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Executive Summary

Women's position and roles in seed systems in Nepal are seldom studied, even though women are believed to have a wealth of knowledge on seed selection and preservation, particularly in the production of maize and wheat, major staple grains in isolated mountain communities. Women's role in maize and wheat agriculture includes a range of tasks, some critical, but men make major decisions regarding cropping system management, including choice of variety to sow. It is important to explore women's access to seed amid increasing male out-migration and the associated feminization of agriculture the gendered prejudices and constraints that women farmers and household heads face. Based on the FAO's household seed security assessment framework, this study documents gender issues in maize and wheat seed systems for 250 households and three castes/ethnicities in two mountain-area municipalities during 2021, with a focus on the availability, suitability, and quality seed, as well as social norms and gender-disaggregated constraints. We found that maize and wheat farmers in the municipalities studied were "seed insecure," that men still held decision-making power over crop variety choices despite women's prominent role in maize and wheat seed management and preservation, and that policies in Nepal should promote: (1) improved formal seed systems and strict seed quality standards; (2) informal seed supply chains that are critical for many farmers and particularly when disasters strike; (3) official recognition of women's role in managing seed; and (4) community-based seed banks in which women may participate and gain agency.

Keywords: Seed system, seed security, maize, wheat, mountain, Nepal

Preface

With the increasing global population and the growing demand for healthy and culturally appropriate food, it is important to reassess the prevalent global agri-food systems. Redesigned and a renewed commitment to resilience and inclusion is needed, in the face of climatic risk and epidemics, including human health risks and plant disease outbreaks. Food insecurity, malnutrition, poverty, and social and gender injustice have worsened the situation further, highlighting the need to redouble our efforts to achieve the UN Sustainable Development Goals.

The Sustainable Agrifood Systems (SAS) Program at CIMMYT generates social and agricultural innovations, cutting-edge agricultural technologies and has an abiding commitment to sustainable, inclusive approaches to agricultural research for development. The prevailing biases faced by youth and women in agriculture, along with minorities and aging agricultural populations, are bottlenecks to resilient and equitable development. CIMMYT strives to bring together other CGIAR scientists, academics, public, private sectors, and civil society to tackle the wicked problems of food and nutrition insecurity and climatic risks.

A foundation for SAS is equitable access to quality seeds that addresses the needs and preferences of farming communities. This includes women, youths, and marginalized farmers, who seek means to increase productivity, adapt to climate change, for equitable and inclusive development that reduces the number of people under destitution through increasing access to ample and nutritious food. Access to quality seed is highly gendered, as is household and community seed security. This paper importantly insights into how to improve seed security equitably in Nepal and contribute to #BreakTheBias in agriculture, within and beyond families, and thus towards gender equality in agriculture and rural development.

Sieglinde Snapp,

Director, Sustainable Agrifood Systems Program (SAS)

International Maize and Wheat Improvement Center (CIMMYT)

Contents

1. Introduction

Women are normally engaged in informal and subsistence types of seed security systems and have limited access to quality seed and lack mobility. Also, they hold limited decision-making in the family and participate little in formal seed systems (Adam et al. 2019; Galiè et al. 2017; Kandiwa et al. 2018), which results in low farm productivity and income. In contrast, a gender-responsive household seed security system could foster the recognition of women's preferences and interests. Access to quality seed, for example, enhances farm productivity and helps in women's empowerment through achieving higher crop productivity and recognizing their diverse varietal preferences. For example, women look for shorter maize varieties for cultivation than taller varieties.

Agricultural income is pivotal to livelihoods and poverty alleviation in agriculture-based developing countries such as Nepal. Women in rural areas of Nepal spend most of their time in farming, mainly seed production, whereas men majorly make decisions (Bajracharya et al. 2016). Though the government of Nepal has launched various policies, strategies, plans and programs aimed at mainstreaming gender-awareness in agriculture (FAO, 2019), the situation of women has hardly changed. Women play a crucial role in saving seeds and maintaining seed security but often have limited access to certified seed (Bawa et al. 2014; Madin, 2020) and their poor economic condition is another major constraint (Bawa et al. 2014). Together with rice, maize and wheat are the world's major cereals and are the second- and third-most cultivated staples in Nepal (Awika, 2011), anchoring many farming systems and contributing significantly to food security and livelihoods. In Nepal, maize is grown on over 0.9 million ha with an annual production of about 2.7 million t (MOAD, 2018), while wheat is grown on over 0.7 million ha with a yearly production of about 2.0 million t (MoALD, 2020).

More than 80% of Nepal's maize is grown in the hills and mountains (MOAD, 2018) with yields far below the national average (1.19 t/ha). Wheat farming is widespread in the lowland, Terai region of Nepal and wheat thrives in the Terai's warm climate, but it is also an important crop for smallholder farmers in the mountain environments, despite there being less favorable for cereal production. Inadequate supplies and inferior seed quality further hinders maize and wheat production. The remoteness of mountain regions limits the access to improved and suitable varieties, adequate seed storage systems, or government support (Gauchan, 2017; Wyss et al. 2018) and insect pests further reduce the quality and quantity of smallholder farmers' crops (Munyaka et al. 2015), affecting households' food security and seed security.

A relatively new concept, household seed security denotes timely access to enough of the right type of quality seed for crop production to support household food security, livelihoods, and resilience in the face of extreme or erratic weather and disasters in general (Sperling, 2006; Sperling and McGuire, 2012). Seeds and food security are linked in that quality seed is a must for increased yields (Bellon et al. 2003), but seed-secure households may be food insecure and food-secure households may be seed insecure. Seed stocks and food stocks are different and affected differently by lower production and other shocks. A production shortfall might induce food insecurity but not always result in a lack of seed to sow; for most crops, a tiny proportion of the harvest is enough for the seed stock (McGuire and Sperling, 2011) and seed can be accessed readily from informal

channels such as neighbors, friends, or relatives through borrowing or bartering grain and goods. Seed access channels also include community seed banks, agro dealers, local markets and sometimes government sources or non-governmental organizations (NGOs). Even though the literature on seed security is not as mature as that on food security, a growing number of regional and country-level studies on seed security are available (Amir 2020; Husenov et al. 2021; Khan and Shrestha, 2020; Shrestha and Gauchan, 2020). Seed security is an aspect of seed systems that can go beyond seeds and households, whereas seed systems capture broader concepts of the process to achieve seed security.

The International Center for Tropical Agriculture (CIAT) has listed three seed security pillars: availability, accessibility, and quality (Sperling et al., 2006). FAO's seed security assessment framework has provided 5 broader pillars of seed security: seed access, seed availability, seed suitability, seed quality, and resilience (FAO, 2016). Seed systems connote the process and the enabling environment that support households to become seed secure. Moreover, the seed system resilience is a socio-ecological system (McGuire and Sperling, 2013; Kansiime and Mastenbroek, 2016) and goes beyond the household level to include seed accessibility, availability, suitability, quality, and resilience (seed flow channels and networks).

Seed security contributes significantly to the food security and livelihoods of mountain communities, given that food production, improved crop yields, and the availability of preferred food varieties depend on the availability of quality seed (Setimela et al. 2004; Pelmer, 2005). Farming households may interact with multiple seed systems to become seed secure; an integrated seed system that involves both the formal and informal seed sectors is ideal to achieve seed security (Wekunda, 2012). Farming households are seed secure only if the seed systems are well recognized and fully established to deliver the seed and crop traits needed for increased production, nutritional gains, and farming system resilience (McGuire and Sperling, 2016). We posit that maize and wheat seed systems in the mountain region have a significant bias in gender and social inclusion and observed biases are in the household decision-making and participation in seed related training.

The maize and wheat seed systems in the mountain would benefit from the greater involvement of women, but development initiatives have seldom considered gender issues. Women face difficulties in seed accessibility and the most vital are the insufficient capital and land (Bawa et al. 2014). This study seeks to answer questions like: What roles do women play in maize and wheat seed systems in the mountains of Nepal? What are the major constraints for women to partake in seed systems, and how do the existing gender and social norms play a role? We need such information to better understand households' seed security status and their resiliency for future risks.

Seed systems in Nepal

There is a high demand for improved seed but a wide gap exists between supply and demand in South Asian countries (Shrestha and Gauchan, 2020), including Nepal. Nepal enacted Seed Act 1988 (amendment 2008) and seed production guidelines 1998 as the initial legal framework for seed production and its supply chain management (Gairhe et al. 2021). The country has a National Seed Policy 1999, Community Seed Bank Guidelines 2009, Seed Regulation 2013 in place, and at present, the National Seed Vision 2013-2025, intended to streamline national seed sector

development (Gairhe et al. 2021). The legal documents initially focused more on seed production and supply chain management, through the active engagement of the public sector in the seed system. However, after the 2000s, the government emphasized private sector and community-based organizations in seed system development, albeit with limited geographies and commodities and despite the fact that 90% of the national seed requirement of farmers (Adhikari, 2014) is met by informal, local seed systems (home saving, exchange, sharing, purchase from local markets) and the seed replacement rate, an indicator of the field use of improved, good quality seed, is minimal (<10%), especially in the hills and mountains (Gauchan, 2019). A recent study, however, stated that the formal seed sector (government and private companies) provides up to 20% of Nepal's cereal crops seed requirements (Devkota and Shrestha, 2020).

The informal seed sector is the primary source of crop varieties and also of knowledge for many smallholder farmers (Otieno et al. 2016; Hussain et al., 2017). Informal seed sources are not only the seed providers but also an exchange of traditional knowledge on farming for improved production (Kiwanuka and Kintu, 2004). Loss of local varieties leads to the erosion of genetic diversity, affecting seed and food security. Some scholars (Jamieson et al. 2016; Devkota et al. 2014) have recommended storing seeds in homes and acknowledged the role of seed exchange to conserve local crop biodiversity. When farmers cannot afford the seeds from the formal seed system, they instead seek to access seeds from the farmer's seed system (Kiwanuka and Kintu, 2004). In Nepal, prior studies (Gairhe et al. 2021, Timsina et al. 2016) stated a domination of the formal seed systems for maize seed, especially in the terai and hills. In contrast, KC et al. (2015) stated <10% contribution of the formal seed systems (Agrovets) to the total households' cereal crop seeds requirement. However, with wheat, most farmers store seeds at home. Sulaiman and Andini (2013) stated that households used 85% of the total wheat seeds and the remaining 15% either stored for the next season, consumed, or exchanged.

Seed quality is the very first prerequisite for healthy crops, good yields and food security (Khan and Shrestha, 2020). Using improved quality seeds alone can cause 20-30% increase in yields (Devkota and Shrestha, 2020). Purchase of a low-quality seed is risky for marginalized farmers, because it compromises harvests, leading to food and income insecurity (Templer and Kariuki, 2016). Farmers in remote villages and those owning small marginal lands have limited access to the formal seed sector (Fredenburg, 2015). Prior studies suggest proper seed testing and certification to support farmers to avoid the use of inferior seeds (Manggoel et al. 2021). However, lack of a quality check in the seeds sector in developing countries (Kugbei et al. 2005; Sperling and Katungi, 2011) including Nepal, is a major issue.

Government policies limit the participation of private seed companies in breeder and foundation seed production; companies are more involved in producing 'certified' and 'labelled' vegetable seed and hybrid crop varieties, mainly for urban and peri-urban markets. Nevertheless, the private sector plays a significant role in maize and wheat seed supply in Nepal --- approximately 85% and 67%, respectively (Shrestha, 2012; Gauchan, 2017). Hybrid seed of maize are majorly imported (Adhikari, 2014). The quality of imported seed is not always satisfactory and, at the same time, households' access to it is minimal. The lack of timely access to affordable, quality seed is severe in mountain

and other remote areas because of challenging geography, the dominance of the informal seed systems, and very low seed replacement rates.

In addition to the issues outlined above, given increasing male out-migration and the resulting "feminization" of Nepali agriculture, wherein women often assume the leadership of farm activities, it is important to explore gendered prejudices and constraints that affect their access to seed (Gartaula et al. 2010; Kelkar, 2010). This study thus aims to document gender issues in maize and wheat seed systems in the mountains of Nepal and specifically to (1) assess the availability, accessibility, suitability, and quality of the maize and wheat seed; (2) assess households' maize and wheat seed security; and (3) document social norms and gender-disaggregated constraints to maize and wheat seed security.

2. Study framework

Particularly in developing countries, women's contribution to agriculture and the rural economy is important. Women make up a large percentage of the agricultural labor force and their involvement has increased in recent decades, as they have shouldered responsibility for household survival and responding to economic opportunities through farming (Lastarria-Cornhiel, 2008). Approximately 60% of the global women make up the agricultural workforce, yet, six out of ten women live with food insecurity (Furey, 2021), and in Nepal agriculture employs more than 80% of women (FAO, 2019). Women employment in the agricultural sector is much more essential for their empowerment than men (FAO, 2011). However, women's contribution to the economy, agriculture labor, and overall rural development has not been recognized in prior research and development programs. Many scholars and development programs still wrongly perceive activities of women. For example, varietal seed selection, producing agriculture crops, following specific farming systems, tending animals, working for wages in agriculture, carrying the agriculture produce to the market and other rural enterprises as not "economically active" employment. Hence, this thought eventually led to gendered policies development projects. Ultimately, gendered policy favored new technologies, innovations, recommendations, and faulty and unscientific seed supply systems, all leading to gender-unfriendly conclusions. For nearly 15 years, Nepal Agriculture Research Council (NARC) and Hill Maize Research Project (HMRP) developed technologies and innovative practices for maize and wheat farming in Nepal. We are in the Anthropocene epoch, frequent arrival of climate-induced disasters is common, and poor and marginalized people, including women, are supposed to be the most affected. We designed this study with a focus on the FAO's household seed security assessment framework (FAO 2016): seed availability, seed accessibility, seed suitability, seed quality and resilience (Figure 1); where we included the women's agency because women are more of a concern in terms of household seed security and excluding them from the analysis could insecure households from the crop seeds. For example, the probability of adoption of improved wheat varieties decreases by 11% for male dominated households as compared to female household heads (Subedi et al. 2019).

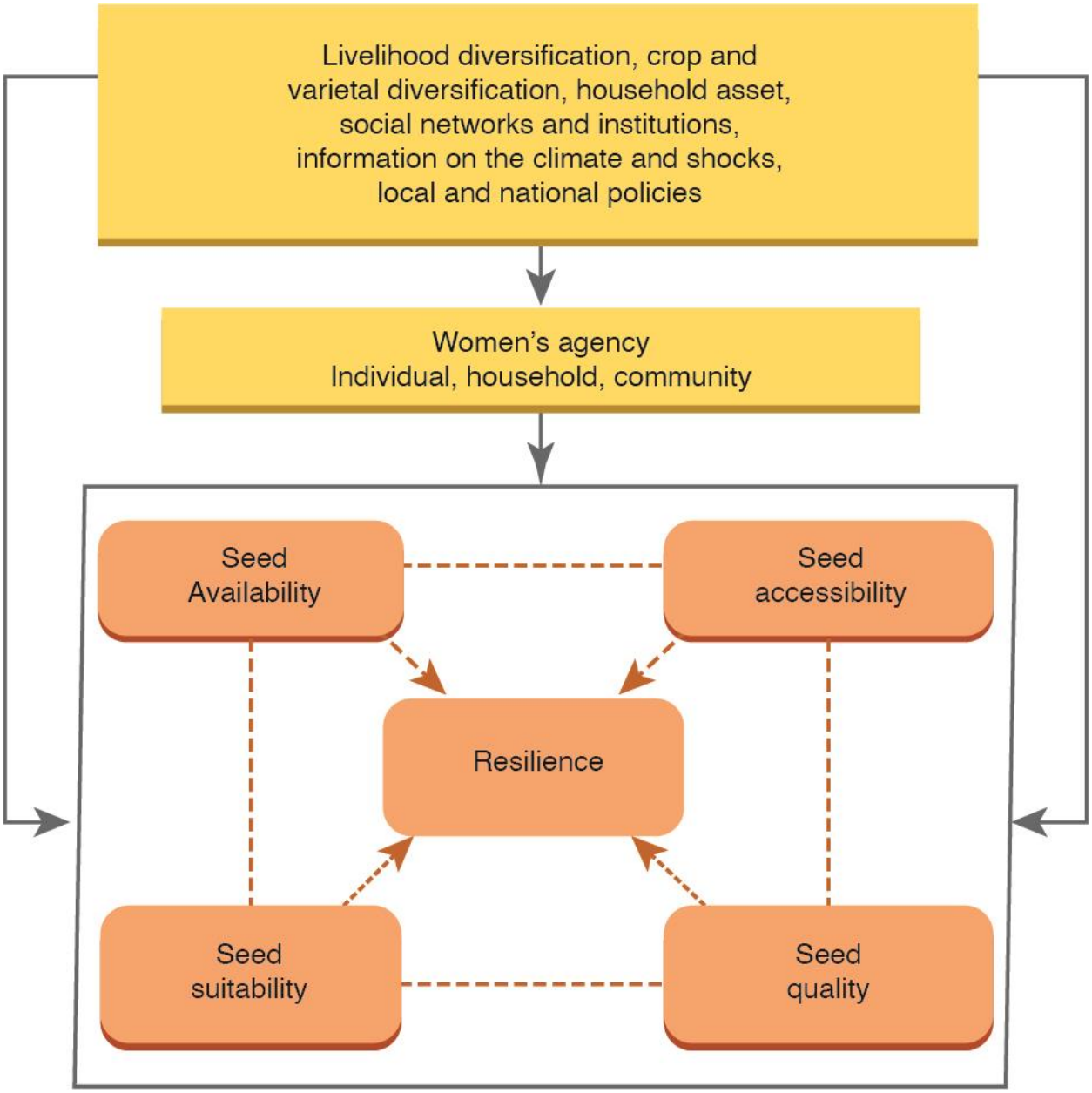

Figure 1. Study framework.

3. Research Methodology

3.1. Study area

We have chosen villages from Mandan Deupur Municipality (MDM) and Panchpokhari Thangpal Rural Municipality (PTRM) of Kavrepalanchowk and Sindhupalchowk districts, respectively (Table 1). Although these areas are near Kathmandu, Panchpokhari has yet to connect year-round motorable roads and thus we can find notable differences in agricultural intensification and markets, and thus possibly seeds, especially for vegetables and cereal crops.

Table 1. Description of the study areas.

Location	Mandan Deupur Municipality	Panchpokhari Thangpal Rural Municipality
Ecoregion	Hills	Mountains
Farming system	Maize and wheat in bariland (dry upland); rice-wheat/vegetables/potato in khetland (wet, lowland)	Maize and wheat in bariland; rice-wheat in khetland
Geography	Access to year-round motorable road (side road from the Melamchi highway)	Limited access to motorable road
Ethnicity	Brahmin, Gurung, Tamang, Dalit	Tamang, Brahmin, Dalit
Agriculture intensification	High	Low
Input use	High use of chemical fertilizer and pesticides, use of hybrid maize seed	Minimum use of chemical fertilizer and pesticides
Income diversification	High (vegetables, dairy, remittances and other off-farm income sources)	Low (remittances, internal tourism, agriculture)
Distant to markets (agrovets for seeds)	Nearby (1 h drive)	Far (at least 3 h walk)
Chosen ward of municipality*	3 (wheat), 4 (maize)	6 (maize and wheat)
Chosen villages*	Baldev (wheat) and Singhe (maize)	Dhap, Bhattarai tole (wheat) and Lekharka, Adhikari tole (maize)

* Through consultation with the municipality and discussions with villagers.

3.2. Study design, data collection and sampling

This study considered maize and wheat seed systems. Within a seed system, households are sub-categorized by caste/ethnicity, comprising Dalits, Janajati, and Brahmin/Chettri (BC). Janajati are indigenous ethnic groups, Dalits are a disadvantaged group, and BC are the so-called 'elite' castes. Intra-household relationships of women differ notably by caste and ethnicity, which often defines gender roles. Prior studies stated that intra-household relationships partly explain women's access to resources and their freedom and wellbeing. We assumed such differences could influence maize and wheat seed availability, accessibility, preferences, and quality in the study area.

Randomization and sample size for survey

In 2021, we visited the area to identify maize and wheat production villages. The criteria used were the number of households cultivating each of the two crops. We then selected villages where most households had cultivated maize and wheat crops last season. We categorized those households by caste/ethnicity. The list became our "sampling frame" for household randomization for the survey. A proportionate random sampling method was used to draw a sample of 250 households from the study area. As there were limited Dalit households in our sampling frame, we sampled at least 10 Dalit households for the survey.

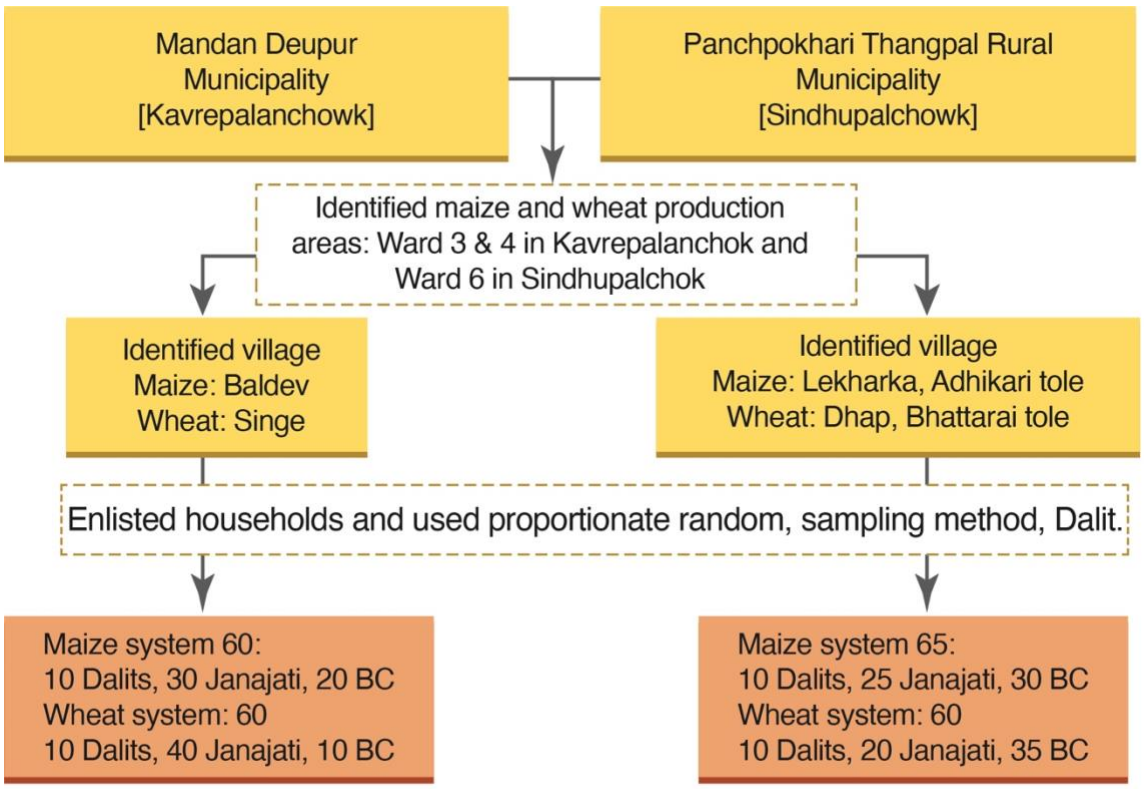

Figure 2: Process to determine the sample size for the household survey.

Data collection tools

Household survey, focus group discussions (FGD), and key informant interviews (KII) were the data collection tools for this study. For the survey, we prepared a questionnaire following FAO guidelines for household surveys. Likewise, we used a well-constructed checklist to conduct FGDs and KIIs. KoboCollect, an Android-based tool, was used for data collection in household surveys. The draft survey questionnaire was first tested and refined through application in nearby households. Likewise, we revised the checklist for FGDs and KIIs.

3.3. Estimation of indices

Based on the theoretical framework (Figure 1), we selected a few context-specific indicators for the four seed security pillars and women's agency (Table 2). Each seed security pillar has been assessed separately; each value was a **summation,** but the sum value of the seed suitability pillar was divided by 2 because it contained 10 indicators, compared to 5 for the other pillars. The four pillar index values were **averaged** to calculate household seed security status. Likewise, women's agency was assessed through a "gender roles index" that describes men and women's involvement in household chores, decision-making, and seed specific activities, among others.

Household seed security index

This is the average of all indices --- availability, accessibility, preference and quality --- nearly synonymous with the "resilience" of the FAO seed security assessment guidelines. The score is one way of assessing household strength/resilience when faced by a major shock or stress. The higher the score, higher the households' capacity to bounce back from any kind of stress and disaster because of their higher seed security status.

All indicators used in estimating household seed security were measured as dummy values. We assigned 1, if the response (typically, "yes") indicates an outcome that enhances household seed security; and 0 otherwise. For example, if a respondent answered "yes" to the question, "did you get the maize (or wheat) seed at the planting time last season?", we coded 1. Seed security index values ranged from 1 to 5 but, for ease of understanding, we multiplied them by 100 in data tabulation. Based on the seed security index, households fell into four groups: none/minimal (below 25), below average (25 to 49), average (50 to 74), and above average (75 and above). Responses for some indicators required further explanation, because we transformed them into 0 or 1 after a series of initial calculations. Those are seed rates, household asset, and seed germination rates.

(i) **Seed used per unit area.** This was first calculated by dividing crop cultivated land area by the respective quantity of seed used during the last season (maize and wheat separately). If the seed rates were higher than the recommended values of 1.5 kg (maize) or 3.5 kg (wheat) per *Ropani* (1 Ropani = 508 m^2), it was coded 1, because higher seed rates indicate adequate seed availability.

(ii) **Household asset index.** We calculated a summative index for household assets, comprising 16: air conditioner, computer, generator, large wooden furniture, LPG gas, motorcycle, power

tiller, refrigerator, smartphone, solar water heater, table fan, television, thresher, tractor, traditional phone, and washing machine. The median value for the asset index was 4, which separated the higher half of households from the lower half of the households. We coded 1 for those households who had an asset index value greater than 4 (median value), thinking that a higher number of assets indicates relative prosperity and, thus, an enhanced capacity to access maize and wheat seed.

(iii) **Seed germination percentage of farms.** Respondents estimated the average seed germination percentage on their farm for the most recent maize or wheat crop. If the stated value was above 85% (the recommended value), we coded 1, as it reflects better availability of and accessibility to quality seed.

Gender role index

We used a five-point Likert scale to measure men and women's participation in various activities, grouped into four categories: (i) daily chores (within the household); (ii) beyond the household; (iii) decision-making; and (iv) seed specific. We developed indices, using several questions asked as indicators (Table 2). Respondents were asked to choose from a continuum of 1 to 5, being 1 “always men”, 2 “usually men”, 3 “both men and women”, 4 “usually women”, or 5 “always women” (Figure 3). We estimated an average index for each category of activities and finally averaged those indices to calculate the overall ‘gender role index’. The index values ranged from 1 to 5, 1 showing men always performing all activities, while 5 showing women always performing all activities; and 3 for about equal participation of men and women (Figure 3). Finally, the “gender role index” values were used to categorize households for the gendered division of labor: (i) “men working” (index value <2.90); (ii) “men and women working” (index values in between 2.90 to 3.10), and (iii) “women working” (index value >3.10).

Table 2. Indicators and indices used in the calculation for seed security and gender roles indices.

Index	Indicators
Household seed security	
Seed availability	Timely availability of seed Adequate amounts of seed Trust in the nearest agrovets for regular seed supplies Number of seed sources available Quantity of seed used per unit area
Seed accessibility	Access to off-farm income Household asset index Prior disaster effect Relationship with seed suppliers Stress because of high seed prices

Seed quality	Free from dirt
	Free from another varietal seed
	Free from diseased seed
	Free from damaged seed
	Seed germination in the field
Seed suitability/preference	Grain yield potential of existing varieties
	Market value of existing varieties
	Food taste quality at home
	Lodging due to wind
	Incidence of insect pests
	Climate suitability, especially rain
	Farm animal preference, especially for green straw
	Prior varietal replacement rate
	Wish to change existing varieties in the next planting season
	Overall satisfaction with existing varieties
Gender roles	
Household chores	Who cleans the house?
	Who cooks the food?
	Who washes the dishes?
	Who takes care of the children?
	Who takes care of the elderly?
	Who takes care of the children's education?
Beyond household	Who buys seed from markets?
	Who pays school and electricity bills?
	Who takes part in the community work?
Decision-making	Who decides on the crops to be grown?
	Who decides for the change of crop varieties?
	Who decides on the land sale and procurements?
Seed work	Who is involved in seed separation?
	Who is involved in seed cleaning?
	Who is involved in seed storage?

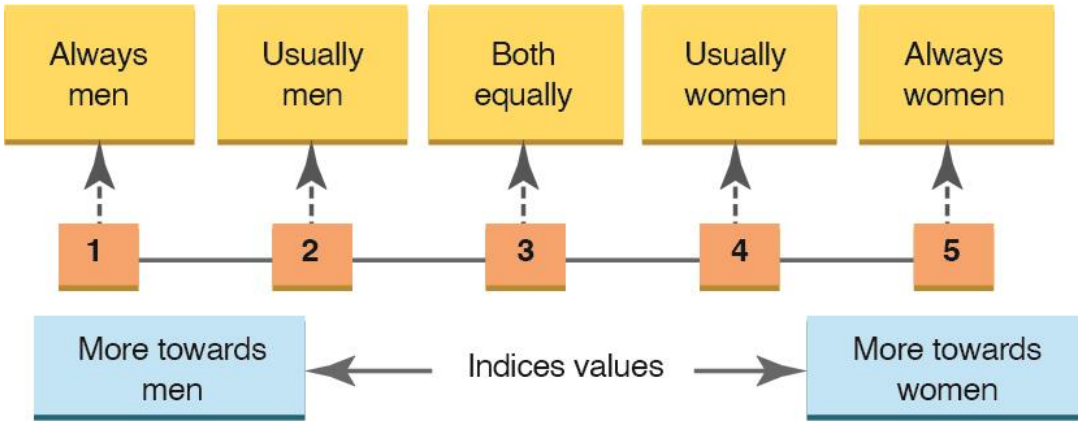

Figure 3. Five-point Likert scale used in estimating gender-related indices.

3.4. Data analysis

The study presents disaggregated data by municipality, seed system, and caste/ethnicity. In most cases, means and frequencies of the indicators are tabulated. We compared the means of the households' seed security index among the three household types, through a rank-based non-parametric test, the Kruskal-Wallis H, at the 5% level of significance.

4. Results

Sample characteristics

The study interviewed 250 households, 120 from Mandan Deupur municipality and 130 from Panchpokhari rural municipality. Approximately one-third of the respondents were males, at an average age of 46 years old, and their education level was poor (Table 3). Females headed a small number of households (17%). Our sample had relatively more nuclear (husband, wife and children) families than joint families (husband, wife, children, grandparents).

Table 3. Respondent and household head characteristics for three castes/ethnicities in two mountain area municipalities of Nepal, 2021.

Variables		Number of households	Percentage (%)	Mean
Respondent sex	Male	164	66	
	Female	86	34	
Respondent age (in years)				45.9
Respondent education (years of schooling)				4.1
Household head sex	Male	208	83	
	Female	42	17	
Household head age (in years)				50.4
Household head education				3.4
Family type	Nuclear	140	56	
	Joint	110	44	

Income sources

All households depended on agriculture for their livelihoods (Table 4). Farm animals and animal product sales were equally vital for their survival. One-third of households relied on daily-wage labor earnings. Households at Panchpokhari were more dependent on daily wages and remittances and had greater access to off-farm income, including salary-based services and self-employed small businesses like petty shops and carpet sales.

Table 4: Income sources of the sampled households.

Income sources	Mandan Deupur	Panchpokhari Thangpal	Total
Agriculture	100%	100%	100%
Farm animals	92%	91%	91%
Wages and labor	23%	42%	33%
Remittances	8%	22%	16%
Private services	8%	14%	11%
Government services	6%	17%	12%
Petty trade/small shop	5%	12%	8%
Hotel	1%	2%	2%
Other businesses	1%	2%	2%
Domestic carpet	0%	8%	4%
Others (driving)	1%	1%	1%

Landholdings and maize and wheat crops

Average agricultural landholdings were highest for BC (0.534 ha) followed by Janajati (0.457 ha) and Dalits (0.254 ha). Maize was cultivated on similar land areas between BC (0.24 ha) and Janajati (0.23 ha) and was low (0.15 ha) in Dalit households (Table 5). Maize grain yield was highest in Dalit households (2.5 t/ha), particularly in Mandan Deupur (3.6 t/ha), which could be due to the higher seeding rates they use. Likewise, wheat cropped area was lowest in Dalit households (0.13 t/ha). Wheat grain yields were highest in BC (1.6 t/ha) and lowest in Janajati (1.2 t/ha) households. Hybrid maize varieties (CP808, Kanchan) were common in Mandan Deupur; whereas Rampur Composite and local varieties of maize were common in Panchpokhari. With wheat, the varieties Gautam and RR21 were the most common in Mandan Deupur; in Panchpokhari, households preferred Gautam, Pasanglamu and RR21. In both municipalities, households preferred mostly white-grain maize.

Table 5: Landholdings and maize and wheat grain yields of 250 households in two mountain area municipalities in Nepal, based on response to a survey conducted in 2021.

Crop area and production	Mandan Deupur			Panchpokhari Thangpal			Total		
	BC	Janajati	Dalits	BC	Janajati	Dalits	BC	Janajati	Dalits
Total cultivable area (ha)	0.75	0.48	0.23	0.43	0.43	0.27	0.53	0.46	0.25
Maize cultivated area (ha)	0.36	0.26	0.13	0.19	0.17	0.16	0.25	0.23	0.15
Maize seed rate (kg/ha)	20.5	21.5	32.5	28.0	29.9	29.5	25.4	24.4	30.9
Maize grain yield (t/ha)	2.4	2.2	3.6	1.6	1.3	1.4	1.9	1.9	2.5
Wheat cultivated area (ha)	0.21	0.24	0.16	0.22	0.19	0.11	0.22	0.23	0.13
Wheat seed rate (kg/ha)	104.7	86.4	76.4	110.6	82.9	97.0	108.9	85.2	89.2
Wheat grain yield (t/ha)	1.7	1.3	1.0	1.6	1.0	1.7	1.6	1.2	1.4

Food sufficiency

Overall, 62% of the households interviewed had insufficient food production for a year (Table 6). This figure was much higher for Dalit (85%) and Janajati (70%) households. Households in Mandan Deupur (43%) are more food secure from their own agricultural production than those in Panchpokhari (34%).

Table 6: Household food sufficiency (yes or no) from own agricultural production.

Ethnicity	Mandan Deupur				Panchpokhari Thangpal				Total			
	Yes		No		Yes		No		Yes		No	
	N	%	n	%	n	%	n	%	n	%	n	%
BC	22	73	8	27	33	51	32	49	55	58	40	42
Janajati	25	36	45	64	10	22	35	78	35	30	80	70
Dalits	5	25	15	75	1	5	19	95	6	15	34	85
Total	52	43	68	57	44	34	86	66	96	38	154	62

Seed sources

Information on maize and wheat seed sources was collected through focus group discussions in both municipalities and categorized by caste/ ethnicity (Figure 4; see also Appendix 1 for notable findings of FGDs). Households obtain maize and wheat seed from both the formal and informal sectors. Most households in Mandan Deupur purchased maize seed from formal markets, whereas, in Panchpokhari, households managed from informal sources. BC households mainly relied on local and distant markets for maize and wheat seed, whereas most Dalit and Janajati households got seed from informal sources. Key informal sources were neighbors, relatives, and saved seed (Table 7). Half the Janajati households saved their own seed. In Mandan Deupur, households relied largely on neighbors, recycling seed from harvests of hybrid varieties of the BC group, resulting in crops of inferior quality. Households relied on multiple seed sources for maize and wheat seeds; however, majorly depended on a single source, either the markets or other sources of informal seed system, mostly the home saved seeds.

Table 7. Households' access to formal and informal seed sources (% of households by municipalities).

Municipality	Ethnicity	Seed sources						Number of seed sources		
		Local Market	Distant market	Neighbor (Exchange)	Neighbor (Buy)	Relatives	Own saved seed	One	Two	>Two
Mandan Deupur	BC	80%	23%	13%	20%	7%	17%	50%	37%	13%
	Janajati	41%	4%	16%	33%	4%	53%	60%	24%	16%
	Dalits	65%	5%	5%	20%	10%	15%	85%	5%	10%
Panchpokhari Thangpal	BC	52%	0%	25%	23%	5%	34%	68%	20%	12%
	Janajati	24%	2%	60%	44%	18%	44%	38%	33%	29%
	Dalits	30%	0%	50%	45%	15%	30%	60%	10%	30%
Total	BC	61%	7%	21%	22%	5%	28%	62%	25%	13%
	Janajati	35%	3%	33%	37%	10%	50%	51%	28%	21%
	Dalits	48%	3%	28%	33%	13%	23%	73%	8%	20%

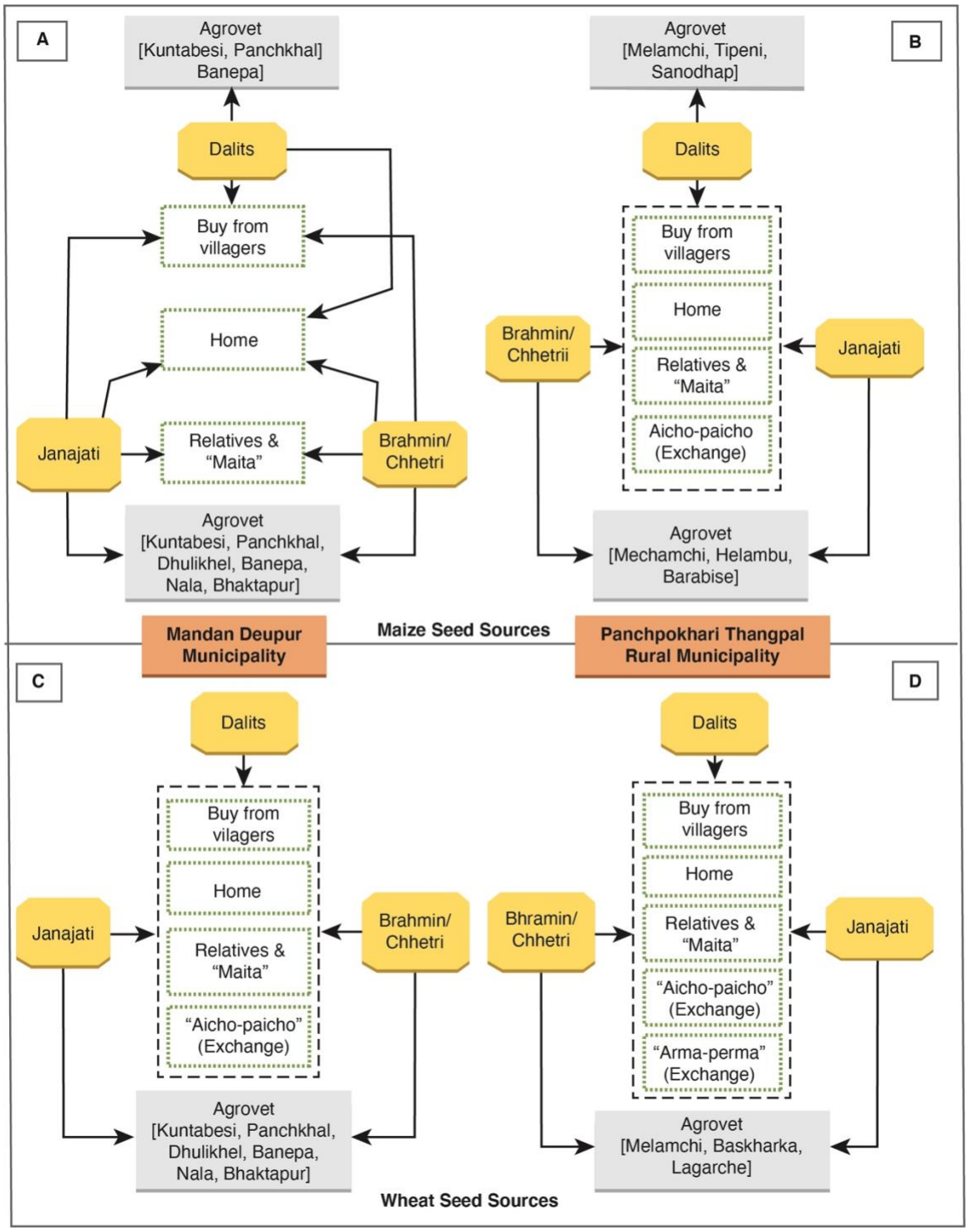

Figure 4. Seed sources stated in focus group discussions: (A) maize, Mandan Deupur (B) maize, Panchpokhari, (C) wheat, Mandan Deupur and (D) wheat, Panchpokhari. "Maita" means women's parental home, "aicho-paicho" is an exchange of seed for kinds, and "arma-perma" is an exchange of seed for labor.

Seed availability

Most households (over 80% in every group) reported timely access to maize and wheat seed, particularly during planting season. From 10 to 12% of Janajati and Dalit households had concern about the timely availability of seeds, especially in Mandan Deupur (Table 8). Approximately 10% of the households complained about inadequate supply of maize and wheat seeds of their choice, and most of them depend on nearby agrovets for a regular supply. Finally, seeding rates, a proxy for household seed availability at sufficient quantity, were nearly similar among castes/ethnicity, except for Janajati in Panchpokhari, nearly 63% of whom used lower than recommended seeding rates.

Table 8. Indicators for household seed availability for different castes / ethnicities for two municipalities in mountain areas of Nepal.

Indicator	Indicator value	Mandan Deupur						Panchpokhari Thangpal					
		BC		Janajati		Dalits		BC		Janajati		Dalits	
		n	%	n	%	n	%	n	%	n	%	n	%
Timeliness	Not available on time	0	0	8	11	2	10	2	3	4	9	0	0
	Available on time	30	100	62	89	18	90	63	97	41	91	20	100
Adequacy	Inadequate seed supply	3	10	13	19	3	15	7	11	4	9	2	10
	Adequate seed supply	27	90	57	81	17	85	58	89	41	91	18	90
Trust on nearby agrovets for timely supply	Do not supply on time	2	7	16	23	3	15	6	9	4	9	2	10
	Supply on time	28	93	54	77	17	85	59	91	41	91	18	90
Seed sources	Single source	15	50	42	60	17	85	44	68	17	38	12	60
	Multiple sources	15	50	28	40	3	15	21	32	28	62	8	40
Seed rates	Lower than recommended rates	13	43	31	44	12	60	32	49	28	62	10	50
	Higher than recommended rates	17	57	39	56	8	40	33	51	17	38	10	50

Table 9 shows the seed availability index estimated by summing 5 indicators. Overall, the timely availability of adequate amounts of maize and wheat seeds was no major concern in the study area, with the exception of Dalit households, and the difference was high in Mandan Deupur for both maize and wheat seed.

Table 9. Household seed availability index.

Seed system	Mandan Deupur			Panchpokhari Thangpal			Total		
	BC	Janajati	Dalits	BC	Janajati	Dalits	BC	Janajati	Dalits
Maize seed system	3.9	3.2	3.0	3.7	3.5	3.8	3.8	3.3	3.4
Wheat seed system	3.8	3.6	3.4	3.5	4.1	3.6	3.6	3.8	3.5
Total	3.9	3.4	3.2	3.6	3.7	3.7	3.7	3.5	3.4

Seed accessibility

The frequency tabulation of the indicators shows that BC households in Panchpokhari had (i) lower sole dependency on agriculture and higher access to off-farm income sources, (ii) better household assets, (iii) lower seed accessibility problems during prior disasters, (iv) were better known to people who could provide seed during a crisis, and (v) felt less of an economic burden due to high seed prices (Table 10). Between municipalities, Dalit households in Mandan Deupur had (i) higher sole dependency on agriculture and lower access to off-farm income sources, (ii) lower household assets, (iii) higher seed accessibility problem during prior disasters, (iv) were less known to people who could provide seeds in the crisis, and (v) felt a higher economic burden due to high seed prices.

Table 10. Indicators for household seed accessibility.

Indicators	Indicator values	Mandan Deupur						Panchpokhari Thangpal					
		BC		Janajati		Dalits		BC		Janajati		Dalits	
		n	%	n	%	n	%	n	%	n	%	n	%
Household access to income sources	Only farm income sources	24	80	29	41	8	40	7	11	9	20	2	10
	Off-farm income sources	6	20	41	59	12	60	58	89	36	80	18	90
Household asset index	Lower or equal to 4 assets	16	53	41	59	10	50	30	46	28	62	20	100
	Greater than 4 assets	14	47	29	41	10	50	35	54	17	38	0	0
Experience of seed unavailability in the prior disasters	Yes	24	80	22	31	15	75	10	15	11	24	6	30
	No	6	20	48	69	5	25	55	85	34	76	14	70
Know persons that provide seeds during crisis	Yes	16	53	36	51	8	40	47	72	37	82	13	65
	No	14	47	34	49	12	60	18	28	8	18	7	35
Experience of economic stress due to high price of seeds	Yes	19	63	23	33	8	40	9	14	8	18	5	25
	No	11	37	47	67	12	60	56	86	37	82	15	75

Households' seed accessibility indexes show that maize growing BC households in Mandan Deupur were less able to acquire seed than other groups (Table 11) and that households in Panchpokhari were better able to acquire wheat and maize seed than households in Mandan Deupur.

Table 11. Household seed accessibility indexes.

Seed system	Mandan Deupur			Panchpokhari Thangpal			Total		
	BC	Janajati	Dalits	BC	Janajati	Dalits	BC	Janajati	Dalits
Maize seed system	1.5	3.1	2.2	3.9	3.0	3.0	3.0	3.1	2.5
Wheat seed system	2.3	2.7	2.6	3.8	4.3	3.0	3.4	3.2	2.8
Total	1.8	2.9	2.4	3.9	3.6	3.0	3.2	3.1	2.7

Varietal preferences/suitability

We measured varietal suitability through 10 indicators (Table 12), especially accounting for varietal qualities and their problems, households' satisfaction with current varieties, and varietal replacement possibilities. Among the 10 indicators, at both the locations, and for all ethnic groups, with only slight variation, grain yield was the most highly-valued trait. An interesting finding was that households' varietal preferences did not necessarily respond to market demand. Over 80% of the respondents in all castes/ethnic groups stated that there was low market demand for their maize and wheat grain. A small portion of farmers wished to change crop varieties, if yields of the new ones were better, while 30-50% of households from each group reported a frequent change in variety in recent years. Nonetheless, most households expressed satisfaction with existing varieties. The varietal suitability index (presented in Table 13) was higher for Janajati households than for households from the other groups, for both crops and locations. Overall, the calculated varietal suitability index was greater for Dalits than for the BC group in Mandan Deupur and was similar in Panchpokhari.

Table 12. Indicators for household varietal preference/suitability.

Indicators	Preference on existing varieties	Mandan Deupur						Panchpokhari Thangpal					
		BC		Janajati		Dalits		BC		Janajati		Dalits	
		n	%	n	%	n	%	n	%	n	%	n	%
Grain yield	Low	6	20	22	31	4	20	21	32	15	33	7	35
	High	24	80	48	69	16	80	44	68	30	67	13	65
Market demand	Low	28	93	56	80	20	100	62	95	37	82	17	85
	High	2	7	14	20	0	0	3	5	8	18	3	15
Taste	Low	15	50	23	33	12	60	21	32	10	22	8	40
	High	15	50	47	67	8	40	44	68	35	78	12	60

Lodging problem	Low	27	90	49	70	14	70	33	51	34	76	11	55
	High	3	10	21	30	6	30	32	49	11	24	9	45
Insect and pest incidence	Low	28	93	55	79	17	85	57	88	41	91	18	90
	High	2	7	15	21	3	15	8	12	4	9	2	10
Rain rots cobs/grains	Low	25	83	14	20	11	55	14	22	17	38	8	40
	High	5	17	56	80	9	45	51	78	28	62	12	60
Less biomass	Low	3	10	12	17	2	10	23	35	19	42	6	30
	High	27	90	58	83	18	90	42	65	26	58	14	70
Change variety frequently	Low	15	50	45	64	11	55	42	65	30	67	11	55
	High	15	50	25	36	9	45	23	35	15	33	9	45
Wish to change variety next planting season	Low	12	40	13	19	3	15	21	32	5	11	4	20
	High	18	60	57	81	17	85	44	68	40	89	16	80
Overall satisfaction with the existing crop varieties	Low	5	17	10	14	0	0	9	14	4	9	6	30
	High	25	83	60	86	20	100	56	86	41	91	14	70

Table 13. Household varietal suitability index.

Seed system	Mandan Deupur			Panchpokhari Thangpal			Total		
	BC	Janajati	Dalits	BC	Janajati	Dalits	BC	Janajati	Dalits
Maize seed system	2.4	2.8	2.7	2.6	2.8	2.6	2.5	2.8	2.7
Wheat seed system	2.1	2.9	2.6	2.7	2.5	2.6	2.6	2.8	2.6
Total	2.3	2.9	2.7	2.7	2.6	2.6	2.5	2.8	2.6

Seed quality

Seed quality was assessed through five indicators (Table 14). Perceptions of seed cleanliness ranged from 70 to 95.6%, with the lowest and highest in the Janajati ethnic group in Mandan Deupur and Panchpokhari, respectively. Most households (>85%) did not note that seed of a particular

variety had been adulterated with that of other varieties. However, 10 to 27 percent of households reported the presence of diseased seeds in the maize and wheat seed they had sown the previous season. Similarly, broken seeds were reported by 10 to 30% of households. Overall, we found that maize and wheat seed used by farmers was neither pure nor free from dirt and other contaminants, which perhaps explains why 16 to 55% of households reported low germination rates (<85%) in their maize and wheat crop stands, and particularly in Panchpokhari.

Table 14. Seed quality indicators.

Indicators	Indicator values	Mandan Deupur						Panchpokhari Thangpal					
		BC		Janajati		Dalits		BC		Janajati		Dalits	
		n	%	n	%	n	%	n	%	n	%	n	%
Seed cleanliness	Seeds were not clean	7	23	21	30	4	20	6	9	2	4	4	20
	Seeds were clean	23	77	49	70	16	80	59	91	43	96	16	80
Seed adulteration	Adulterated with another variety	4	13	9	13	3	15	8	12	3	7	5	25
	Not adulterated with another variety	26	87	61	87	17	85	57	88	42	93	15	75
Free from diseased seed	Contained diseased seeds	8	27	19	27	2	10	8	12	5	11	4	20
	Not contained diseased seeds	22	73	51	73	18	90	57	88	40	89	16	80
Free from damaged seed	Contained damaged seeds	7	23	21	30	2	10	11	17	8	18	4	20
	Not contained damaged seeds	23	77	49	70	18	90	54	83	37	82	16	80
Seed germination	Germination was <85%	5	17	22	31	5	25	31	48	19	42	11	55
	Germination was >85%	25	83	48	69	15	75	34	52	26	58	9	45

The household seed quality index (Table 15) shows that maize seed quality is better than that of wheat seed. Dalit households, especially in Panchpokhari, used the lowest quality of wheat seed (index value 2.7), however, they acquired comparable quality maize seed.

Table 15. Household seed quality index.

Seed system	Mandan Deupur			Panchpokhari Thangpal			Total		
	BC	Janajati	Dalits	BC	Janajati	Dalits	BC	Janajati	Dalits
Maize seed system	4.3	4.1	4.4	4.3	4.4	4.5	4.3	4.2	4.5
Wheat seed system	3.4	3.4	3.9	3.8	3.9	2.7	3.7	3.6	3.2
Total	4.0	3.7	4.2	4.0	4.2	3.6	4.0	3.9	3.9

Household seed security

Most households (67%) stated “average” seed security, with the remaining 27% scoring their seed security as “above average” (Table 16). Households in Panchpokhari felt they had better seed security, with nearly 39% qualifying it as “above average”, than those in Mandan Deupur (only 14.2%). Likewise, by caste/ethnicity, 12.5% of Dalit households responded that their seed security was “below average”. Within the municipalities, however, we observed notable differences. A similar percentage of BC households in Panchpokhari responded “below average” and “above average” regarding seed security; however, in Mandan Deupur, only 3.3% of BC households said their seed security was “above average”. Overall, we conclude that (i) most households in the study area feel they are “seed insecure,” (ii) households in Mandan Deupur felt they were even less seed secure, (iii) BC households in Mandan Deupur responded as feeling less seed secure than other groups, and (iv) 1 in 10 Dalit households see themselves as being severely seed insecure.

Table 16. Overall household seed security (% of households).

Ethnicity	Household seed security category	Mandan Deupur		Panchpokhari Thangpal		Total	
		n	%	n	%	n	%
BC	None/minimal	0	0	0	0	0	0
	Below average	3	10	2	3	5	5
	Average	26	87	34	52	60	63
	Above average	1	3	29	45	30	32
Janajati	None/minimal	1	1	0	0	1	1
	Below average	4	6	0	0	4	3
	Average	52	74	27	60	79	69
	Above average	13	19	18	40	31	27

Dalits	None/minimal	0	0	0	0	0	0
	Below average	2	10	3	15	5	13
	Average	15	75	14	70	29	73
	Above average	3	15	3	15	6	15
Total	None/minimal	1	1	0	0	1	0
	Below average	9	8	5	4	14	6
	Average	93	78	75	58	168	67
	Above average	17	14	50	38	67	27

Household gender roles

Household gender roles on the four broad activities was measured through 'gender role index', that ranged from 1 to 5, 1 showing men always performing all activities, while 5 showing women always performing all activities (see Figure 3). Overall, the gender roles index for households was 3.2 (slightly towards women performing activities), however it varied from 1.9 (mainly men performing activities) to 4.8 (mainly women performing activities), which shows that there was variation across households in participation in household work between men and women (Table 17). On average, women were mainly involved in household daily chores (index value 3.9) and seed related activities (index value 3.8), whereas men mainly took part in activities that are performed outside the household (index value 2.4), with an equal level of involvement of men and women in decision-making (index value 2.9). By ethnicity/caste, BC women tended more to perform mostly daily household chores (index value 4.0) than women in the other two groups.

By municipality (Table 18), BC men in Mandan Deupur usually took part more in the community work (index value 1.9) compared to the BC men in Panchpokhari (index value 2.7). Overall, we found that women are confined to household daily chores and they are heavily involved in the management of crop seeds. A notable observation is that women are involved in household-level decision-making but their participation in activities beyond household is minimal.

Table 17. Average value of gender related indices.

Gender related indices	Minimum	Maximum	Mean	Std. Deviation
Household chores	3.0	5.0	3.9	0.41
Beyond household	1.0	5.0	2.4	0.70
Decision-making	1.0	4.3	2.9	0.58
Seed works	1.7	5.0	3.8	0.48
Gender roles index	1.9	4.8	3.2	0.39

Table 18. Municipality and caste/ethnicity wise gender-related indices

Gender indices	Mandan Deupur			Panchpokhari Thangpal			Total		
	BC	Janajati	Dalits	BC	Janajati	Dalits	BC	Janajati	Dalits
Household chores index	3.9	3.8	3.9	4.0	3.7	4.1	4.0	3.7	4.0
Beyond household index	1.9	2.2	2.4	2.7	2.6	2.6	2.5	2.3	2.5
Decision-making index	2.5	2.7	2.8	3.1	3.1	3.1	2.9	2.9	2.9
Seed work index	3.6	3.8	3.9	3.9	3.7	3.7	3.8	3.7	3.8
Gender roles index	3.0	3.1	3.2	3.4	3.3	3.4	3.3	3.2	3.3

Relationship between household seed security and gender roles

We finally compared the household seed security index with gender roles. For this, we prepared a gendered “households x labor” division: “men working”, “men and women working” and “women working”. A Kruskal-Wallis H test showed that household seed security differs significantly between the different household groups, χ^2 (2) =7.852, p = 0.020, with a mean rank seed security score of 100.86 for “men working” households, 113.88 for “men and women working” households, and 135.25 for household “women working” households. Table 19 shows that seed security between “men” versus “women” households and “men and women” versus “women” households was statistically different (significant at 5%). We found a clear effect of gender roles on household seed security.

Table 19. Pair-wise comparison of household seed security by gendered household

Household category	Test Statistic	Std. Error	Std. Test Statistic	Sig.
"men" versus "men and women"	-13.027	16.162	-0.806	0.420
"men" versus "women"	-34.391	14.827	-2.320	0.020
"men and women" versus "women"	-21.364	10.460	-2.042	0.041

5. Discussion

Seed systems and sources

Although we found limited maize and wheat varietal diversity in the study areas, farmers accessed seed for those crops from both formal (local Agrovets and distant markets) and informal (traditional local providers) seed systems (Table 7). Both BC and Janajati households relied on multiple sources for maize and wheat seeds. However, Dalits had limited seed sources and vital for them were informal sources, especially for the wheat seeds in which they had no access at all to commercial seeds from agrovets. Dalit households in both locations do not visit agrovets for wheat seeds, informal seed sources have fulfilled all of their wheat seed requirements to date. Figure 4 illustrates that seed systems vary by caste/ethnicity and municipalities, as well as seed systems. Farmers in Panchpokhari majorly relied on local seed sources (villagers, home, relatives, and “aicho-paicho”). However, the local seed system was “broken” in Mandan Deupur - where agrovets (formal seed suppliers) provide maize seeds to most farmers. A local “kind to kind” exchange system, “aicho-paicho”, for example, exists in Panchpokhari for both maize and wheat seeds. However, it was not observed in Mandan Deupur for maize seed exchange. Likewise, another “labor to cash/kind/labor” exchange system, “arma-perma”, only exists for wheat seeds in Panchpokhari.

We argue that the formal seed system has superseded the farmer’s seed system that once existed in Mandan Deupur and foresee a similar outcome soon in Panchpokhari, especially for maize seed. Agrovets are the only formal seed sources at local levels at present. As private entities, they are motivated by profit and, furthermore, monitored less because of a weak governance system. Farmers’ access to quality seed is only possible by developing the formal seed systems (Omolehin et al. 2008; Khan and Asim, 2020), that is by strengthening agrovets, and is vital for quality seed availability and higher yields. We thus suggest harnessing the strengths of both formal and informal seed systems and linking them more effectively in the mountains of Nepal.

Seed availability

We stated that timely availability of adequate amounts of maize and wheat seeds was not a major issue in the study area under normal conditions, yet Dalit households had higher difficulties with seed availability, especially in Mandan Deupur (Table 8 and 9). However, it was a serious issue for all of them during extreme climatic shocks and disasters; for example, the Gorkha earthquake and the COVID-19 lockdown. The effects differed according to the degree of household dependency on formal vs informal seed systems. For example, BC households in Mandan Deupur were unable to access adequate supplies of maize seed immediately after the earthquake, probably because of their higher dependency on agrovets for maize seed. However, that was not the case in Panchpokhari. Nonetheless, during times of crisis and shocks, farmers access most of the seed they require through local, informal channels (Sperling et al. 2004); and we observed broken local seed channels for maize in Mandan Deupur, whereas in Panchpokhari those channels were still functioning. We did not observe seed availability problems in recent planting seasons in the municipalities studied, but the formal seed system collapsed in the aftermath of the Gorkha

earthquake and during COVID-19 lockdown, especially in Mandan Deupur, as noted during focus group discussions, so the informal seed system supported farmers at that time.

Seed accessibility

We found that BC households in Mandan Deupur were less able to acquire maize seed than Janajati and Dalit households (Table 10 and Table 11). Limited access to off-farm income sources (less money for purchase) and sole dependency on agrovets (more disconnect from the informal seed system) could be the reasons. Another notable finding was that the accessibility of maize and wheat seeds was relatively better in Panchpokhari than Mandan Deupur, probably because of a well-functioning farmers' seed system in Panchpokhari. Households' access to quality seed is vital for higher crop yields and food security, and a viable seed supply system is a key support for this (Omolehin et al. 2008; Khan and Asim, 2020; Manggoel et al. 2021). Access to quality seeds is influenced by many contextual factors, including seed prices (Sugri et al. 2013), knowledge of improved crop varieties (Setimela et al. 2004), and land holdings (Munyaka et al. 2015). Poor households cannot easily access high-priced crop seeds (Gill et al., 2013), thus they save and sow own seed. During focus group discussions, participants noted the high price of hybrid maize seed (NPR 600/kg for the hybrid CP808, vs NPR 90/kg for the improved variety Rampur Composite) during the preceding planting season. Because of the expensive seed price, some households, especially Dalits, often compromised maize yield by sowing F1 hybrid seed stored at home and by neighbors. Households often sowed hybrid maize on fertile land, and home-stocked seeds on relatively less fertile land. During a focus group discussion at Mandan Deupur, a BC woman stated, *"I see a wonderful production of CP808* (hybrid maize) *in my villager's field, but my husband does not buy the expensive seed. It is obvious because the money needed to buy seed from an agrovet would buy us a few folds more maize grains. So, instead we cultivate local maize varieties"*. Furthermore, sowing of seeds without prior testing can cause crop failure and lead to seed insecurity (Sulaiman and Andini, 2013). In Panchpokhari, farmers seldom sowed newly introduced hybrid maize varieties on a large scale. Instead, they often cultivated hybrid maize on small land with home-stocked seeds for initial self-evaluation.

Seed suitability/ preference

We stated that grain yield was the preferred characteristic for both maize and wheat seeds (Table 13), and farmers were satisfied overall with the performance of existing maize and wheat varieties. Nonetheless, farmers reported high incidence of insect pests, especially on hybrid maize, and only a few expressed a wish to change from existing varieties to new, higher-yielding ones (Table 12). Hybrid maize is largely used to feed farm animals and sold to markets whereas, for its superior flavor and texture, local maize is used mostly in preferred household foods (e.g., *dhindo*, *satu*, roasted green cobs, *chyang*). Likewise, households occasionally consume wheat food products (e.g., *dhindo*, *roti*, *pan roti, gahuko bhat, alum*, and *chyang*) but use wheat mostly as feed for farm animals in products such as *khole* and sell any surplus on markets. The seasonal popularity of roasted green cobs led to a few households in Mandan Deupur, especially at lower elevations (beyond our study areas, but within the municipality), to seek seed of a tastier hybrid maize variety ("Shrestha") at the local market, without success.

Varietal preferences may differ from individual to individual (men/women, for example), household to household, and according to diverse factors, including availability (local, community, market). Studies reported that varietal preference largely depended on grain yield and insect pest resistance (Mulesa et al. 2021; Jamieson et al. 2016), along with seed prices (Jamieson et al. 2016), economic returns (Omolehin et al., 2008), and farmers' concerns about the loss of local varieties and erosion of genetic materials (Jamieson et al. 2016). In our case, almost all farmers in Mandan Deupur preferred hybrid maize, but such was not the case in Panchpokhari, where people preferred improved ("Rampur Composite") and local varieties. The most widely grown wheat varieties are "Gautam" and "RR21". In Panchpokhari, the third most common wheat variety "Pasanglamu" was used for making a local alcoholic beverage, *"Chyang",* especially in the Janajati households. Adoption of "Gautam" has been reported in the mountains of Nepal to maintain seed self-sufficiency (Chaudhary et al. 2018).

In conclusion, yield potential and local food culture have largely determined varietal choices. However, due to the diminishing yields of hybrid maize in recent years, especially in Mandan Deupur, some farmers are worried. In a focus group discussion, a Dalit woman raised questions about maize hybrid CP808: "*Farmers do not know where this maize seed comes from; we would like to know if we can produce the maize seed that suits our locality, soil and climate; and want to develop our own seed system. Currently, we buy seeds by reviewing the performance in neighboring fields, without knowing its authenticity and suitability"*. Likewise, a Janajati man in another group said, "*It is usually men who buy the seed, but both genders know nothing about the varietal suitability and quality*". We thus argue that, although most of the farmers stated overall satisfaction with the existing maize and wheat varieties, they enjoy limited varietal choices, lack knowledge about varietal suitability, particularly for hybrids, and wanted to replace existing hybrid maize because of its declining yield performance and seed quality concerns. Locally unsuitable crop varieties increase farmers' vulnerability, wasting resources such as land, labor, and water that might have been used to more productive ends (Sperling, 2020).

Seed quality

Maize and wheat seeds used in recent seasons were neither pure nor free from dirt and other contaminants, thus compromising healthy germination (Table 14 and Table 15). This problem was more severe in Panchpokhari, probably because of their higher dependency on the local seed systems. Maize seed was of higher quality than wheat seed because it was easily available in markets or agrovets, whereas wheat seed was mostly home saved. We also observed the lowest quality of wheat seeds in the Dalit households, especially in Panchpokhari. Dalits neither visited agrovets for quality wheat seed nor saved seed from their harvests (see Figure 4), due to their limited land to grow food and general poverty. They generally consumed all what they harvested and later reached out to villagers to buy seed and "arma-perma" (exchange of seed for labor). Dalit households --- especially in Panchpokhari --- had limited access to quality seed of wheat.

Many households in our study obtained seed from informal channels and continuous use of untested seed and varieties led to a decline in seed quality (Tonapi et al. 2012). Almost all farmers trusted agrovets for quality seed. We believe the formal seed system guarantees greater quality of seeds (Fredenburg, 2015), but no authority oversees the quality of the formal seed system at local levels

(Templer and Kariuki, 2016). Prior studies (Mulesa et al., 2021; Sperling et al., 2006) reported that seed purchased from formal markets were often of inferior quality.

Farmers also lacked good seed storage facilities, simply they stored seed in an open container for example plastic/cotton bags and sacks, which also diminished its quality and performance (Kiwanuka and Kintu, 2004; Kshetri, 2013). Pandey et al. (2019) reported minimal use (13%) of metal bins and high use (87%) of locally available materials (87%) for seed storage. Likewise, super grain bags are superior to farmers' containers for seed storage (Devkota et al. 2018). Sometimes, a simple modification of the storage facilities (Colville and Pritchard, 2019) and avoiding machine threshing for wheat seed could enhance seeds' lifespan. For example, a Dalit participant in the focus groups stated that storing at lower temperatures and air-sealed containers prevented insect (mainly weevil) infestation. Likewise, a participant said that the use of threshing machines compromised seed quality, damaging the pericarp. Studies (Hamal et al. 2010; Maharjan et al. 2013; KC et al. 2015) have long recommended a highly successful community-based seed production program in Nepal, even for remote areas (Hamal et al. 2010), but the practice does not exist in our study area. Heavy dependence on the informal seed system reduces the certainty of obtaining quality seed (Mazvimavi et al. 2017; Shrestha and Gauchan, 2020). We thus suggest starting community seed production based on local knowledge to enhance the availability of quality seed, especially for the marginalized population.

Household seed security

"*No matter how expensive the seed is, we need to buy it. Otherwise, we will have no grains in our stock for the next season*", a Dalit male participant in a focus group speaks about seed prices, his willingness to purchase seed of improved varieties, and its importance for food security. Overall, this study found that households are "seed insecure" for maize and wheat (Table 16). Seed insecurity is most severe in BC households in Mandan Deupur and Dalit households in Panchpokhari. This corroborates the findings of previous studies that document chronic seed insecurity among the marginalized populations (Sperling et al., 2006). Households in our study are more insecure for wheat seed than maize. Although most farmers did not report seed availability as a major issue for the last season, their heavy dependency on a single source for seed is worrisome. For those households, timely availability of seeds is not ensured, especially during shocks, in part because hybrid maize seed is mostly imported from abroad (Adhikari, 2014).

We found the informal seed system broken for maize in both locations and farmers dependency on agrovets is gradually increasing even for the wheat seeds, which has already started in Mandan Deupur and is yet to happen in Panchpokhari Thangpal. This study found that farmers who rely on informal channels have better access to seed than those who depend solely on agrovets. Varietal preference are inclined towards higher production and lower crop loss, but the authenticity of varieties available is not trusted by many, as the varietal selection and replacement is done by looking at other farmers' experiences and suggestion of agrovets. Hence, farmers are at risk of crop loss due to seed unsuitability. Farmers dependent on agrovets have seeds of relatively greater quality than those getting seeds from other informal channels, which is also found by previous studies elsewhere (Fredenburg, 2015; Shrestha and Gauchan, 2020). Farmers in the study area are not fully seed secure until formal seed channels are made more accessible and the suitability and

quality of seed is assured, while the informal seed channels can be equally prioritized as community-based seed production systems which have been found to be vital for smallholders' seed and food security (Mazvimavi et al., 2017; Amir, 2020).

Gender and household seed security

We finally compared the household seed security status among households categorized as "men working", "men and women working" and "women working" through gender related indices (Table 17 and 18). The Kruskal-Wallis H test showed a higher mean rank for "women working" (135.25) compared to "men working" (100.86) households. It shows that household seed security is not gender neutral and skewed towards women's roles (Table 19). Prior studies highlighted the crucial role of women in conserving local seeds and maintaining household seed security (Sperling and Katungi, 2009), despite their facing difficulties in access to quality seed because of male land ownership and capital (Sperling, 2004; Sperling and Katungi, 2011; Bawa et al. 2014; Choudhary et al. 2020). Even though men are easily able to take part in activities outside the household, including participation in training and workshops (Bushell, 2008), women have practically earned the traditional wisdom of seed management over many generations as a part of homemaking.

In the informal seed system, women are key actors in seed selection, sorting, grading and storage. However, their critical role is seldom acknowledged in policy formulation and program implementation. Moreover, their overall contribution in agriculture is overlooked while making decisions within and beyond households and women remain in a position to bargain with men in order for their voices to be heard (Gram et al. 2018; Pradhan et al. 2019). For example, men are the ones who take part in most of the training and meetings related to agriculture and rural development (Mulesa et al. 2021), and most times women have to hear from their husbands before making household level decisions even when they are not at home (Halbrendt et al. 2014; Pandey, 2019). At the same time, out-migration of working-age inhabitants in search of earnings to sustain livelihoods is clear and gendered in Nepal (Gartaula et al. 2010); mostly men migrate, leading to the so-called "feminization of agriculture," whereby women (Kelkar, 2010) assume the labor of agriculture (Kim et al., 2019), if not the decision-making (Sperling and Katungi, 2011; Pandey, 2019) or managerial roles (Pandey, 2019). Under these circumstances, varietal preferences and quality standards may differ according to female-valued traits, but access to seed and decisions regarding seed use may follow patriarchal social norms.

Literature (Maharjan et al. 2013; Saharawat, 2016) suggests community-based seed enterprises foster women's involvement in seed preservation and selection, using their traditional wisdom to maintain seed quality, increasing women's agency by enabling them to take part in a critical activity beyond household chores. Hence, inclusive community-based seed systems would be the best way to harness female wisdom for improved seed security outcomes.

Women performed the selection and storage of seed in the informal seed system; their involvement in decision-making and empowerment-based activities would also improve household seed security. Farmers agreed that men and women have different roles in household seed security. For example, a Dalit male participant in FGD stated that *"The seed quality of own stock is better in female-headed households, because they clean, sort, grade, dry, and store the seeds better than men"*.

6. Conclusions and policy implications

Macro level policies help determine seed system development for cereals such as maize and wheat (Erenstein and Kassie, 2017). Particularly in developing countries like Nepal, a strategy of fostering a pluralistic seed system including both formal and informal seed channels could be the best way to ensure seed security (Mulesa et al. 2021). Prioritizing the informal seed system would help ensure seed security, on the one hand, and practices such as seed exchanges help conserve the agrobiodiversity and indigenous seeds (Kiwanuka and Kintu, 2004). Inasmuch as farmers' purchasing power, location, and access to transportation can limit household access to seed from the formal sector, policies should also prioritize community seed supply chains (Sugri et al. 2013; Khan and Asim, 2020). While farmers in Mandan Deupur and Panchpokhari Thangpal are looking to start community-based seed production to reduce their vulnerability, we suggest including this win-win approach in the agenda for discourse and research in support of seed systems.

In summary, this study showed that households in the mountains of Nepal are seed insecure for maize and wheat and that the informal seed system plays a vital role in maize and wheat seed supplies. Promotion of formal seed systems, a priority of the Nepal government, while ignoring or working to the detriment of informal supply chains, would be missing an opportunity to offer farmers the best of both. Agrovets, which serve as formal seed suppliers in the remote parts of Nepal, need support for quality assurance. Caste/ethnicity and local geographies notably determine household seed security and household seed security is gendered. Women are key to maintaining informal seed channels and household seed security in the mountains. We recommend the promotion of women-focused community-based seed production, including seed banks and skill-based training and knowledge on crop varieties, and formal and open recognition of women's knowledge in maintaining maize and wheat seed systems.

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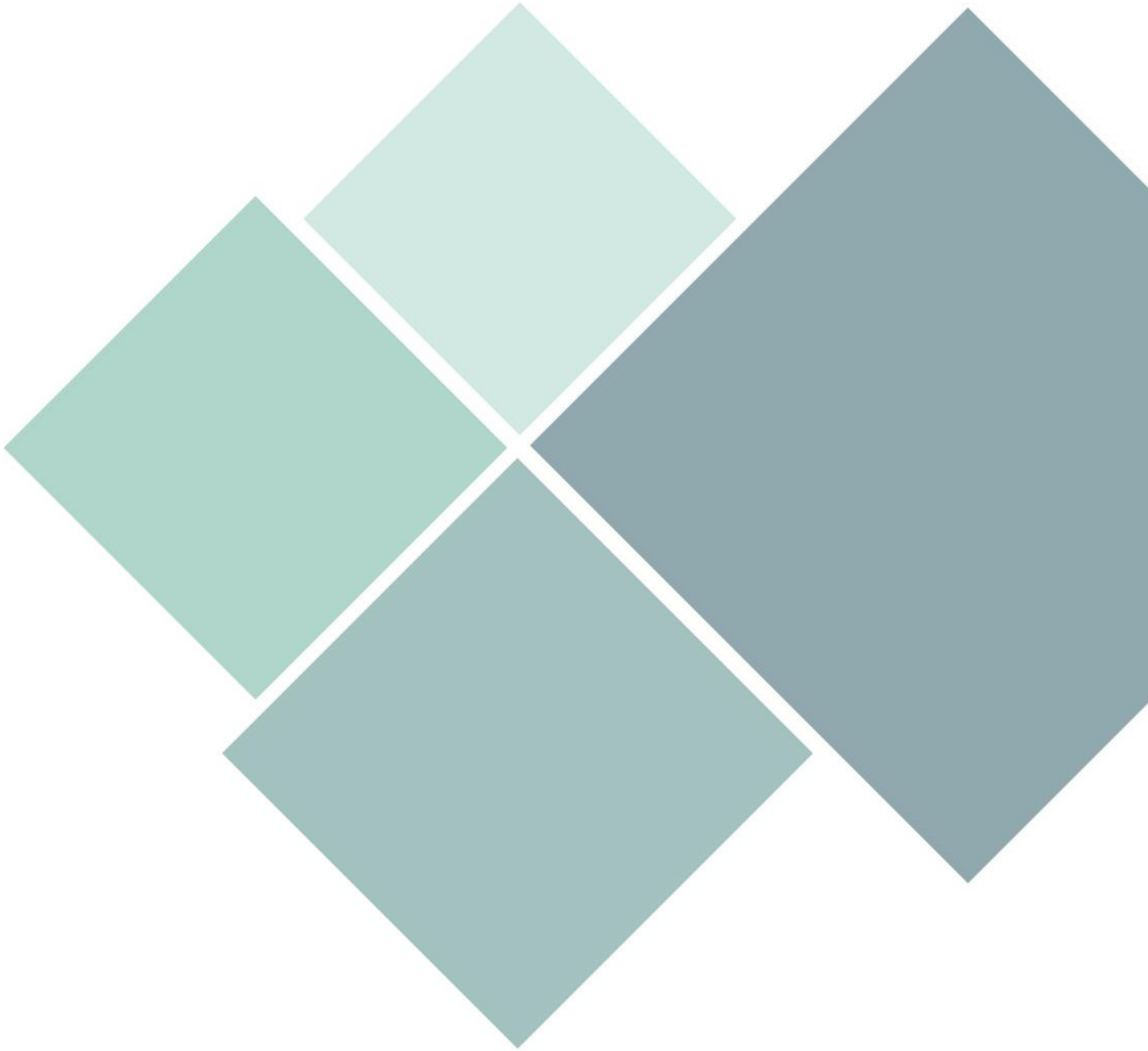
Appendix 1. Major findings of focus group discussions.

SN	Availability	Accessibility	Preference	Quality	Resilience
Brahmin / Chhetri	Comparatively greater number of seed channels and sources; depended more on formal seed channels (agrovet).	Better access to agrovet but access influenced by wealth status and community involvement; less frequent market visit by women due to household responsibilities and reproductive roles.	Shorter height, high productivity and less pest infestation preferred; moderate satisfaction in seeds currently used; women were less involved in formal systems but involved more in home saving of seeds.	Better quality of locally available seeds; seeds obtained from formal systems were often broken and of mixed sizes; maize seed quality degrading over the years.	More seed channels, community cohesion in seed procurement and fair enough purchasing power for the majority indicated better resilience comparatively.
	Inadequate availability of wheat seeds during COVID-19 lockdown.	Good access to wheat seeds; high involvement of women in seed related activities for example seed selection, grading, drying and storage.	Highly preferred existing varieties because of local availability of seeds, good yield, good taste and white wheat flour; hybrid maize was less preferred however some were often produced for livestock.	Seed quality was better, physically pure, productivity however declining over years.	Higher risk of disaster and insect pests, nonetheless high preference of local varieties, more seed channels, and community cohesion made them resilient.
Janajati	Relied largely on own stock and villagers; more dependency on informal seed channels	Poor access to seeds from agrovet; distant market and poor network with formal seed stakeholders	Mostly observed other farmer's farms and experienced for varietal selection; lower seed purchasing power; gender wise equal role on variety selection and preferred similar traits.	Seed packets comprised the seeds of mixed sizes and broken seeds	Few formal seed channels; poor accessibility; lesser involvement in groups and cooperatives and high reliance on informal seed system
	Inadequate availability of seeds; multiple seed channels; both formal and informal seed systems active.	Good access to seeds of preference; women often bought seeds from BC.	Highly preferred existing varieties because of high yield, bigger grain size, good taste; Pasanglamu better for making quality alcohol 'Chyang'.	Better quality of wheat seeds bought from an agrovet compared to home saved.	More resilient because of highly preferred varieties and high reliance on informal seed systems.

Dalits	Largely relied on neighbors for seeds; complete dependence on informal seed channels especially for wheat seeds.	Poor access to seeds due to lower purchasing power and distant market and poor social network.	Less awareness of the varieties grown; seed replacement depended upon neighbors' experience; higher involvement of women in training, local groups and farmer's cooperatives than men.	Locally produced low quality seeds were often used at a cheaper rate.	Poor availability and access to quality seeds indicated poor resilience.
	Unavailability of formal seeds at needed time; high incidence of insect pests on the home saved seeds; more women were involved in groups and cooperatives but lacked money to buy seeds.	Income affected accessibility; distantly located agrovets, so more seeds received from informal seed systems; labor exchange for seed was common ('perma') in Panchpokhari Thangpal.	Existing varieties were highly preferred because of high yield, uniform spikes (in wheat), good taste, less lodging, and nutritionally rich local varieties.	High seed quality, high seed germination (in wet soils); insects and disease infested seeds, use of high seed rates; intentionally did not follow seed purity for the sake of tying up the wheat bundles.	Poor availability and accessibility to quality seeds; no physical seed purity maintained; insects and disease infestations indicated poor resilience.



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