crop category. Source: Data from Gyelthsen (2022), based on a representative national survey of 355 households in Bhutan. Sample size by crop category: cereal crops (n=310), legumes and spices (n=303), oil crops (n=164) and vegetables (n=345). Note that in this data set potato was considered a vegetable crop.

only the middle one, remove the borders and [those that are] black at the base".

Ratings of the quality of other sources tended to be lower, particularly seed obtained from neighbors. Indeed, eight out of 10 communities raised concerns about the quality of seeds obtained from their neighbors, explaining that seeds are often mixed or of lower quality as compared to their own saved seeds. Some expressed that this was because neighbors keep the best seeds for themselves and only offered those kept for consumption and explained this as a trust issue. However, farmers in two gewogs had more positive perceptions of the seed obtained from neighbors, explaining that they relied on their immediate neighbors, whom they considered "trusted and accountable" and that seed from neighbors is well adapted to their local conditions as it is from the same locality and altitude. In this sense, farmers in Orong noted that seed obtained from farmers in other gewogs, even if nearby, is considered a "last resort".

Regarding seeds obtained through formal system, farmers' assessment of quality varied. In some gewogs, farmers expressed trust in the quality of seeds obtained from government and NGO sources. For instance in Orong, farmers indicated that the government (NSC) provides certified and quality seeds for cole crops and fruits. Others noted the positive varietal qualities of improved varieties, such as orange seedlings provided by ARDC Wengkhar (see 4.2.4). Nonetheless, in a number of FGDs, farmers rated seed from formal sources to be at par or below as compared to their own saved seeds. In some cases this appears to be due to varietal preferences rather than physical or physiological quality of the seed. For instance, in Samar Gewog, farmers rated turnip seed obtained from NCOA Yusipang to be "poor", due to its long shape that they do not like (see 4.2.4). Similarly, in Singgye, farmers indicated that rice seed from extension agents "may be good, but we would still prefer our own seed", likely due to preference for traits of local varieties compared to the improved variety Bhur Kamja 1 (see Appendix 1). In Kabijsa farmers noted quality issues such as low germination and variable maturation with seed purchased from ASSRs, which is the main source for cole crops. In Mendrelgang farmers expressed that commission agents are "second in reliability and trust" compared to their "local seed dealer", a farmer who produces and sells bean seeds in the local market.

Seed production and storage: Although farmers generally expressed confidence in their own farm-saved seeds, they also identified some challenges in seed production and storage at household level. In terms of seed production, some of the most common issues in seed production were related to pests, diseases and weather patterns. For example, farmers in Senggye Gewog experience challenges growing and selection of healthy areca nut seedlings due to the incidence of pests and diseases in their nursery, while in Sombaykha production of cardamom production is heavily impacted by wilt. In Samar, root maggots and fungal diseases affect turnip seed production, for which local extension agents have recommended crop rotation. A few communities also mention untimely rainfall at harvest time as issues for cereal crops such as maize, finger millet and buckwheat. Farmers in Sombaykha explain that in the case of buckwheat this can lead to important losses: Zani di phara zha, sen tabni ya metho bay (forget about keeping for consumption, we do not even get any seed).

Bhutanese farmers usually do not have separate seed plot unless they are registered seed growers or community-based seed producers. Seeds are either selected by marking the best plants in the field and harvesting them separately or by keeping seeds selected from the harvest. Both selection methods were mentioned in the FGDs, and in most cases were viewed as unproblematic. However, in a few gewogs farmers indicated the need to improve their knowledge and skills in selection. For example, in discussing maize seed production, farmers in Wangphu explained: "We do not have a good understanding of the scientific aspect. We do not select from the field. We keep them in bulk and select only at the time of sowing". In a few FGDs, farmers indicated that seed selection is difficult as it requires experience. In Bumdeling for instance, participants explained that for millet: "Women select good and big heads. The problem is if we do not select good head by the experienced women." Lack of knowledge for production of vegetable seeds was also a concern in some groups, which some said led to dependence on government sources.

In a few cases limitations in land or other resources were found to be constraints. For instance, in Kabijsa, farmers mentioned that lack of land was a problem for producing chile seed, as the paddy season coincides with chili maturity, while in Wangphu farmers pointed out: "We have to do nursery raising of orange outside in the normal field condition, which takes many years. So, this is a challenge. However, if we had a greenhouse and other facilities, then we might be able to get seedlings faster."

Seed storage problems appear to be a major concern among farmers, being mentioned in all 10 gewogs, especially for crops like potato, maize and rice. Storage conditions are particularly challenging in the gewogs located in wet and humid subtropical regions. For instance, in Senggye farmers note: "we are not able to store seeds for a longer period due to storage pests and high humidity and temperature", while in Phuntshothang, participants explain that "quality seed production and management of potato is problematic and burdensome" due to the climate and agroecology. However, farmers at higher elevations also experience difficulties in storing seeds of crops like potato, maize, millet, wheat and buckwheat, pointing to inadequate storage facilities and problems with pests and diseases. Many FGDs indicate that they rely mainly on traditional knowledge and facilities for storing seeds (such as jute sacks and wooden boxes) and that these are susceptible to pests and diseases. For example, in Bumdeling, farmers explain that millet seeds are "kept in bora (sacks), so they are infested by rodents and fungus, because of no proper aeration". Similarly, in Samar, which is located in the cool temperate zone, farmers have no problem in storing wheat, but for potato they said they have "no good storage", leading to sprouting and attacks by rodents of tubers that they otherwise consider to be "good and clean". Nearly all gewogs that selected rice, maize and potato as their key crop mentioned storage problems with these crops. In some cases, farmers noted that specific varieties were more susceptible, such as the improved maize variety Yangtsipa which farmers in Bongo note is more susceptible to weevils compared to the local white maize variety. Some farmers observe that these problems are increasing. For instance, in Wangphu farmers said that storage pests for beans was not seen in the past as it is today. In Sombaykha, farmers attribute problems to climate change, and suggest that new knowledge is needed: "Before, our parents used to do. We used to keep in the traditional way.

But with the increase in climate change, we see a lot of problems, so we may not have the knowledge to take good care of seed storage."

While these challenges in seed production and storage do not seem to affect farmers' ratings of the quality of their own saved seed, which they generally considered excellent, they are reflected in their assessment of the availability of seed, discussed in the next section.

4.2.3 Seed availability

In the FGDs, farmers were asked to assess whether seed was always, sometimes or rarely available in sufficient quantities at planting time. In general, farmers rated their own saved seeds as "always available" irrespective of crop type. Farmers stated that they are mindful of the quantity that they need next year, so they save enough seeds, and it is a reliable source of seeds for them. However, shortages were noted for some crops, in cases where farmers' seed production is affected by diseases or other problems. This is the case of wilt which has caused severe shortages of cardamom seedlings in Sombaykha, and problems with diseases and poor seedling growth in areca nut nurseries in Senggye (although this does not seem to be a problem in Phuntshothang, where farmers indicate that areca nut is "always available due to mass production as it remains always as a dominant sources of income generation"). Similarly farmers in Sombakha indicated that shortages of buckwheat seed sometimes occur, while in Wangphu orange seedlings are sometimes in short supply, presumably due to the production challenges discussed above (untimely rains and lack of infrastructure, respectively).

Other seed sources are generally considered more uncertain in terms of availability than own-saved seed. This includes seed from neighbors, which in most FGDs was rated as only "sometimes available", since neighbors only sell or exchange seeds when they have a surplus. For some crops, such as orange in Wangphu, neighbors are said to only rarely have seedlings to share, which as mentioned above is often insufficient even for own use. In Phuntshothang, farmers explained that this also occurred at times for staple crops like rice, when wild animal attacks and extreme weather events damaged paddy seedlings. In such situations they indicate that "every household makes first priority to plant their own source of seedling and then secondly sources from the neighbors, but sometimes it is rarely available in sufficient quantity".

Seed obtained from research centres, extension agents, and ASSRs were invariably rated as "sometimes" or "rarely" available, which in some cases appear to be linked to bottlenecks in the formal seed system. For example, in Singgye participants indicate that interested farmers do not submit their seed quantity requirements for improved maize seed to the extension agent, whereas in Kabijsa farmers explain that "despite giving the demand for the seed, the seed does not reach on time and less in quantity" to the ASSR/commission agent. Farmers in Mendrelgang also note that vegetable seed is often not available on time, and also consider mandarin seedlings only "sometimes available" as they depend on nursery growers. In several FGDs, farmers rated seed provided by ARDCs and extension officers to be limited in quantity. An example is given by farmers in Samar, who explain that the availability of the improved potato variety, Yusi maap, was initially limited as extension officers only provided small amounts to one "progressive farmer" who multiplied and sold the seed to others. Availability has since improved as farmers began accessing and maintaining their own seed. Nonetheless, they point out that the process took many years, and that extension should provide seed to at least 10 farmers for more rapid dissemination in the community. At the same time, farmers in Samar note how seed of certain varieties have become more scarce in their communities, including, for example, seed of local potato varieties that have been displaced by Yusi maap, as well as the improved wheat variety Sonalika that they used to grow years ago but is no longer supplied by the government due to susceptibility to rust.

4.2.4 Seed access

In terms of seed security, seed access refers to having the means to obtain seed as well as information related to the seed. Means of access can refer to cash, credit, social relations, or other. According to the FGD participants, seed is accessed from neighbors or relatives through a range of different transaction types, including cash, exchange of seed, labour exchange, loan, and barter. Gift was also mentioned in one FGD,

but in general seed appears to be accessed primarily through some kind of exchange of cash or goods. For instance, in Wangphu, orange seedlings can be bought from neighbors at a rate of BTN 100 per seedling, or through labor exchange at a rate of three seedlings for one day of labor. In Phuntshothang participants explained that when seed is obtained through loan, the terms are negotiated between the farmers; a loan of two dreys[4] of seed could be repaid for example with three drey, where the additional drey is an interest on top of the principle amount. Farmers also explained that these exchanges of seed through social networks is a source not only of seed, but also of new varieties, as illustrated by the dissemination of Yusi maap in Samar Gewog. In Bumdeling, farmers also explained that the rice variety Machum was introduced to their community by a relative who brought it from another dzongkhag and exchanged it for their local rice.

Seed from ASSRs, commission agents and other commercial actors (nurseries, local seed dealers) is purchased, but from government sources (extension agents, research centres) it is often obtained either for free or at a subsidized rates (see chapter 3.5). For example, farmers in Senggye mention that they buy improved maize seed from extension agents at a subsidized rate of BTN 30/kg. The one NGO identified in this study that distributes seed also does so for free.

Generally, FGD participants indicated that members of their communities do not have difficulty in accessing seed, as they rely either on their own stocks or else on their social networks. As farmers in Orong explain: "There is no difficulty, as we share seeds to those who don't have, free of cost, and even if we don't have the seeds, we provide information about those who do". In the literature, cost is often a barrier for smallholder farmers to access certified seed, however, the fact that government agencies provide seed for free makes it more accessible. In Wangphu, farmers considered that government distribution was in fact more equitable than access through social networks: "Some farmers may not know how to produce orange seedlings and they also may not have money to buy from neighbors. When government brings there is balanced and equal distribution". However, in some cases, participants indicated that farmers must travel to the extension office to obtain seed, and that this could be difficult for some: "People who are far from the gewog extension office has difficulty getting seed as they have to travel long distance."

Farmers shared several local customs and beliefs that influence their seed use. The most commonly mentioned beliefs relate to specific days which are considered good for sowing, drying or storing seed as well as to giving, acquire or purchase seed. Some also mentioned beliefs about certain crops that are considered bad luck. Many variations were shared but this explanation from Phuntshothang is representative:

Jack fruit tree is considered a bad omen because its roots spreading in front of one's house is not good and feasible. People seeing jack fruit bearing trees may have a short life or be struck with sudden misfortunes. Even papaya cultivation in front of the house is deemed as not good. Planting mango is not considered good as per oral account of the past because the one who planted it will have a short life once bountiful fruits been harvested and taken.

Providing or sharing seeds especially on Tuesday and Friday is prohibited due to Yangza (Lucky or good merits days of the week). Insect days are on 3rd, 9th, 19th day of the Bhutanese lunar calendar and no sowing or cultivation can happen on this particular day. If done on this particular day, a lot of pests and diseases outbreaks could happen in the village.

These local customs and beliefs are all based on past ancestors and families' oral accounts and presentations passed down from generation to generation. But with the passage of time and space, this evolving trend of stories and culture are slowly dying because of education and technological perspectives of young and inquisitive minds of these generations.

4 1 drey=1.5 to 1.8 kg

4.2.5 Varietal suitability

Varietal suitability refers to the extent to which available crop varieties are adapted to farmers' growing conditions and have traits that correspond to farming households' agronomic, culinary, market, cultural or other preferences. We assessed varietal suitability using Four-Cell Analysis. FGD participants first listed the varieties cultivated in their gewog for each key crop, and then categorized each variety into one of four cells, based on the number of households that cultivate the variety, and land area that is usually dedicated to that variety. This was done using a matrix in which cell 1 was "large area, many households", cell 2 was "large area, few households", cell 3 was "small area, many households", and cell 4 was "small area, few households". Participants were also given the option to place varieties no longer or very rarely cultivated in a fifth cell. They then discussed the distribution of the varieties in their gewog, identifying traits considered both positive and negative. Finally, FGD participants were asked to consider their overall satisfaction with the varieties they currently have and whether they perceived a need for other varieties with different traits. It is important to note that the varieties were identified with local names only; we did not conduct field surveys nor collect samples to characterize the varieties. The data therefore do not provide a precise measure of varietal diversity in the study sites, but rather generate insight into farmers' self-expressed needs and preferences in terms of varieties.

Table 9. Summary of varieties identified in the four-cell analysis for 16 key crops.

Key Crop		# FGDs that analyzed the crop	# varieties identified			
			Local	Improved	unknown	Total
Staples	Rice	7	39	6	1	**46**
	Maize	4	12	4		**16**
	Finger millet	1	5	1		**6**
	Potato	3	3	2	1	**6**
	Wheat	1	4		1	**5**
	Bitter buckwheat	1	2			**2**
	Foxtail millet	1	2			**2**
	Sweet buckwheat	2	1			**1**
Vegetables	Chili	2	10		2	**12**
	Cole crops	1		5		**5**
	Turnip	1	1	1		**2**
	Ginger	1	1			**1**
Fruits	Orange	1	1	1		**2**
	Mandarin	1			1	**1**
Spices & stimulants	Cardamom	1		3*		**3**
	Areca nut	2			1	**1**
Total			**81**	**20**	**7**	**111**

*These are local cardamom varieties that have been registered and released in Bhutan.

A total of 111 varieties were identified for the 16 key crops analyzed by the FGD participants (Table 8). Rice, maize, and chili were the crops with the largest number of varieties identified, followed by potato, finger millet and wheat. Based on the local names, we estimate that the large majority (73%) are farmers' varieties (landraces). Nonetheless, all the FGDs identified at least one improved variety; these included varieties of rice, maize, potato, finger millet, cole crops, turnip, and orange (Table 8). Some of these improved varieties are circulating within the informal seed system, being saved and exchanged among farmers. Some varieties appear to have been obtained from adaptation trails that extension services carry out with farmers. For example, the rice variety farmers in Bumdeling call "ang 11" (meaning "number 11") likely refers to the number assigned to it during an adaptation trial. Similarly, farmers in Mendrelgang identified a maize variety they simply call "popcorn". They indicate that they obtained this variety from extension services, however no popcorn varieties have been released in Bhutan, although some have been tested for adaptation. It is therefore likely that farmers saved seed of this variety from an adaptation trial and have continued to produce and exchange the seed. In the following sections we discuss farmers' assessment of the suitability of both local and improved varieties by key crop.

Rice: Rice was selected as a key crop in 7 of 10 FGDs, and participants identified between two and 11 rice varieties per gewog. As a key food crop with high cultural significance (one of the Nine Fundamental Crops), culinary traits such as cooking quality, expansion upon cooking, taste, aroma, use in special dishes featured prominently in farmers' assessment of the varieties. Agronomic traits were also commonly discussed, including local adaption, grain yield, straw yield/quality, height, lodging habit, susceptibility to pests/diseases, water requirement, cycle length, as well as characteristics important in post-harvest handling such as threshability, milling recovery, and ease in sorting. Market value was mentioned for a few varieties but seemed generally less salient to farmers than other traits. Of the 46 rice varieties identified, 14 of these are cultivated in "large areas, by many households", indicating that they are dominant varieties in their localities. Many of these were noted primarily for their good taste and aroma, with farmers also noting some positive agronomic traits, but also some negative ones. For example, in Phuntshothang Gewog, farmers noted that the variety Khamti dhan is aromatic, soft, and easy to thresh, requires less irrigation water and is thus less labour intensive, and has good market value, but its taller height makes is susceptible to lodging (Annex 1). Only one of the dominant rice varieties was considered to have negative culinary profile. This was the variety called Dolangdep in Bumdeling Gewog, which farmers considered "not that tasty" but is commonly grown due to its adaptability to high elevations. A further 13 varieties were classified as being cultivated in "large areas by few households" (7 varieties) or "small areas by many households" (6 varieties). Farmers' assessment of these varieties follows the same overall trend as those in cell 1, with positive traits being especially linked to culinary attributes, such as taste, aroma and several are used for special dishes like making zaw (roasted rice), sip (pounded rice), or torm (ritual cakes). A few varieties are also noted for good agronomic traits (e.g., non-lodging, early maturity or wind resistance), but many of the varieties in this group have disadvantages like low yield, poor threshability, or high water requirements. For instance, in Kabijsa the variety Ngap ja is scented, with good eating quality and used for making zaw, but has low yield. A few varieties that are planted in small areas by many households also have negative culinary qualities, and this becomes even more common among the least cultivated varieties (produced in "small areas by few households"). Examples are varieties like Jacham which has a good taste but becomes blackened when cooked, Ap dhan and Bet kuti dhan that are non-aromatic, and Fauday as well as the improved varieties Bhur kamja 1 and Khangma maap that have hard grains, that are difficult to thresh or not preferred for eating. These often have other positive agronomic, post-harvest or use traits (e.g. Bet kuti dhan has good milling recovery and straw quality, and Bhur kamja 1 is drought tolerant), but the overall trend emphasizes the importance of culinary qualities. A few of the other less cultivated varieties do have good taste but have other challenges. For example, Mashino dhan has good taste and is preferred for making mats due to its soft straw, but is late maturing, lodges easily and

is burdensome to sort. It is interesting to note that of the six improved rice varieties identified in the FGDs, only one (Zhungray) is reported to be widely planted ("large area, many households" in Sombaykha), while the others are planted only in small areas, and mostly by few households. Although farmers in some gewogs expressed satisfaction the varieties they grow, others indicated that they are not satisfied, and would like to try other varieties.

Maize: FGDs in five gewogs selected maize as a key crop and together identified a total of varieties, with the number per gewog ranging from three to five (Annex 1). Four of these are improved varieties. Like with rice, participants emphasized the uses of the varieties for different foods as well as other uses like staking or fodder, as well as agronomic and post-harvest management traits. Market value was only mentioned for one variety. Six maize varieties were classified as dominant ("large area, many households") in at least one of the gewogs. Of these, five are local varieties that are appreciated for their good taste and use in preparing dishes like kharang (grits) and tengma (beaten maize). The variety Kaap is also mixed with rice or popped, and is resistant to weevils, while the variety called Sethi in Senggye tolerates gray leafspot, while in Mendrelgang farmers note this varieties' multipurpose use, including for fodder. The two dominant varieties identified in Wangphu also have some drawbacks: Bayulpa asham being late maturing and Nepala asham tending to lodge due to its tall height. The sixth variety in this group is the improved variety Yantshepa and is the most widely grown maize variety identified by the FGDs, being mentioned in all five gewogs. In Bongo, it is only grown by few households in small areas, having only recently been introduced but in all other gewogs it is grown in large areas. Farmers appreciate this variety for large cob size and yield, good milling recovery, as well as the strong, wind resistant stalk that can be used as staking. However, several FGDs mention that its kernel is hard, which is not preferred for kharang, and that its tall height makes Yantshepa susceptible to lodging and the cobs are difficult to reach at harvest. Despite these drawbacks, Yantshepa is still a main variety in four of the gewogs (planted by few households in Wangphu and Mendrelgang, and by many households in Senggye and Orong). Another improved variety, Chaskharpa, is a main variety for some households in Senggye, due to its suitability for mid-altitudes. Six further maize varieties are only planted in small areas. Two of these are planted by many households, and in the case of Tsalu asham this appears to be due to its specific adaptation to high altitudes of Wangphu Gewog where it is considered to provide good yields. The remaining four varieties are only cultivated by few households, and some of these have quite specific uses. This includes two varieties of popcorn (Munang or Gupi ashom from Wangphu and the "popcorn" obtained from the adaptation trial in Mendrelgang) as well as the variety Phophora ashom from Orong that is tasty and aromatic in roasted form and easy to prepare and take when in haste. Farmers note that these varieties are all low yielding but given their specific uses they are perhaps not required in large quantities. Nonetheless in Mendrelgang, FGD participants mentioned also that there is no market for the popcorn variety, suggesting that this also limits its cultivation. In Mendrelgang, farmers also include in this group the improved variety Ashom serbu, which they appreciate for kharang and tengma as well as high yield and low water requirement but is susceptible to pests and diseases. Finally, farmers identified three local varieties of maize the are no longer or rarely cultivated in their gewogs (two in Orong and one in Bongo). They did not specify the reason, but in Orong the farmers note that the varieties are still available from other localities, and thus may have disadvantages that discourage farmers from planting them. No comments were recorded in any of the FGDs about the overall satisfaction with the maize varieties.

Potato: Potato was selected as a key crop by farmers in three of the temperate zone gewogs (Orong, Bumdeling and Samar). Each FGD identified three potato varieties in their gewog, for a total of six varieties overall, although one of these, called Joktang balingmie in Orong, was said to be no longer cultivated. Of the other five varieties, we note a clear distinction in farmers' appreciation of the values of improved and local varieties. On the one hand, the four local varieties are valued for their good taste and flavour but have the drawbacks of lower yields and/or late maturation. On the other hand, the improved varieties Desiree (called Joktang taslu in Orong) and Yusi maap are valued for their high yields but are not considered very tasty. In both Orong and Samar, the improved

varieties dominate (cultivated in large areas by many households), while the local varieties are produced only in small areas by few households. Farmers in Orong explain that Desiree has good market value, which seems to be the main reason that it is more widely cultivated than the tastier local variety Jamu joktang. Indeed, both Desiree and Yusi maap are red-skinned varieties that are preferred by the general Bhutanese population over the local white-skinned varieties, which has led to displacement of local varieties. Markets also influence varietal choice in Bumdeling where FGD participants mention that the least cultivated variety Local kaap has no buyers. However, here the variety Local maap is widely cultivated (large area, many households), followed by Yusi maap (large area, few households). FGD participants in both Bumdeling and Samar express a lack of satisfaction with their potato varieties and indicate a desire to try others. Farmers in Orong did not comment on this, but they did indicate that both varieties they grow are susceptible to pests and diseases, while the third one is lost.

Wheat: Wheat was only analyzed in Samar Gewog, located in the cool temperate agro-ecological zone. FGD participants in Samar identified five varieties, four of which are local. These are all noted to be good for flour and making ritual cakes (torm), and indeed better for this use than wheat imported from India, as well as being free from pests. This contrasts with the fifth variety, Zhung kaa, which is high yielding, but susceptible to army worm. In terms of distribution, two of the local varieties (Jama kaa and Jo) are widely grown (large area many households), whereas the other two (Byo kaa and Kaa chungku) are only grown by a few households in small areas. Farmers explain that the variety Jo has increased in cultivation area due to its usage as "kaapchi" (roasted wheat flour) in rituals. Zhung kaa is grown in small areas by many households, which appears to be a strategy to minimize risk given its susceptibility to army worm, while still benefitting from its good yields. Farmers in Samar expressed interest accessing other varieties, indicating that they are not fully satisfied with their current varieties.

Millets: In Bumdeling Gewog, FGD participants identified six varieties of finger millet, which they describe primarily in terms of colour of the grain and seed coat, and the length and openness of the fingers. The main variety is a dark-grained local variety called Khoshomo khray, that is cultivated in large areas by many households, whereas the other five are only grown in small areas. This includes the improved variety Membja1 (locally called Chakhrela or Faramla) and four local varieties, with varying characteristics. For example, Membja1 is noted for its wide adaptability, while the local variety Prangpo matures early, within three months, and Tshiksumpa has closed, tight fingers. The only negative trait noted is for the variety Chambura which tastes a bit sour. Farmers from this FGD also expressed interest in trying other varieties of finger millet. In Bongo, farmers note that millet used to be the most important crop, but this has declined in recent years due to the availability of other foods. Nonetheless, FGD participants chose foxtail millet as a key crop, in part due a NUS project that has been trying to revive the cultivation of this crop. Farmers in Bongo identified two varieties of foxtail millet. The first is Setho membja, cultivated as a winter crop by many households in large areas, has high yield and is considered good for making drengo (a cooked dough flattened with a pestle), while the poorer yielding Jhatho membja is only cultivated by some households in small areas, and used for producing bangchang (a fermented beverage).

Buckwheats: In Bongo, FGD participants mentioned two varieties of bitter buckwheat, Bjo kaap that is less bitter and widely grown for food, and Bjo maap that is more bitter and grown only by some households in small areas for producing alcohol. In both Bongo and Sombaykha, sweet buckwheat is widely cultivated for making a range of traditional dishes like derengo (thick porridge), putta (noodles) and khuli (pancake), however they only have one variety that they simply call Geray, meaning sweet buckwheat. Farmers in Sombaykha expressed the desire to have access to other

Vegetables: Chili, cole crops and ginger are all important cash crops in the Gewogs where they were analysed, though chili and ginger also have important cultural values, as does turnip in Samar (see 4.2). Although 12 varieties of chili were identified in Kabjisa and Orong Gewogs, only three of these were reported to be planted in large areas, mostly due to their productivity and market value. In Kabijsa, the

main variety (Wookup ema) can be produced in the off-season and harvested fresh at the peak of the rainy season, when fields start being prepared with rice. Most of the other chili varieties are produced on a smaller scale for both household consumption and sale, some of these being very hot and spicy. While the 12 chili varieties from Kabjisa and Orong are all local, all five of the cole crop varieties identified in Kabijsa are all improved, appreciated for high yields, and in the case of the cabbage Copenhagen market, for its early maturation, and tight head. In Samar, farmers report having two varieties of turnip. One of these, Yusipang endo, is an improved variety but is much less popular that the local variety due to its long radish-like root, which is not preferred. Farmers here express interest in trying other varieties of turnip if available. In Phuntshothang, farmers do not have any specific variety name for the ginger they cultivate, but they indicate they are satisfied with it, even if they note that ginger requires frequent rotation and is difficult to store.

Fruits: Two varieties of orange are grown in small areas in Wangphu: a local variety and an improved variety that farmers have obtained from Wengkhar ARDC since 2013. The shape of this improved variety allows farmers to pack more oranges in the boxes they are sold in, making the transport cheaper, nonetheless, it is only cultivated by few households, whereas many households produce the local variety. Mandarin is produced in large areas by many households in Mendrelgang. Farmers do not have any specific variety name for mandarin, but note that although it produced well, with large, sweet fruit, it is difficult to harvest due to its dense canopy and susceptible to pests like trunk borer.

Spices and stimulants: Farmers in Sombaykha identified three local varieties of cardamom that have been registered and released in Bhutan. Two of these are susceptible to pests and diseases, farmers express a need to access other varieties if possible. In Phuntshothang, areca nut does not have any variety name, and farmers report being generally are satisfied with it, although there are challenges in general with human-wildlife conflict for this crop.

Rice landrace varieties inspected by NBC in Daga, Bhutan. Photo: NMBU

5 TOWARDS RESILIENT AND INCLUSIVE SEED SYSTEMS IN BHUTAN

The research presented in this report was informed by a launch workshop held in Tsirang in October 2022 and validated during a Round Table Meeting held at the same place in October 2024. These two meetings were attended by key seed system actors at both national and local levels. Inputs from the meetings are integral to the results presented in the preceding chapters. The inclusion of stakeholders from across seed system functions at both the beginning and end of the research phase added an important temporal dimension to our analysis. The meetings brought together stakeholders with different functional mandates in the seed systems and their perspectives on their role and linkages with other actors evolved over the period from inception to validation and project co-development. In this final chapter, we present the results of a cross-linkage exercise done at the launch workshop and discuss this in relation to the research findings. Finally, we present an overview of the project proposal co-developed by all actors at the Round Table Meeting at the end of the research phase.

5.1 Perceived and actual cross linkages

During the launch workshop in 2022, the seed system stakeholders present were engaged in a group work exercise to solicit perceptions of the relative contribution and dependence of pairs of actors in the seed system. The groups were asked to score (from 0 to 3) the relative contribution and dependence of one actor against another. The aggregate result of this perception ranking is presented in figure 7.

The actors in the upper right corner of the diagram are perceived as both making a relatively high contribution to other actors and being relatively highly dependent on others. It is notable that the four public organizations with clearly defined mandates within conservation, variety development, seed production and dissemination all are found in this upper right square. Two other conspicuous features of figure 7 is the relatively low ranking of farmers' contribution to other actors and the high contribution score of

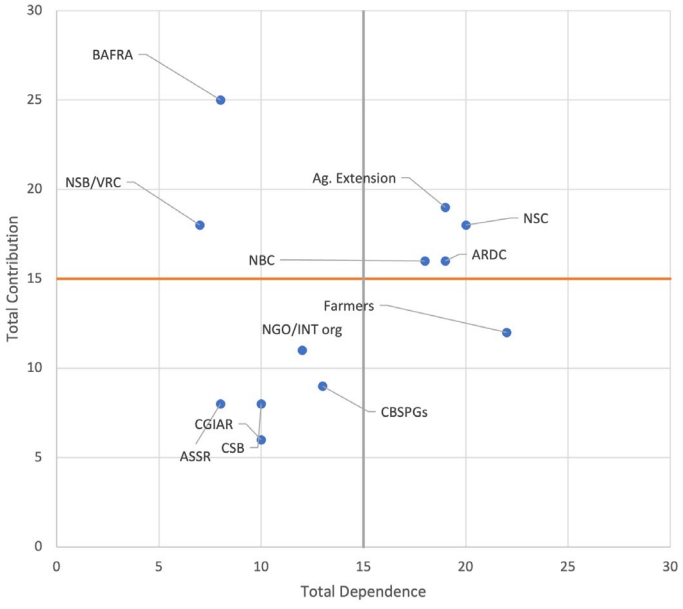

Figure 9. Aggregate results from a cross-linkage contribution perception exercise held among participants of the launch workshop in 2022.

BAFRA (now BFDA). The former could indicate a lack of appreciation of farmer participation in R4D and the latter show a high perceived importance of seed quality assurance among participants.

Considering figure 7 in relation to the research results it is interesting to see that NBC clusters with the big players in the formal seed system, the ARDC, NSC and the Dzongka Ag Extension. This central role of NBC is quite special in an international context. There is often a disconnect between PGRFA conservation and the formal seed system (Westengen et al., 2018) and the relatively strong linkages in Bhutan between NBC and ARDC are therefore noteworthy. As discussed at length above, the research phase showed that the working relationship between ARDC, NSC and the Extension service is very good, although there are many challenges with matching supply with demand along the entire chain from EGS to truthfully labelled seed production.

While the strong connection between the four seed system actors in the upper right corner corresponds well with the research findings, the perceived importance of formal seed certification was not confirmed during the research phase. The former BAFRA has played a limited role in EGS seed quality assurance and in certified seed production for certain crops and markets, but the majority of the seeds used in Bhutan are farm saved and even for the proportion produced and distributed to farmers by the formal system, the majority is truthfully labelled and thus not formally certified. On the other hand, it seems farmer involvement in the research and evaluation phase is more widespread and streamlined than perceived by actors participating in this cross-linkage exercise at the beginning of the research. Another set of actors appearing as relatively less important in figure 7, is the heterogenous cluster of CGIAR centres, CSBs, CSPGs and ASSRs. The clustering in the lower left corner of the ASSRs corresponds with the research finding that farmers hardly used these centers for other inputs than fertilizer. Similarly, this location of the CSBs corresponds with the reported difficulty organizations have had with establishing well-functioning CSBs in Bhutan. The location of the CGIAR in this lower left corner is however not entirely warranted seen in light of the research presented here. Several CGIAR centres have been and are working with the ARDC, inter-alia introducing improved varieties for evaluation. The perceived low contribution may stem from the fact that some centers have been more important collaborators in the past than they are currently. Finally, in relation to figure 7, it is important to point out that the research phase elicited a number of important actors not included in the cross-linkage exercise at the launch workshop. Organizations like CNR, the RSGs, and the private seed companies and nurseries emerged as key actors from the research. Their continued and potentially larger role in Bhutan's seed systems going forward is reflected in their inclusion in the co-developed project proposal.

5.2 A proposal to strengthen seed systems and seed security in Bhutan

Following the validation of the research findings, the participants at the Roundtable Meeting engaged in co-developing a proposal to address the challenges identified. The proposal has the following general two-fold objective: i) Increase farmers' access to diverse, quality planting materials; ii) Strengthen the linkages and capacity among seed system actors, including the national genebank. Activities were clustered into three outputs: 1) Participatory variety evaluation, release and management; 2) Participatory seed production and dissemination; 3) Strengthen collaboration and capacity among seed system actors. The project leadership will sit with the Department of Agriculture. A task force consisting of members from ARDC, NBC, NSC and CNR have led the proposal development following the Round Table Meeting. Below we present a summary of the activities proposed under each output.

5.2.1 Participatory variety evaluation, release and management

This component aims to evaluate and release farmer-preferred varieties to improve adoption rates and productivity in four target districts (Samtse, Sarpang, Tsirang, and Mongar). FGDs with farmers and agriculture extension officers, four-cell analysis and tricot experiments will be conducted. These activities will help to understand the farmer-preferred traits

and also the distribution and diversity of rice and maize varieties.

Purification and characterization (morphological and molecular) of popular rice and maize varieties (identified from the above activities) will be conducted at ARDCs after sourcing seeds from farming communities, national genebank and ARDCs. Farmer preferred varieties that are not yet in the national catalogue will be registered so seed production can commence.

5.2.2 Participatory seed production and dissemination

This component is proposed to enhance seed production systems and ensure the timely dissemination of quality seeds to farmers by developing standard practices and strengthening institutional coordination. The interventions are targeted at priority crops like rice, maize, quinoa, broccoli, cauliflower, beans, tomato, and onions in line with the 13th FYP of Bhutan.

In synchrony with national plans, seeds of prioritized crop species will be made available through developing Packages of Practices (PoP) for seed production by engaging crop specialists within the country. The existing PoPs for crops are for production purposes, which don't serve quality seed production adequately. Hence, specialists, seed technologists, and researchers will be engaged to develop PoPs for the identified crops. To strengthen farmers', private seed nurseries', and RSGs' capacity for quality seed production, training programs will be organized using PoPs on seed production.

One of the findings in the research phase was the low penetration of the formal seed system. This is partly because of the lack of information on the availability of seeds from NSC and private nurseries. Hence, an advocacy program through developing a seed app, through which growers can place seed demand and seed producers can share the inventory of seed availability, will be developed using app developers in Bhutan.

For timely dissemination and to enhance accessibility to seeds, existing facilities and infrastructure will be assessed and upgraded. This will include improvements in seed processing units, storage facilities, and nursery areas. The NSC, RSGs, and private seed producers, including organic seed producers, will scale up production based on demand forecasts. The project will also work with the intermediary seed system actors CSBs and CBSPGs to increase their capacity in seed production and dissemination. Seed accessibility and service delivery will be enhanced by improving the logistics and distribution systems and strengthening extension services for remote areas.

5.2.3 Strengthen collaboration and capacity among seed system actors

The proposed project will strengthen linkages and address capacity-building needs among seed system actors. Hands-on training of seed technicians of the NSC, BFDA quality inspectors, and producers will be carried out to produce disease-free seeds and seedlings of identified crops. Members of CBSPGs and RSGs under NSC will be trained on quality seed production based on the PoPs developed under the previous output.

Capacity building on hybrid seed production is also considered an important step to develop competitive hybrid varieties of Bhutanese vegetables. Thus, in collaboration with CNR, selected researchers and seed technicians will be trained in modern technologies to develop hybrids. Beyond that, extension officials from Mongar and Tsirang will be trained in hybrid maize production. After the training, the project will facilitate the hybrid development of selected vegetables.

Furthermore, Bhutan needs expertise in plant breeding and genetics to contribute to strengthening the formal seed system in the country, which currently has very weak penetration. To make our seed system more sustainable and resilient, a long-term study (Master's/PhD) opportunity for one candidate is planned in plant breeding and genetics at CNR in collaboration with NMBU. Such an investment will be a long-term asset to the seed system in Bhutan.

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Annex 1: Key informant interviews and focus group discussions by date

Interview no	FGD Sites/KII Organizations	Date
KII1	National Seed Center	22.03.2023
KII2	Bhutan Alpine Seed	22.03.2023
FGD1	Farmers of Tsento Gewog/AEO/Paro DAO	23.03.2023
KII3	Department of Agriculture	23.03.2023
KII4	BFDA	24.03.2023
KII5	NCOA	24.03.2023
KII6	ARDC Bajo	24.03.2023
KII7	CNR	25.03.2023
KII8	Bumthang CSB/DAO/AEO	26.03.2023
KII9	RSG of Tang for Radish	26.03.2023
KII10	ARDSC Lingmethang	27.03.2023
KII11	ARDC Wengkhar	28.03.2023
KII12	NSC-Regional Officer Trashi Yangtse	28.03.2023
KII13	ARDSC Khangma	29.03.2023
KII14	Legal Division MOAL	31.03.2023
KII15	Tarayana Foundation	31.03.2023
KII16	Bhutan Agro-Industry	04.01.2023
KII17	Reva Seeds	04.03.2023
KII18	Phasooma and Zamsa Chiwog farmers under Bongo Gewog	05.02.2023
KII19	Bongo Gewog Extension	05.05.2023
KII20	Food Corporation of Bhutan	05.04.2023
FGD2	Tshangkha Farmers	06.10.2023
KII21	ARDSC Tsirang	05.01.2023
FGD3	Mendelgang farmers	05.02.2023
KII22	ARDC Samteling	05.03.2023
FGD4	Singye farmers	05.04.2023
FGD5	Kabjisa farmers	13.06.2023
FGD6	Samar farmers	06.09.2023
FGD7	Sangbay farmers	06.12.2023
KII23	Haa Dzongkhag Extension	15.06.2023
KII24	Trashiyangtse Dzongkhag Extension	15.09.2023
FGD8	Bumdeling farmers	14.09.2023
FGD9	Wangphu farmers	18.09.2023
KII25	Gomdar CSB	19.09.2023
KII26	NSC Bajo Region	24.03.2023
KII27	Samdrup Jongkhar Initiative	21.09.2023
FGD10	Bongo farmers	05.02.2023
FGD11	Orong farmers	16.09.2023
FGD12	Phuntshothang farmers	19.09.2023

Annex 2: Four-cell analysis results

This annex is provided as a separate supplementary file.