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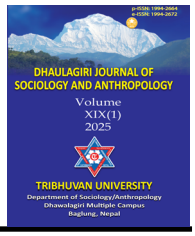

Women's Roles in Enhancing Food Security Through Postharvest Management Among Tharu Indigenous Communities

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Article Info
Received: April 5, 2025
Revised received: June 11, 2025
Accepted: June 26, 2025
Available online: June 30, 2025
DOI: https://doi.org/10.3126/dsaj.v19i1.77340

Abstract

Postharvest loss in agriculture is considerably high in developing countries due to the lack of infrastructure and technology. Changes in agricultural practices and climate variability further aggravate the risks of postharvest losses. Postharvest loss can be minimized using technologies, including generationally tested local knowledge of Indigenous Peoples, where women play critical roles. Despite its significance in developing new knowledge and technologies, Indigenous knowledge in postharvest management and its resiliency to climate change, particularly the contribution of women, is poorly documented in Tharu communities in Nepal. This paper thus documents the roles of Tharu women and Tharu Indigenous knowledge to ensure food security and promote resilient agriculture in general and postharvest improvement in particular. The study utilized qualitative research methods to explore and document postharvest management practices and technologies of the Tharu from gendered perspectives, considering cases from the eastern region (Bara), central region (Chitwan), and western region (Bardiya) of Nepal. The research revealed that the Tharu have locally evolved postharvest practices and technologies, such as sun drying after harvest and *dehari* or *kothi* grain storage technology, that minimize postharvest losses from insects, fungus, rodents, and climatic stresses. Women are central in postharvest processing, storage, and conserving seed grain. Therefore, development approaches that enhance women's knowledge, capacity, and efficiency in agricultural postharvest management can contribute to household and community food security and income.

Keywords : *Climate change, indigenous knowledge, Nepal, postharvest, Tharu*

Introduction

In many regions of South Asia, women are the custodians of agriculture (Sundberg, 2016; Atreya, et al., 2025). Their role in agriculture is extremely important in many developing countries, especially those marked by male labor outmigration, since in these regions women stay home while men are mostly mobile (Chaudhary et al., 2025; Suman & Adhikari, 2016). Their role is becoming more crucial than in the past due to the increasing rate of outmigration of men to the cities and abroad for jobs, contributing to increased feminization of agriculture (Tamang et al., 2014). Women contribute to crop production at all stages, from sowing or planting to harvest and postharvest activities.

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Postharvest management is critically important in crop production, and careful management in this phase is required (Hodges et al., 2011) to manage grain for food and seed for the next season. Postharvest operations involve carrying crops from the field, threshing, winnowing, cleaning, packaging, processing, drying, and proper storage in various types of storage systems for different crops. In effectively managing postharvest activities, women have often gained the necessary knowledge from their mothers, in-laws, other female members in the family, relatives, friends, and other people in the society.

Although women have the necessary skills to manage their crops after harvesting, agricultural challenges have evolved, including new pests and diseases. Increased hazards and disasters have further impacted food production, harvesting, and storage, exacerbating the challenges of maintaining food security (Chaudhary et al., 2021 & 2022). Climate change further intensifies threats to postharvest activities, particularly due to uncertainty and unpredictable weather conditions enhanced by increasing climate variability (Chaudhary et al., 2021). For instance, untimely and erratic rainfall impacts grain storage quality during or just after harvest and during seed drying and processing.

Although these problems have occurred in the past, they are now experienced differently due to changing agricultural practices, such as the use of improved rice varieties whose early maturation coincides with the late monsoon rains in the Tarai or southern lowland belt of Nepal, thus potentially causing substantial losses in matured and harvested rice. Therefore, it is important to know how farmers, particularly women, adapt to climate change risks and devise programmes to build on their existing local knowledge to accommodate the changing risks. According to the Food and Agriculture Organization of the United Nations (FAO, 2004, p. 1), local knowledge is community knowledge of people who may or may not be Indigenous Peoples and may have various sources. In contrast, traditional knowledge has the connotation of being "rural, isolated, static and not interacting with other knowledge systems", while Indigenous knowledge has a close association with "tribal groups" and the "original inhabitants of an area." In this article, Indigenous knowledge is used specifically regarding practices of the Tharu indigenous community.

As one of the Indigenous Peoples in Nepal, the Tharu have lived primarily in 20 districts across the country, mainly in the Tarai and inner-Tarai regions enclosed by Himalayan foothills of Nepal since at least the tenth century and consider themselves the original inhabitants of this region, often known as "*Adivasi*" in Nepali language. The Tharu in the Tarai were the only frontier group continuously settling in the area and supported Nepali rulers throughout previous centuries (Guneratne, 2010). The Tharu of the western Tarai have been, for generations, dependent on agriculture, with limited engagement in services, business, and foreign labor (Avis, 2018; Bista, 1972; Guneratne, 2002; Rajaure, 1981). Women have historically played active roles in agriculture at all stages, including postharvest management (Rajaure, 1981). Postharvest activities are complex and critical, as the potential destruction of all harvested crops, grains, and seeds can render production efforts futile. Therefore, a critical analysis of Tharu's postharvest activities is important for its seed maintenance and food security, including its adaptation to climate change risks. As research from a gendered perspective on this critical issue has been limited, this article explores local management tools, techniques, and methods to manage harvested crops, grains, fruits, and seeds, emphasizing the role of women in postharvest management in the context of Indigenous knowledge associated with these key activities among the Tharu.

The Nexus of Gender, Indigenous Knowledge and Climate Change in Regard to Postharvest Activities

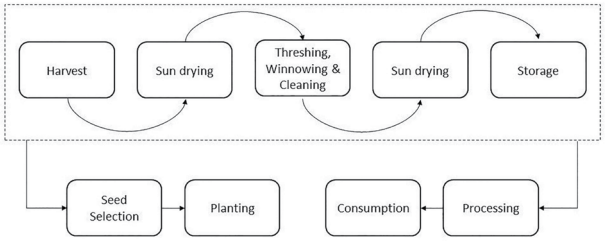
In Nepal, the postharvest losses at the farm level vary by crop. Postharvest losses of fruits and vegetables can be as high as 20-50% because of improper harvesting methods, postharvest handling, and inadequate transport and storage infrastructures (Gautam & Bhattarai, 2006). GC & Ghimire (2019) found the highest losses in lentil and mustard (5%) and the lowest in potato (3%) in Nepal. Postharvest loss reduction is important to increase production and productivity, particularly in labor-intensive farming in developing countries (Hodges et al., 2011). Farmers in rural areas in developing countries use various traditional postharvest practices and technology. Many of these often reflect cultural orientations, such as postharvest processing and use of spices among Newar in Kathmandu Valley (Tamang, 2016), maize storage among the peoples in the Hill Region (Atreya et al., 2025), and potato and grain storage among the Tharu in the Tarai of Nepal (Chaudhary et al., 2022). These technologies have achieved varying levels of successful preservation (e.g., avoiding fungus in maize) with zero-energy use (Chaudhary, 2021). However, improvements can be made, for example, in culturally embedded storage structures, such as the *dehari* among the Tharu. *Dehari* are earthen storage structures for grain storage, legumes and other crops. *Dehari* are known by names based on shape, size, and structure, such as the *Kothi* in Chitwan and Bara, Nepal. Using local traditional structures and practices remains one of the dominant options for local farmers in the absence of availability and access to advanced climate-resilient technologies and institutions. A gendered perspective contributes to illuminating how various postharvest practices, technology, and the local knowledge underlying them are associated with conserving crop genetic diversity to maintain agrobiodiversity and food security (Bhattarai et al., 2015). Seed preservation and cultivation are deeply associated to gendered sociocultural factors. For example,

whereas men tend to prioritize yield attributes, Tharu women preserve traditional glutinous *Anadi* rice in Nepal (Chaudhary, 2021), while Indian women prefer wheat varieties suitable for making *chapati* (homemade bread) (Gartaula et al., 2024).

Postharvest activities among the Tharu may include sun drying of harvested plant parts (e.g., paddy, wheat, lentil, and mustard) in the field, threshing and cleaning (e.g., winnowing), sun drying grains and seed to maintain an appropriate moisture level, various types of processing (e.g., milling) and curing (e.g., pickle making), storage, and cooking. Storage can be for different purposes: preservation of seed stock for future planting, consumption, and marketing (Figure 1).

Figure 1

Framework of postharvest activities (Seed selection is done at different stages depending on crops and farmers' needs and priorities)



Adaptation and mitigation of emissions in agriculture are largely focused on pre-harvest management stages, such as land management, technology, agrochemical use, and productivity increments relating to labor, land, and irrigation (Bhatta & Aggarwal, 2015; Caritas, 2016; Datta et al., 2022; Sterrett, 2011). In the food supply chain, "losses and wastage may be 50 percent between field and fork" (Lundqvist et al., 2008, p. 4). Losses from postharvest handling in the field, processing, and storage can be considerable in developing countries due to the inefficient transport facilities, processing, and storage technology (Gautam & Bhattarai, 2006; Hodges et al., 2011; Lundqvist et al., 2008). Despite the increasing role of women in agriculture in Nepal, they are still considered economically inactive, subsistence, and less important (FAO, 2019). Therefore, this study utilizes contemporary theories of gender, their Indigenous knowledge system for postharvest and seeds in the scenario of changing climate variabilities and the farming system of the Tharu women in Nepal.

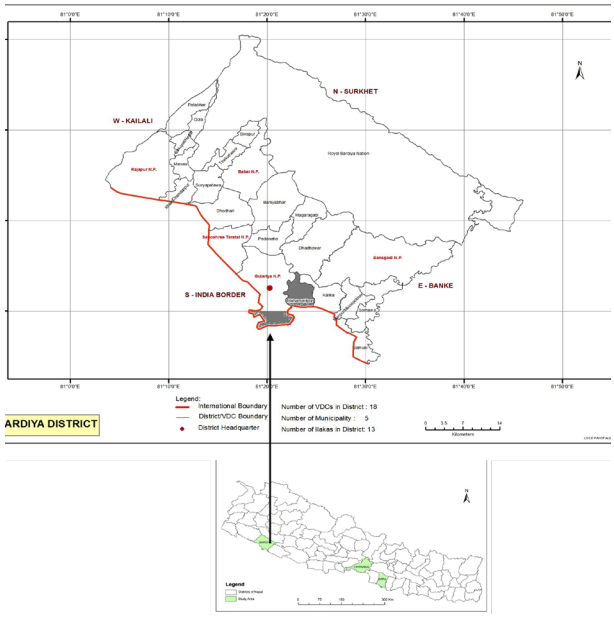
Methods and Methodology

Research Area

The study was conducted in Tharu communities in three districts representing different geographic regions, languages, and cultures to capture wider perspectives in the subject matter – Bara (eastern region), Chitwan (central region), and Bardiya (western region) (Figure 2). This study is primarily based on a detailed fieldwork in two villages, Thapuwa and Bikri, in Bardiya (Figure 2), complemented by information from Chitwan and Bara districts.

Figure 2

Map of Nepal showing study area - Bardiya, Chitwan and Bara districts (bottom). Upper map showing Bikri and Thapuwa study villages in Bardiya district.



Field Study and Information Analysis

The research was carried out with approval from the Human Research Ethics Office (reference number RA/20/4133) of the University of Western Australia, Perth. It utilized a sequential mixed-methods approach, with quantitative data collected through a household survey followed by qualitative data elicited through focus group discussions (FGDs) and interviews conducted over six months in two phases in 2018.

We adopted qualitative methods to gain an in-depth understanding of "phenomena of interest" (Creswell & Plano Clark, 2011) related to Indigenous practices in this case study. The first author conducted six months of fieldwork in two phases during his PhD research in 2018. The third and fourth authors conducted interviews during April-May 2022 in Chitwan and Bara districts, respectively. The 22 interviews with the key informants were conducted in Chitwan and Bara districts, while only one focus group discussion with Tharu women farmers was held in Bara District. The first three authors belong to Tharu communities, bringing their living memories and practices from their communities and insights from their elders. They also interacted with their parents/ grandparents, other family members, and relatives to refresh their memories and extract additional information

Table 1
Interviews, focus group discussions (FGDs), and household surveys during fieldwork in Bardiya, 2018.

Village	No. of households surveyed	No. female respondents in the survey	Female-headed households	No. of FGD	No. of participants in FGD	No. of female participants in FGD	No. of interviews	No. of female interviewees
Thapuwa	143	45 (32%)	1 (1%)	1	12	3 (25%)	6	2 (33%)
Bikri	86	32 (37%)	8 (9%)	1	10	5 (50%)	4	2 (50%)
Totals	229	77 (34%)	9 (4%)	2	22	8 (36%)	10	4 (40%)

on postharvesting practices.

After one month in the field, a census survey was conducted with all 229 residents in two sample villages (143 in Thapuwa and 86 in Bikri (Table 1). Two FGDs were conducted in each village (Thapuwa and Bikri) with the household heads or the representatives and traditional village leaders (*barghar*, *guruwa*, and *chaukidar*) to gain information on postharvest practices in the village households. The first author recruited participants in each FGD to ensure representation of different age groups, genders, education levels, and landholding sizes. Informal seed distribution channels were also discussed during the FGDs. Four women from the FGDs were selected for in-depth interviews and observations of postharvest activities. During administering in-depth interviews, the first author observed and took notes on postharvest activities, such as threshing, winnowing, cleaning, grading, drying, and storage. The collected information was then analysed thematically, pertaining to the research questions, and interpreted accordingly.

Results

Household characteristics are presented in Table 2 below to provide an overview of the fieldwork community. We organized the findings into the following topics, as presented in the processual framework above (see Figure 1): Harvesting, sun drying, threshing and cleaning, sun drying for storage, storage, processing and consumption, and seed for planting. The findings in this section focus on knowledge, technology, and practices in the Tharu, emphasizing women's roles and gender perspectives. Three of the subsections highlight the Tharu Indigenous technology of *dehari* for the storage of grains and other crops with reference to women's experience and knowledge.

Household Characteristics

Landholdings and other essential household characteristics are presented in Table 2. The households are small landholders; normally, a household head owns the land. Households in Bikri have smaller landholdings (0.6 ha/household) than in Thapuwa (1.2 ha/household). There are 19 *mukta kamaiya* families (former agricultural bonded laborers) in Thapuwa with small plots of land (0.1 ha/family). Despite the small landholdings, particularly in Bikri, the primary occupation of people in both villages is agriculture. The Tharu have been a patriarchal society, but the household leadership role of women is increasing in nuclear families.

Table 2
Average household characteristics of the study villages in Bardiya district.

Characteristics	**Thapuwa (n=229)**	**Bikri (n=86)**
Mean landholding (ha)	1.2	0.6
Mean family size	5.8	5.7
Median age of household head (hhh)	42	39
Literacy of hhh	96%	99%
Occupational agriculture of hhh	88%	85%
Female-headed households	4%	5%
Sharecropper (*bataiya*) percentage	64%	27%
Local non-cultivators with land	6%	2%

Most large farmers cultivate the land themselves, while some of them lease additional land or rent out part of their land for cultivation. When renting land, 50% of the product is usually shared, which is called *adhiya bataiya* (sharecropping). Sharecropping is common among many families, with 64% (n=91) in Thapuwa and 27% (n=23) in Bikri participating in the practice. There are a small number of non-cultivators, 6% in Thapuwa and 2% in Bikri, who own land but do not farm themselves. These families mostly engage in salaried work or are in skilled employment.

Table 3
Landraces cultivated in Thapuwa and Bikri.

Crop	Landrace	Characteristics	Reason of cultivation
Rice	Karangi	Black seeded with awn	Early maturity, direct seeding in dry or wet bed, early or late sowing possible, suitable in upland
Rice	Sauthyari	Covered in sheath, black and seed with awn (shorter hair than Karangi)	Early maturity, early or late sowing possible, direct seeding in dry or wet bed
Rice	Andi	Tall plant, red seed coat, large seed	Sticky rice, cultural value, *jaar* (sweet rice beer)
Maize	Raksi/Gaiji	Short plant, normally two cobs, short and compact seed	Popcorn, hardy, short growth duration allows timely sowing of mustard in winter, taste
Mustard	Local lahi	Blackish brown seed, dwarf	Productive, oil has strong smell and taste, short crop duration
Lentil	Kariya Masri	Small and blackish seed coat, red cotyledons	Taste, mixes well in cooked rice, locally adapted, drought-resistant
Pea	Local	White and medium-size seed	Taste, withstands drought and cold waves
Potato	Tharu alu	White small tubers, red eyes in tuber	Taste, resistant to late blight, long postharvest life
Vegetable	Poe sag *(Basella alba)*	Perennial, climber, red vine, berry red upon ripening	Waterlogging tolerant
	Kundhru *(Coccinia grandis)*	Perennial, climber, year-round fruiting	Drought tolerant

Crop Landraces

Landraces are an important source of genetic agrobiodiversity among the Tharu women play particularly important roles in selecting and preserving seeds. Many landraces may produce lower yields than improved varieties, but many have characteristics that farmers prefer. Table 3 lists some of the most important crop landraces in the study area.

Despite lower yields, farmers grow local landraces for their hardiness and taste, sometimes because they lack access to improved varieties. These landraces contribute to food security, as total crop failure does not occur for these landraces under hard climatic circumstances (drought, flooding, pests, and diseases). However, Tharu farmers are open to adopting new crop varieties, technologies, and practices.

Harvesting

Harvesting crops at the right time and using appropriate methods to avoid potential losses is important. Preparing for harvest includes the drainage of excess water from rice fields and planning for harvesting and drying. There is a higher engagement of women in harvesting. However, the role of men is higher in pre-harvest preparation oriented to finishing the farm activities in a timely fashion, so that men can then go outside the village for casual jobs. The role of women is again greater in postharvest, though men also support women throughout the process. Although there is less distinction in postharvest work between men and women in the Tharu communities because they help each other in most of the activities, men normally do not perform winnowing of threshed or milled rice in Bardiya. Tharu use various traditional methods and strategies based on crop type, seasons, and harvesting techniques and methods (Tables 4 & 5). Harvesting is mostly performed manually using the sickle, but machine harvesters have been introduced for wheat and rice. Rice is harvested 15-20 cm above the soil level in normal conditions. However, the height of stubble is increased if the field is wet due to the onset of the rainy season before harvesting has been completed, such as *Chite dhan* (spring rice) in Chitwan. Wheat is harvested when it has dried in the field, turning a golden colour. Similarly, maize is harvested when cobs are brownish-white and the cob silk is dried. During the spring, farmers remove tassels above the cob one week before harvest. The upper part, including the tassel, is used as animal fodder during the dry season.

Pulses are hand-harvested with or without sickles in Bardiya, Chitwan, and Bara. Lentil and mustard are harvested in the morning with more moisture to avoid pod dehiscence. Plants are harvested and placed in small piles in the field for field drying. Mustard is harvested when plants turn a pale yellow colour. Field drying is done for 1-2 days.

Seed selections are performed during pre- and postharvest stages and are mostly done by women. Rice seeds are selected based on small plots (about 200 – 500 square meters) and on the specific grain quality of panicles when a few seeds are needed. Similarly, maize is selected based on the quality of individual plants, and lentil and pea seeds are selected at the later stages of postharvest, normally during cleaning and grading. This is mainly done by the Tharu women across the three districts.

Sun Drying Before Threshing

Post-harvesting activities, including sun drying, are mostly done by women in the field. These activities are

done to reduce the moisture of plant parts, ease threshing, and reduce loss during shattering and beating. Farmers sun-dry plant parts in the field and yard (*khalihan* or *kharihan*). Table four shows sun drying methods of different crops for threshing and storage, with indicators experienced by the Tharu women. Rice and wheat are harvested in thinly spread rows called *nihna* for 1-2 weeks. Dried crops are transported by carts, tractors and manually to the yard. Men carry crop bunches on their shoulders by using a special type of wooden sticks (*bhattha* – straight – and *suila* – slightly bent). Crops are piled open to the sky in the yard in specific stacks (*kharhi*) before threshing to protect the harvested crops from rain (Figure 3). Sacks have different shapes, but normally in a circular form, topped by a pyramidal shape. Men and women perform the work together. The importance of *kharahi* is decreased because of threshing machines, but it is still common to store hay similarly in raised beds called *tauwa*.

Figure 3
Temporary rice stack (Kharhi) in rice field

(Photo credit: Samantha Day)
Photo source: https://www.recordnepal.com/what-happened-to-agriculture-in-nepal

Table 4.
Local indicators for harvesting preparation and pre-storage crops

Crop	Indicators
Rice	Harvest and leave in the field to dry until green stem completely dry. *Kharhi* (drying piles) in the *kharenhwa* (threshing yard). Undried rice breaks during milling.
Wheat	Dry as a standing crop, harvest, tie in bunches, and left in the field to dry. No need to dry after threshing.
Maize	Harvest, remove husk from cobs, sun-dry for 2–3 days, thresh and sun-dry for another 2–3 days until it produces a metallic sound during drying.
Red Lentil	Harvest and sun-dry for 2–3 days in the field or threshing floor and then thresh by trampling animals. Women biting, it should produce a *kitik* (sharp sound).
Pigeon pea	Harvest and sun-dry for 4–5 days in the field and then manually thresh.
Pea	Harvest and sun-dry for 4–5 days and then either walk animals over it or manually thresh. Biting easily separates cotyledons with a sharp sound.
Mustard	Harvest and carry out to yard for sun drying to protect from pod splitting. Sun dry until brownish seed turns to a blackish colour, immerse in hot edible oil, as cotyledons split when dry; watery burst when seed is not well-dried.
Potato	Air-dry in the shade. No moisture in the ground and the outer surface of tuber is an indicator for proper storage for the medium and long term.

Threshing and Cleaning

Traditionally, crop threshing is performed by making oxen and buffalo trample the plants or stalks. Some people also used to do manual rice threshing by beating the stalks on a wooden log when lacking cattle. Men and women generally perform this task. Maize is threshed manually by hitting the cobs with a wooden stick (*mungra*) and later removing grains by hand. Nowadays, there has been a transformative shift to harvest and thresh crops using a mechanical thresher for most crops, such as rice, wheat, and maize. Women participate equally with men during the threshing of crops; however, large machinery, such as threshers and harvesters, is usually operated by men. Some women have realized that such machinery has reduced the need for men's labor in threshing the crop, and women's jobs have increased due to their participation in machine threshing.

Cleaning of threshed grains is solely performed by women in Bardiya, but men also participate in Chitwan and Bara Tharu communities. Threshing by cattle trampling requires more cleaning than machine threshing, which usually uses a fan to blow husks. Women remove fill grains, husks, and other inert materials through winnowing by using a *suppa* (bamboo winnow) in concert with judging air speed and direction. During the process, women confirm the suitability of grains for home consumption, selling, and use as seed for the following year.

Grading and selection of seed is also performed at this stage. Grading is normally categorized as superior quality (no. 1 grade) and low/inferior quality (no. 2 grade). Superior quality seeds are mostly stored for subsequent planting (Figure 4). Grading of grains, their use (e.g., for planting seed, consumption, and sale), and preparation for storage are mostly decided and carried out by the Tharu

women. Farmers often clean and grade crops before sale to receive a higher market price.

Figure 4

Drying of quality rice seeds, known as Jhilmiliya in the Tharu language

(Photo credit: Bhaskar Chaudhary)

Sun Drying for Storage

The cleaned processed grains are sun-dried in a yard until their moisture level is reduced sufficiently to make it appropriate for storage. Women use their tacit knowledge to identify the appropriate crop storage indicators. There are no techniques other than women's judgement based upon Indigenous knowledge to determine the seed storage moisture. For example, some women bite the grains and feel hardened to decide whether they have been sufficiently dried. Their expertise in ensuring seeds are adequately dry and thus can be stored for medium to long periods without succumbing to mold or attacks by weevils and other pests is a major contribution to food security among the Tharu.

Threshed grains are spread thinly in the yard during the day for sun drying and covered into heaps at night. The drying period depends on the moisture content of seeds and ranges from 2 to 4 days. After sun drying, storage is done in containers such as *dehari*, *bakhari*, sacks, and other containers (Table 5, Figure 5 & 7).

Storage

Various postharvest technologies are available for agricultural produce to add value to the products before they are marketed or stored for food and seed. The Tharu use a variety of locally made structures and technologies to store and produce agro products. Table 5 shows a few common postharvest storage structures with typical functions in western Nepal.

Table 5

Common postharvest storage structures in the western Tharu.

Storage structure	Function	Storage duration
Dehari (earthen grain storage, see Figure 5 and 6)	Storage of agricultural produce, tools and goods. Rice can be stored for 4–5 years without damage. Hulled rice storage for short-term.	Long-term storage (>1 year)
Chhitni (made from bamboo) *Jhauwa* (made from climber plants)	Storing onion, garlic, potato and taro for a month to a season.	Short-term storage (<6 months)
Bakhari (made from bamboo, elephant grass, refer Figure 7)	Mostly used to store rice before sale and excess rice that cannot be stored in *dehari.*	Medium-term storage (up to 1 year)
Surli (hanging maize outside the house)	Maize hanging in a sunny open area for sun-drying and storage.	Medium-term storage
	Garlic, hanging in shade and open area for storage.	(up to 1 year)
Alu poka (seed potato wrapped in rice straw and plastered with cattle dung and hung in shade)	Tharu Indigenous technology to store potato; little decay (<25%) inside the bundle.	Medium-term storage (6–9 months)

Underground storage	Taro storage underground for seed. Mixing taro with turmeric and plastering on the ground with straw and cow dung is better than the sole storage of taro.	Medium-term storage (up to six months)

Pulses and cereal grains are stored in *dehari* or *kothi* – a medium- to small-sized storage container made of mud and dry straw. *Dehari* and *kothi* are different names for the same structure in western and eastern Nepal. These containers, *dehari* or *kothi*, are generally placed 15-30 cm above the ground to keep them dry and protect them from insects and ground moisture.

Crops are properly stored in the storage structures (e.g., *dehari* and *bakhari/ bhakari - Chitwan* and *Bara,* Figure 7) for various purposes, such as consumption, sale and seed. Rice, wheat and maize are stored for one to five years for household food security. Storage is generally done by women, and the storage structures are also made by women. Grains are stored for a few months before selling when the market price is high. Men's roles are clearly differentiated in the selling of agricultural produce. Mostly, men decide when and where to sell because of their access to market information. Men also mostly control the cash gained from selling the agricultural produce. Our livelihood capital assessment showed that men have higher land ownership and better access to education and financial institutions (banks and cooperatives) than women. However, participation of women in saving and credit groups is higher than that of men because of their financial discipline and responsibility for household chores and farming after males have migrated to seasonal and international jobs. The crop is also stored generally by women to provide the seeds for the next season's cultivation, which are often exchanged through informal networks of family members, relatives and friends.

Among the various postharvest structures, *dehari* is probably one of the oldest Indigenous technologies in Tharu communities. However, potato storage in rice straw plastered with slurry of cattle dung has gradually been replaced with the availability of cold storage and transport (tractors). In the following sub-subsections, we will describe the *dehari* and experiences using it, as well as its role in climate adaptation and working towards a low-carbon society.

Dehari—Tharu Indigenous Technology for Seed and Grain Storage

Dehari is an earthen storage structure built at home by Tharu. There are different types of *dehari*, each known differently according to its shape, size and use: *dehari, kuthli*, and *jabara*. *Kuthli* is a small form of *dehari,* which is normally chest height (80 cm). It is used for the temporary storage as a pantry of daily use goods for the kitchen, such as hulled rice and split pulses. *Jabara* is circular, increasing gradually from the bottom to the centre and decreasing from the centre to the top, making a dumbbell shape. Unlike *dehari* and *kuthli*, it does not have an *aan* (lid). It is used to store blankets, beds, utensils and art crafts (*dhakia, gondari, suppa,* etc.).

The main parts of the *dehari* are the *pendi* (base), body, neck and *bharkan* (cover) (see Figure 5). All parts of the *dehari* are constructed separately and then assembled. The *pendi* is as large as the main body. It holds the main body of *dehari* and is one of the thickest parts (~5 cm); if the *pendi* breaks, then the life of the *dehari* is over. The body part is normally made of 2–3 sections and determines the height of the *dehari*. The thickness of the clay wall of the body is 3–4 cm. The neck is slightly narrowed, and it holds the cover. The thickness of the neck is similar to that of the main body. The *bharkan* (cover) is circular and slightly thinner than the *pendi* (base). There are two additional parts of *dehari*, *aan* and legs. The hole from which grain is removed is called *aan*. It is located about 15–20 cm above the *pendi*. The entire *dehari* structure stands upon the legs (usually two), which are made of wood, brick or mud. Termite attack is unlikely with *sakhuwa* wood (*Shorea robusta*) and brick legs. The legs are generally 20–30 cm long, depending on the need, and about the width of a brick (20 cm).

Figure 5
Rice storage in dehari

(Photo credit: Buddhi R. Chaudhary)

Figure 6
A woman constructing a dehari

(Photo credit: Buddhi R. Chaudhary)

Figure 7

Bakhari or *Bhakari* to store grains among the Tharu communities in the Bara district of Nepal

(Photo credit: Reena Chaudhary)

Dehari and its Importance in Tharu Communities

Dehari is not only used for seed and grain storage, but also as a room separator; it has cultural importance, e.g., as a wall painting (*Astimki*) to celebrate the birthday of Lord Krishna. *Astimiki* falls on Krishna janmasthami, but the ritual is a broader cosmological and spiritual event. It's not only focused on Krishna, but also depicts the whole universe, such as plants, animals, natural spirits, gods, and demons, showing the Tharu community's connection with nature and the universe.

Pataha dehari (also called *altar dehari*) is one of the biggest and most important *dehari,* which separates the *deuhrar* (divinity room) and the *bhittar* (kitchen). *Pata* is the place for deities; the *Maiyak pata* (the central place for the main deity) is in front of the *pataha dehari* and is where the holy bag (with *Guru Baba,* the first Tharu and the creator god) and other divine tools, such as a cane and a sword, are hung. It also promotes family ties, since it is a gift from the mother-in-law to the daughter-in-law for her assuming post-marital residence with her husband's family. One informant asserted:

> *Dehari* is not only a structure, but it also reflects the skill of women and is a remarkable gift from her elders. She honoured and remembered her mother-in-law, who made *patha dehari* 18 years ago (2000), and there is a 28-year old *dehari* that has been made by the middle daughter-in-law.

The importance of *dehari* persists in the modern house[1], as it does in the traditional wooden house in the Tharu community. However, due to the modern concrete types of houses, *dehari* are gradually being moved from the main house to separate subsidiary houses. Various alternate storage structures have been introduced in the villages, but many are unused and inferior to *dehari*. Participants had experience storing cereal grains in *dehari* for 5-7 years without damage to the grains. There is zero-energy use for storage, which is resilient to heat, cold, and even moderately resilient to rain in flood-affected areas, such as in Thapuwa, Bardiya.

Women's Experience with *dehari* Use

One woman at Thapuwa said:

> There is no storage better than *dehari*. Y u can see [showing the damaged wheat that she was drying]! When I opened my wheat stored in a plastic container, it was black. I lost my seed and had to buy from the market.

Aluminium and plastic bin storage are promoted in the villages by governmental and non-governmental organizations, but the *dehari* remains the most common and preferred storage practice of the Tharu. The use of aluminium and plastic bins for grain storage is a recent initiative that most of the interviewed women in the village have been trying since 2014. All the interviewees except one have had poor experiences storing rice in bins. Two participants agreed to store rice/grains in aluminium bins, but only briefly (<3 months). *Dehari* is a multipurpose storage structure that the Tharu have used for generations; hence, their attachment to *dehari* is high. All participants described how paddy could be stored for up to five years without damage in the *dehari*. However, one of our participants (50 years old) shared her experience of decreasing use of *dehari* because of the frequent flooding in the village:

> Tin storage bin-stored rice and other grains stored in tin bins are inferior to *dehari*. The grain stored in tin becomes green, blackish, and mouldy even in one year. Because of the flood problem in the village, the use of *dehari* has decreased. Instead, people are storing food in plastic drums and plastic tanks. It floats over the water in floods and thus needs to be tied with strong poles so that it cannot float away in the water.

Frequent flooding and easy access to plastic bins have reduced the use of *dehari*. The floods regularly damage homes and infrastructure, including the *dehari.* At the same time, the growing presence of cheap plastic containers has replaced many handmade items that once required labor to produce and maintain.

Processing and Curing

Curing and processing are mostly applied to fruits and vegetable crops to extend the postharvest life of lean or off-season produce. Women have a wide range of knowledge and skills for curing fruits and vegetables. There are different techniques to cure and process fruits and vegetables. The most common are drying (sun and fire), water boiling (e.g. turmeric), fermentation (pickles,

1. Modern houses among the Tharu are made of brick, cement and iron rods, which are permanent in nature, whereas local traditional houses are constructed with timber and locally available forest materials and roofed with grass and tiles.

sinki, and *jaar*), and distillation (*daru/madd* – a local liquor). The *jaar* (rice beer) and *maar* (boiled rice soup to drink in the summer) exemplify unique food culture within the Tharu community.

Food preservation provides food during lean periods, contributing to household food security, as dried and preserved vegetable items are not only an important source of food, but the preserved food also reduces the daily burden of women cooking vegetables during the off-season. Some examples include dried vegetables (*pithari, sinki, and lechara*), homemade food for long-term use (*maslar, maseura*), and fruits such as mango (*amoth* and pickle). However, cultivating vegetables in the off-season period at the household level and the availability of vegetables in the market have reduced the use of preserved food.

Seed Selection

Women play a crucial role in conserving seed genetic diversity through seed conservation, cultivation, and its distribution. The landraces have been maintained through storage and sowing for over 30 years and distributed informally to relatives, neighbours, and friends. However, there is an increasing trend of using improved and hybrid rice, maize, and wheat seeds.

Informal seed distribution channels are still strong in the area. For example, it is found that seeds from Bikri village are dispersed to neighbouring districts, such as Banke, Dang, Kailali, and Kanchanpur through relatives and friends. Similarly, seed distribution channels from Thapuwa extend to Jaliha in India following marriage ties and to the neighbouring districts of Nepal. Seed exchange is not a barter system; rather, seeds are given as gifts to relatives and commonly sold to neighbours and friends for cash. Vegetable crops such as coriander, garlic, turmeric, potato, gourds, okra, and hot peppers are commonly distributed through such channels, including local varieties of cereals and pulse crops. Participants revealed historical and cultural connections with landraces for preservation and cultivation.

Discussion

This study has focused on the gendered division of labor and associated traditional knowledge in various stages of cultivation, with a heightened focus on postharvest activities, particularly highlighting women's roles concerning the storage structures prevalent in the Tharu community. The study also relates how Indigenous knowledge in postharvest practices, grain storage, and food preservation enhances the climate resilience of the Tharu communities in Nepal. We argue that the postharvest knowledge held by the Tharu women, such as understanding optimal grain moisture levels for harvest and storage, constructing diverse storage structures, and conserving and exchanging seed genetic materials, improves the resiliency of farming communities from climatic stress, hazards, and disasters.

The Assessment Reports of the IPCC (2007 and 2014) have recognized the value of Indigenous knowledge in generating scientific knowledge and strengthening the resilience of Indigenous peoples. The role and prospects of science will increase in agriculture. In contrast, Indigenous knowledge remains a source of knowledge for modern science and a way of life for many rural farmers in developing countries, including the Tharu communities in Nepal. The knowledge of the Tharu men and women on weather and climate, perceptions of change in climate patterns (Chaudhary et al., 2021), helps them to apply in crop production and postharvest management. Traditional grain storage technologies such as *dehari*, practiced by the Tharu women, contribute to climate change mitigation by reducing the need for chemical pesticides and external energy inputs, thereby lowering greenhouse gas emissions and associated costs. The broader contributions of Indigenous knowledge to agronomic practices, plant protection, and agrobiodiversity conservation are described, particularly in relation to low external input use, genetic resource conservation, and environmental protection (Fitzwater, 1970; Warren, 1991; World Bank, 2004).

The gendered division of labor is culturally specified. While some agricultural roles are performed by men and women together, some specific tasks are solely performed by men and women separately. Bullock ploughing, driving animal-pulled carts, and house construction are predominantly performed by men, and even ploughing is said to be prohibited for women. Masculinity is socially constructed to perform outside, heavier jobs. At the same time, women are associated with household chores, kitchen work, and caring for family members in accord with local cultural constructions of femininity.

However, despite such norms of gender complementarity, the usual distribution of roles in agricultural activities can be transgressed. Traditionally, only men used to construct bunds in the farm, particularly during rice field preparation, seed sowing in seed beds, furrow making for potato cultivation, crop threshing, and management (*Aakhain chalaila*). However, the first author observed women undertaking such activities in both study villages (Thapuwa and Bikri) in Bardiya and was informed by many women that they undertook such activities. For example, he witnessed Bharose's sister, who had recently graduated from college, top dressing in a potato field for two whole days. Her parents and other villagers said, "There are indeed a few women who work hard in agriculture". The first author also observed Bharose's wife preparing the bund in the rice seed bed when her husband leveled the rice field in June 2018. Moreover, his wife helped sow rice seeds when it got dark. Women are thus now undertaking what used to be male-defined work in agriculture and farming. Tharu women have been diversifying their agricultural roles not only in a

supporting capacity, but sometimes in leadership roles, due to demographic imbalance in the household due to male deaths or outmigration of men undertaking labor outside the villages.

In contrast, men still do not undertake certain activities under any conditions, such as winnowing milled rice and much work in the kitchen. In most Tharu homes, women prepare food, serve it to their children and men, wash dishes, and are the last to eat rice. Such asymmetries still index the unequal status accorded to men and women despite changes in the gendered division of labor in agricultural field activities. The feminization of agricultural activities has not led to a corresponding masculinization of domestic activities.

Although both women and men perform crop harvesting, women tend to put in more work hours on this task. The norms of Tharu society designate crop harvesting as a woman's job. Men often try to escape from crop harvesting and use nontraditional methods or become involved in other agricultural activities. In recent years, large farmers have used wheat harvesters and even combine wheat harvesters to accomplish rice and wheat harvesting. Manual harvesting with a sickle is also common in the area on small holdings. Some farmers in Thapuwa village also have rented a combine harvester for wheat from a nearby village (Bandhupur) or even from neighbouring villages in India.

Tharu women's roles in agriculture in general and postharvest in particular are changing, often manifesting in their increased workload in agriculture, sometimes combined with foreign labor work or seasonal work in other domestic and foreign labor markets, including India. Various researchers have described women's increased agricultural workload and the general feminization of agriculture in Nepal (Sunam & Adhikari, 2016; Tamang et al., 2014). Agriculture and postharvest jobs have become further labor-intensive to adapt to climatic factors (rainfall patterns, increased temperatures, and shifting in agroecological zones) (Practical Action, 2009; Chaudhary et al., 2021). For example, *chaite dhan* (spring rice) in Chitwan must be harvested before the onset of summer rains. Similarly, early maturing rice varieties in the Tarai region of Nepal are at increased risk of damage due to post-summer rainfall, which can affect both mature and harvested rice.

The use of farm machinery has significantly reduced farmers' workload. The use of crop harvesters and other technology has reduced the workload of women in particular (Paudel et al., 2020), but the threshing machine has further increased the workload of women in threshing. In the past, males were responsible for threshing crops by cattle trampling. Men now mostly operate tractors, harvesters and threshers. Therefore, there is a need for training and skill development of women or the introduction of machinery that reduces the workload of women. The use of wind blowers (fans) facilitates women's work in winnowing, whereas earlier they had to depend on the wind. However, the adoption of small-scale farm mechanization, such as the mini-tiller, has been significantly lower in female-headed households in Nepal due to gender-differentiation and the absence of market access.

The traditional knowledge and storage structures, such as *dehari,* have been resilient regarding climate variability. Zero-energy use has thereby contributed to climate change mitigation in agriculture. There is low damage from insects in the *dehari*, thus promoting long-term storage and food security. Women believe that there are fewer attacks of weevils and rice moths and no mold formation in *dehari*; moths even die in it, and the grain remains safe. There is a risk that termites enter from the wooden or mud legs, so termite-resistant materials, such as brick legs and plastic inserted between the legs and *pendi* (base), are desirable. *Dehari* has an essential role in food security, as it is mostly used to store unhulled rice for next year's crop.

Dehari are the most important structures for storing a variety of crops in the short and long term. Grains, pulses, and mustard are widely stored in *dehari*. Furthermore, milled rice and split pulses are also stored for day-to-day use in the kitchen. The *dehari* is based on the principle of being airtight, with heat insulation. It maintains the temperature and protects from moisture absorption from the atmosphere, two essential factors for seed storage, longevity, germination, and vigour, also noted by Justice & Bass (1978). *Dehari* are sealed airtight, which decreases the level of oxygen and increases the level of CO_2, causing asphyxiation to weevils (Cheng et al., 2012). *Dehari* are semi-resistant to flooding; however, an extended period of waterlogging during flooding destroys *dehari*. Techniques to improve traditional storage structures, including *dehari,* have been tested in flood-affected areas of Nepal, including raising legs and base and plastering surfaces (Khadka, 2018).

Traditional knowledge in postharvest phases improves the resiliency of farmers in local conditions in the absence of alternative technology and infrastructures. The tacit knowledge of farmers in judging crop maturity, appropriateness of drying crop in fields, and seed moisture for storage remains important in Tharu farming communities, and the latter two are primarily the domains of women. Such tacit knowledge is important in the rural farming communities where such technologies as grain dryers, seed moisture recorders, and climate-controlled storage facilities are not yet available. The future adoption of such innovative technologies and their integration in the existing postharvest management arrangements may facilitate postharvest tasks being carried out in a more efficient and cost-effective manner, but their impact regarding the gendered division of labor is difficult to predict.

The significance of *dehari* goes beyond just its function as a grain storage structure. D*ehari* are culturally inherited in the Tharu society and have become a salient

aspect of local culture. Their transmission from mother-in-law to daughter-in-law can provide an important means of integrating a virilocally resident wife into her husband's household. They are an integral part of a traditional Tharu house due to their function in separating the house into different rooms, and the *pataha dehari* also fulfills important functions in household religion. Grains can be stored for several years in *dehari*, providing a safety net for farmers facing adverse climatic conditions, such as droughts, crop failure, and flooding disasters. *Dehari* also indicates the agricultural produce and storage capacity of the household, serving as an indicator of the economic prosperity of the household. Rivera-Ferre et al. (2013) have also mentioned the use of *kothi* (i.e., *dehari* in the western Tarai) for storing grain among the Tharu of eastern Tarai, Nepal, where the number and size of such storage structures reflect the economic prosperity of households.

Women have a very important role in the conservation of agricultural biodiversity and in the continuity of local and Indigenous knowledge and practices in the Tharu community. Seed is the foundation of agriculture and basis of food security, and Tharu women remain important in its selection, processing, saving and subsequent replanting in the next season for many local crops. There is an increasing role of men in buying improved and hybrid seed from the market, but women retain a very important role in informal seed exchange and its distribution. *Andi* rice (sticky rice), a popular Indigenous type of rice among the Tharu, is conserved and cultivated in the Tharu community because of the role of women in decision making and informal seed distribution. *Andi* rice is culturally important, as this rice is eaten in *Maghi*, the biggest festival of the Tharu celebrated as the New Year. *Jaar* (local rice beer) from *Andi* rice is sweet and has a greater volume than other rice-based beers. Indigenous food, such as *bagiya and bhakka* (also called *dhikari* in western Nepal – steamed rice flour) also plays a role in landrace seed conservation in the Tharu community in Nepal (Tamang, 2016). Analogously, Gartaula et al., (2024) describe a different crop variety preference among Indian farmers, where women prefer chapati quality whereas men focus on yield.

Conclusions

Indigenous knowledge, skills, and traditional practices relating to postharvest operation and management have enhanced farmers' capacity to secure agricultural produce safely in different climatic conditions. The skills and practices associated with harvesting, drying, cleaning, grading, and storing crops help farmers maintain food security, and in the current situation, to adjust to changing weather conditions and climate trends, ultimately enhancing the adaptive capacity of the farmers in the changing context of climate change. However, knowledge, skills, and practices can be improved by adopting improved technology, such as harvesting and threshing machines. Such machines increase work efficiency, as well as reducing the risk of crop damage from post-monsoon flooding. Such technological adoption has reduced the workload of both men and women, but there is a need for social transformation to change the gendered division of labor in postharvest handling and storage. In particular, there is a need to emphasize gender equality in farm machinery adoption and use in agriculture. There are some positive signs of change in the allocation of gender-based roles, where both men and women are contributing to each other, but the introduction of heavy machinery runs the risk of emphasising male dominance in its use.

Women continue to perform numerous roles in ensuring food security among the Tharu through their participation in various phases of agriculture, but particularly in their roles in postharvest activities. Their expertise in assessing sufficient drying of harvested crops assures minimization of loss due to moisture or pest attacks, such as weevils. Their role in seed selection contributes to the preservation of agrobiodiversity and the distribution of crop types for subsequent plantings that contribute to agricultural resilience. Their acumen in choosing appropriate storage structures for harvested crops is crucial in ensuring food preservation for their households and seed stock for future planting. Among various postharvest storage structures, *dehari* are deeply embedded in the Tharu culture and tradition for grain storage, and they contribute to traditional house design and the performance of domestic rites. They provide a zero-energy form of storage, are semi-resilient to flooding, and can indirectly curb emissions of greenhouse gases and enhance adaptive capacity in the absence of other improved storage technologies. *Dehari* also functions as a seed bank for a household, ensuring seed security in extremely adverse climatic conditions. The culture of storing grains for the following season, made possible by *dehari,* also serves as a traditional safety net for resilient farmers. *Dehari* are iconic of women's predominant role in postharvest food storage. They are solely constructed by Tharu women, who have recently modified the legs with bricks and wooden logs to be further resilient to flooding. Transmission of *dehari* from mother-in-law to daughter-in-law in some contexts also contributes to the stability of the household. It symbolizes the continuity of women's role in food storage and agriculture in general.

Indigenous knowledge, skills and technology have contributed to farmers' coping strategies and adaptations to emergent adverse situations. However, improved and transformative approaches in technological innovation are needed to confront the even greater adversities expected with climate change. However, such innovations will not be effective unless the salient roles of women in agriculture, particularly in postharvest activities, are fully recognized and their engagement is improved in transformative innovations.

Further research is needed on various dimensions of their roles and the factors leading to changes in them, as

well as emergent transformations of local understanding of women's capacities and performance of an ever greater role in agricultural and other tasks. The impact of men's outmigration for a variety of jobs in domestic and international contexts upon the feminization of agriculture needs to be assessed more fully across a wider range of Tharu contexts and among neighbouring agrarian communities in Nepal. Emergent paradigms such as intersectionality (Collins & Bilge, 2020) assessing how multiple factors affecting a person's identity can impact upon trajectories of marginalization will help to contextualize how gender conceptions and expectations in agriculture interact with other factors such as religious identity, class position, regional location, norms of care-giving and others to define the parameters and constraints upon women's productive contributions to household economy. As a contribution to this continuing process of analysis, this article has endeavoured to document and assess the evolving roles and knowledge of Tharu women in agriculture to highlight the importance of their knowledge and contributions to labor, particularly concerning food security, but also increasingly to resilience in the face of climate change.

Declarations

Ethics Approval and Consent to Participate

The research was carried out with the approval from the human research ethics office (reference number RA/20/4133) of The University of Western Australia, Perth.

Consent for Publication

Written consents were taken from the participants for interviews, participant observations and photographs to publish for this research and publications.

Availability of Data and Materials

Data from Bardiya district, Nepal, in the form of hard and electronic data are stored as per the policy of the University of Western Australia, Perth. Data can be shared with approval from the University of Western Australia, Perth. Data from Chitwan and Barad districts are stored by the respective researchers.

Competing Interests

There is no financial gain or interest from this research and publication.

Funding

This work derives in part from the PhD thesis research of the first author, which was supported by The University of Western Australia.

Authors' Contributions

Dr Buddhi R. Chaudhary: Information collection from Bardiya, analysis, synthesizing analysis, original draft, revision and finalization.

Dr Greg Acciaioli: Conceptualization and contextualization of the argument, structure of the article, and writing style and regularization of the format.

Dr Pashupati Chaudhary: Data collection from Chitwan district, conceptualization of research, contributed to original draft

Dr Sunita Chaudhary: Data collection from Bara district, contribution in original draft, inputs on revision.

Dr William Erskine: PhD supervisor of first author, technical aspect of postharvest.

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