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Productivity and sustainability assessment of dry direct seeded upland rice in the central mid-hills of Nepal

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Abstract

The dry direct-seeded upland rice is locally known as Ghaiya Dhan, is a crucial crop for food security in the hills of Nepal. However, its cultivation area and production have declined sharply over the past decade due to various biotic and abiotic stresses. A field study was conducted in the spring season 2023 across four central mid-hill districts like Dhading, Gorkha, Tanahu, and Sindhupalchowk. The findings reveal that the smallholder farmers and ethnic minority communities are found predominantly engaged in upland rice production with average field size ranged from 0.10 ha (Sindhupalchowk) to 0.24 ha (Tanahu) with an overall average of 0.15 ha.The field preparation predominantly involved three rounds of ploughing using local tools with seed sowing through broadcasting method @ 80–100 kg seed per ha. A total of 16 rice varieties were cultivated by the farmers including 13 local landraces and 3 improved rice varieties. Approximately 70% of farmers applied organic manures for crop nutrition. The major constraints identified were weed infestation (41.7%), soil moisture stress (13.3%), and low productivity (8.3%). The five most problematic weeds were *Cyperus rotundus* L.,*Cynodon dactylon* L., *Echinochloa colona* L., *Ageratum houstonianum* Mill and *Digitaria sanguinalis* L.The key pests included were stem borer and rice gundhi bug,while rice blast and brown spot were the predominant diseases. The grain yields were found low, ranging from 1.6 to 2.8 tons per hectare which is primarily due to above mentioned constraints and the use of low-yielding varieties. The grain nutrient analysis report revealed that the local landraces possess superior nutritive value, with higher crude protein (12.34 %) and calcium (99.01mg) content compared to popular improved varieties (10.63 % and 71.03 mg). These findings highlight the need for targeted interventions to improve upland rice productivity and sustainability for ensuring continued food security in the hilly regions of Nepal.

Keywords: Biotic stress, Dry direct seeded rice, food security, upland rice, weeds, yield

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INTRODUCTION

Rice (*Oryza sativa* L.) is Nepal's principal cereal crop, contributing approximately 20% to the agricultural gross domestic product (AGDP) and accounting for 53% of the total cereal crop production (MoALD 2023). In 2024, rice was cultivated on about 1.4 million hectares, producing around 5.4 million metric tons (AITC 2024). Despite its critical importance in the national food system, domestic rice production has not been sufficient to meet internal demand, leading to rising imports in recent years.

Rice in Nepal is broadly classified into lowland and upland types based on agro-ecological conditions. Upland rice is cultivated in dry, rainfed, and naturally well-drained fields where no standing water is present during the growing season, and seeds are broadcast directly into dry field (Joshi et al 2000). Globally, upland rice covers nearly 14 million hectares, with about 8.8 million hectares located in Asia and contributing roughly 6% to total rice production (Saito et al 2018). Major upland rice-producing countries include Bangladesh, Cambodia, China, India, Indonesia, Myanmar, Thailand, Nepal, and Vietnam. In remote upland regions, it serves as a staple crop, primarily supporting subsistence farming systems (Wang, 2010). However, upland rice cultivation has declined over the decades due to recurring droughts, low soil fertility, and both biotic and abiotic stresses (Barik et al 2019; Lafitte et al 2022).

In Nepal, dry direct-seeded upland rice—locally known as Ghaiya Dhan is mainly cultivated on marginal terraces and tars in the central mid-hills (Poudel 2018).The crop is generally established by broadcasting under rainfed conditions, with no standing water throughout the season (Joshi et al 2001). The area under upland rice has declined significantly, with the last reliable estimate indicating about 126,000 hectares in cultivation (Sthapit 1992). Upland rice farming is predominantly practiced by ethnic and disadvantaged communities and plays a vital role in ensuring food security in regions lacking irrigation and viable alternative crops (Joshi et al 2001).

Sowing time varies depending on the agro-ecological zone typically from the last week of April to mid-May in the mid-hills, and from the last week of May to early June in the foothills (Malla 2021).Traditional landraces, cultivated over generations, possess a wide genetic diversity and are often favored over improved varieties for their superior grain quality and taste (Joshi et al 2007; Tiwari et al 2019).However, many of these landraces remain underutilized in scientific research.Strengthening support for smallholder farmers through the development of suitable upland rice varieties and improved agronomic practices is critical to sustaining productivity and food security in Nepal's hill regions (Pokhrel et al 2013). In this context, the primary objective of the present study was to assess the current status and cultivation practices adopted by farmers engaged in dry direct-seeded upland rice production in the central mid-hills of Nepal.

MATERIALS AND METHODS

The study was conducted from March to May 2023 across four districts in the central mid-hills of Nepal: Dhading (Salyantar and Jawalmukhi), Gorkha (Palungtar and Devkot), Tanahun (Bandipur and Aanbukhaireni), and Sindhupalchok (Bhotang).These sites were purposively selected as key areas for dry direct seeded rice (DSR) cultivation. A structured survey approach was employed using questionnaires developed in consultation with subject matter experts. Survey locations were identified through consultations with staff from the Agriculture Knowledge Centres, local rural municipalities, agricultural officers, technical experts, and local farmers. Purposive sampling was adopted to determine the sample size in each district, following the methodology of Cochran (1977) and Ahmed (2024). The final sample comprised 16 farmers from Dhading, 20 from Gorkha, 12 from Tanahun, and 12 from Sindhupalchok, representing the distribution of upland rice growers in the study area.

Table 1. Geographical locations of the study areas recorded in 2023

Districts	Sites	Latitudes	Longitudes	Elevation	No of Samples
Dhading	Salyantar, Jawalamukhi RMC	27°59'74 "to 28°00'69 " N	84°26'96"to 84°30'78" E	492 m to 981 m	16
Gorkha	Palungtar, Devkot	27°59'74 " to 28°00'69 " N	84°26'96"to 84°30'78" E	492 m to 981 m	20
Tanahu	Bandipur and Abhukhaireni	27°55'36 " to 27°56'87 "	84°22 '74"to 84°25 '79"to E	391 to 610 m	12
Sindhupalchowk	Bhotang	27°58'31" - 27°58'16"	85°38'44" to 85°39'77"	1639 m to 1724 m	12
Total					**60**

Data collection was carried out through face-to-face interviews with farmers and Focus Group Discussions (FGDs). These covered a range of topics, including field preparation, varieties and landraces cultivated, weed species and control methods, pest and disease incidence, and general crop husbandry practices such as seed rate, sowing time, planting method, and weeding. Other aspects explored included area coverage, use of manure and fertilizers, cultivation costs, use of green or brown manure, labor availability and shortages, marketing, gender roles, post-harvest practices, seed availability, reasons for adopting dry direct-seeded rice (DSR), and commonly followed cultivation practices. Additional insights were obtained through group interactions with farmers to gain a comprehensive understanding of dry DSR practices.The seeds of four upland rice land races were collected from the farmers and analyzed for nutrients content along with one improved variety Khumal 4.

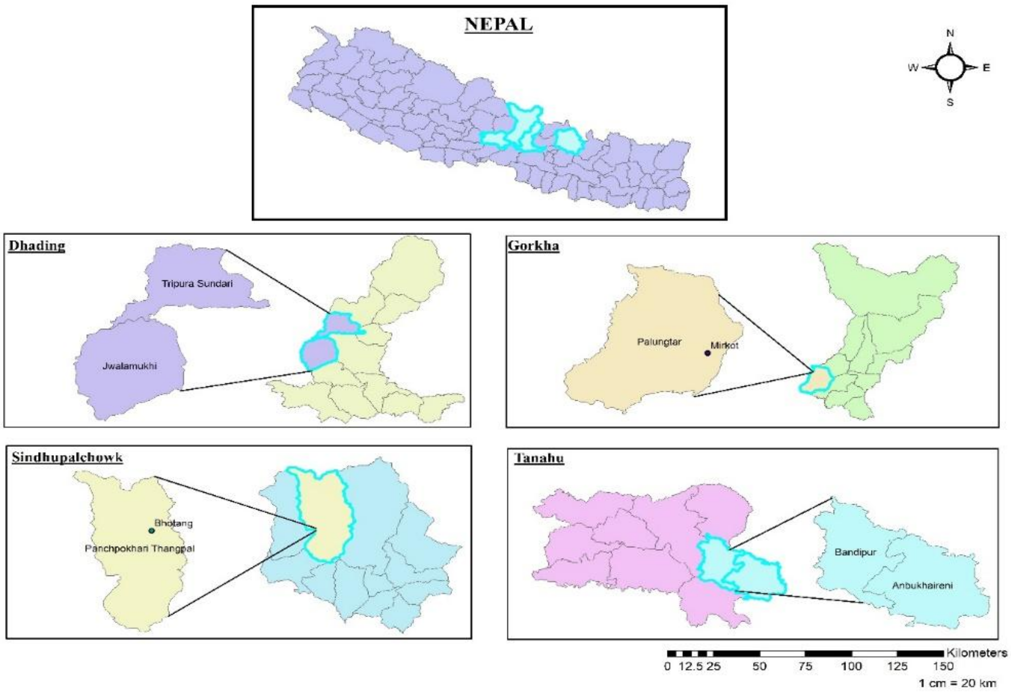

Figure 1. Map showing the different places of the districts of the study areas in 2023

The collected data were processed and analyzed using Microsoft Excel and IBM SPSS Statistics Version 25.0, and the results were presented through tables and figures for interpretation.

RESULTS

Status of farmers based on ethnicity

The majority of farmer respondents across all four surveyed districts belonged to ethnic minority communities, including Sarki (26.7%), Magar (20%), Kumal (16.7%), Tamang (13.3%), Gurung (8.3%), Chhetri (8.3%), and Brahmin (6.7%) (Table 2). In each district, specific ethnic groups were predominant among those practicing dry direct-seeded upland rice cultivation: Kumal in Dhading (62.5%), Sarki in Gorkha (80%), Magar in Tanahun (100%) and Tamang in Sindhupalchowk (66.7%).

Table 2. Ethnic groups engaged in upland rice cultivation in the study areas in 2023.

S.N.	Ethnicity	Frequency (%)
1.	Brahmin	4(6.7)
2.	Chettri	5(8.3)
3.	Tamang	8(13.3)
4.	Gurung	5(8.3)
5.	Magar	12(20)
6.	Kumal	10(16.7)
7.	Sarki	16(26.7)
	Total	**60(100)**

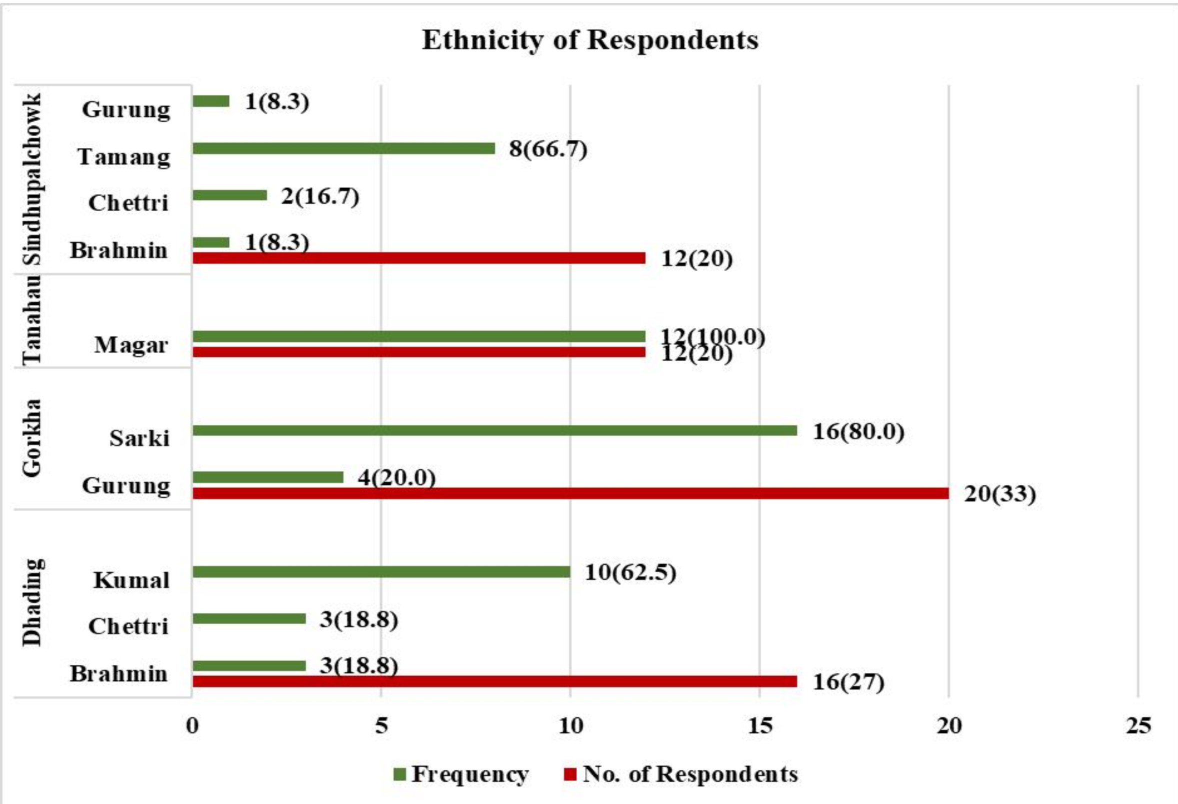

Figure 2.District wise status of ethnic groups involved in upland rice cultivation in 2023

Landholding size for upland rice

The size of land used for upland rice cultivation ranged from as small as 0.05 hectares to as large as 0.8 hectares. The average field size varied by district: 0.12 hectares in Dhading, 0.15 hectares in Gorkha, 0.24 hectares in Tanahun, and 0.10 hectares in Sindhupalchok. Across all surveyed districts, the overall average field size was 0.15 hectares (Table 3).

Table 3. District wise land size (ha) allocated by farmers for upland rice cultivation in 2023

District	N	Mean (ha)	Std. Deviation
Dhading	16	0.12	0.07
Gorkha	20	0.15	0.08
Tanahau	12	0.24	0.21
Sindhupalchok	12	0.10	0.05
Overall	**60**	**0.15**	**0.12**

Cultivation practices adopted for dry direct seeded upland rice

Field Preparation

Field preparation generally takes place in the month of March to April and is carried out manually.Farmers ploughed the land using bullocks with a traditional plough called a *halo,* along with a *lindko* (leveller) and hand hoe (*kodalo*).The number of ploughing varied between two and three, depending on soil type and land slope.Approximately 30% of farmers ploughed their fields twice, while 70% ploughed three times (Table 4.).For leveling the field and breaking clods, a locally made tool called a *lindko* is commonly used.

Table 4. Frequency of the ploughing for field preparation carried out by farmers in the mid-central hills of Nepal in 2023

S.N.	Number of Ploughing	Frequency (%)
1.	2	18(30)
2.	3	42(70)

Seed sowing and Varieties used

Seed sowing for upland rice typically occurs between March and April. Farmers either use seeds saved from their own harvests or purchase them from neighbors. Sowing is done using the broadcasting method at a rate of 80–100 kg per hectare.The varieties cultivated under dry direct-seeded upland rice are predominantly local landraces, including Chobo, Morange, Tauli, Begoni, Paksali Dhan, Chotte, Aapjhutte, Thathar, Nani, Bena, Gorkhali, and Bhutte (Table 5). In addition to these traditional landraces, improved varieties such as Sukha Dhan-2, Makwanpur-1, CH 45, and Chaite Dhan are also grown. Among the landraces, Tauli is the most widely cultivated (15%) across the survey area, particularly in Gorkha district (40%). The second most common landrace is Chobo (13.3%), which is widely grown in Tanahun district (33.3%).None of the landraces are grown in more than 15% of the overall survey area, and their productivity ranges from 1.0 to 2.8 tons per hectare.

Table 5. The Landraces cultivated by farmers in the study area in 2023

S.N.	Varieties	Frequency
1	Chobo	8(13.3)
2	Sukha dhan-2	4(6.7)
3	Morange	2(3.3)
4	Tauli	9(15)
5	Begoni	4(6.7)
6	Chaite dhan	1(1.7)

S.N.	Varieties	Frequency
7	CH-45	1(1.7)
8	Paksali dhan	2(3.3)
9	Bhutte	6(10)
10	Chotte	6(10)
11	Aapjhutte	1(1.7)
12	Thathar	2(3.3)
13	Makwanpur-1	2(3.3)
14	Nani	4(6.7)
15	Gorkhali	2(3.3)
16	Bena	6(10)
	Total	**60(100)**

Table 6. The districts wise upland rice landraces cultivated by farmers in the study area in 2023

S.N.	District	Varieties	Frequency
1	Dhading	Chobo	2(12.5)
		Sukha dhan-2	2(12.5)
		Morange	2(12.5)
		Tauli	1(6.3)
		Begoni	3(18.8)
		Chaite dhan	1(6.3)
		CH-45	1(6.3)
		Paksali dhan	2(12.5)
		Bhutte	2(12.5)
2	Gorkha	Chobo	2(10)
		Sukha dhan-2	1(5)
		Tauli	8(40)
		Chotte	5(25)
		Aapjhutte	1(5)
		Thathar	2(10)
		Makwanpur-1	1(5)
3	Tanahau	Chobo	4(33.3)
		Sukha dhan-2	1(8.3)
		Begoni	1(8.3)
		Nani	4(33.3)
		Gorkhali	2(16.7)
4	Sindhupalchowk	Bhutte	4(33.3)
		Chotte	1(8.3)
		Makwanpur-1	1(8.3)
		Bena	6(50)

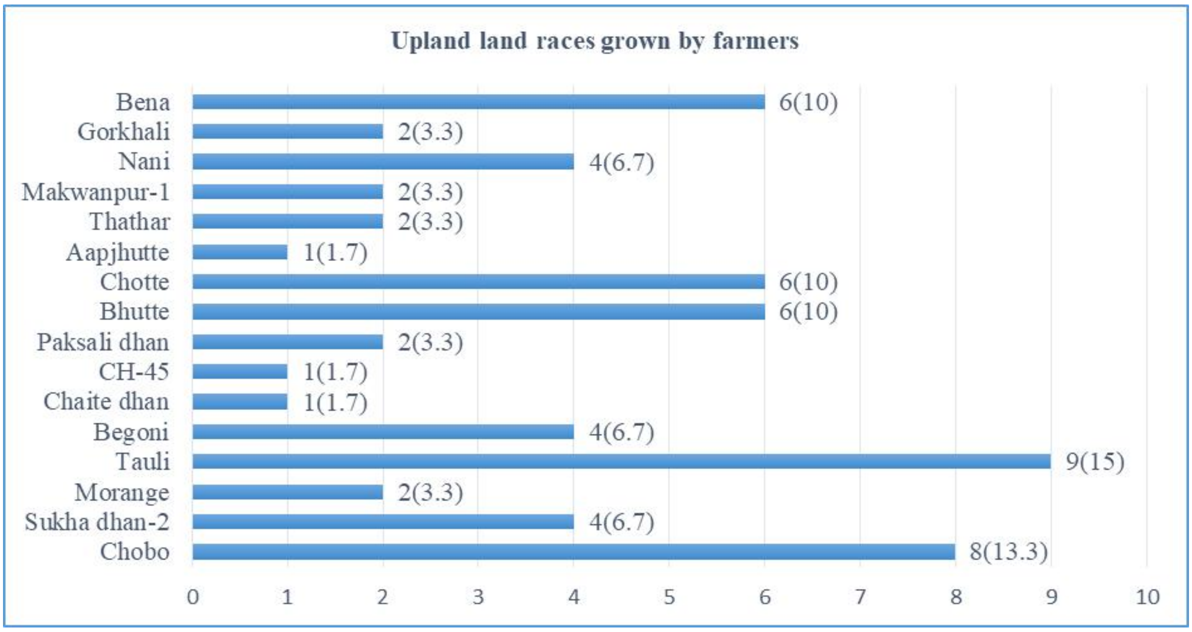

Figure 3. Upland rice varieties cultivated by farmers in the study areas in 2023

Manures and fertilizers

The application of manures and fertilizers in upland rice cultivation remains insufficient to meet the crop's nutrient requirements. Farmers mainly depend on organic manures such as cow dung, goat manure, buffalo manure, and poultry manure. The quantity of manure applied varies by district, largely influenced by the size of livestock holdings. Manure were applied at the dose of 5–6 tons per hectare in Dhading, 1.5–2 tons per hectare in Gorkha, 2–3 tons per hectare in Tanahu, and 1.5–2 tons per hectare in Sindhupalchok.The use of inorganic fertilizers is minimal, with only 30% of farmers applying urea at a rate of 50–100 kg per hectare. And no green manures were reported to be used for soil improvement.

Water management

Water management in upland rice cultivation is entirely depend on rainfall.This type of upland or dry direct-seeded rice is grown under rainfed conditions, often on sloped and uneven terrain where rainwater cannot be effectively collected or stored for irrigation. The study confirmed that 100% of the cultivated area relies solely on rainfall.Throughout its growth cycle, the crop experiences moisture stress at all stages. All surveyed farmers reported that the most severe stress occurs during the early growth stages, particularly during germination and tillering. In contrast, the later stages of crop development generally coincide with the monsoon rains, which help alleviate moisture deficits.

Major constraints in dry DSR

Farmers identified several major constraints affecting dry direct-seeded upland rice including soil quality, seed availability, irrigation, weeds, diseases, and low yield. Among these, weeds were reported as the most significant challenge by 41.7% of respondents across the study areas. This was followed by issues related to seed availability and irrigation, each accounting for 13.3%, while low yield was considered the least critical constraint by 8.3% (Table 7).

Table 7. Major constraints faced by upland rice farmers in cultivation in 2023

SN	Constraints	Dhading	Gorkha	Tanahu	Sindhupalchok	Overall Frequency(%)
1	Soil quality	2(12.5)	2(10)	2(16.7)	1(8.3)	7(11.7)
2	Seed availability	2(12.5)	2(10)	2(16.7)	2(16.7)	8(13.3)
3	Soil moisture	0	5(25)	0	3(25)	8(13.3)
4	Weed	8(50)	9(45)	4(33.3)	4(33.3)	25(41.7)
5	Disease and Insects	3(18.8)	1(5)	3(25)	0	7(11.7)
6	Yield	1(6.3)	1(5)	1(8.3)	2(16.7)	5(8.3)
	Total	**16**	**20**	**12**	**12**	**60(100)**

Weeds species and their management

Weeds are a major constraint in upland rice cultivation, accounting for 36.3% of the total production costs (Table 14).Timely weeding remains a significant challenge for farmers cultivating traditional upland rice varieties.

Table 8. Percent positions and Garrett values of problematic weed species

S.N.	$100(R_{ij}-0.5)/N_j$	Calculated value	Garrett value
1. Purple nut sedge	100 (1-0.5)/5	10	75
2. Bermuda grass	100 (2-0.5)/5	30	60
3. Jungle rice	100 (3-0.5)/5	50	50
4. Goat weed	100 (4-0.5)/5	70	39
5. Crab grass	100 (5-0.5)/5	90	24

Table 9. Problematic weeds species in the upland rice with their rank of infestation

S.N.	Weeds	Scientific Name	Local Name	Rank of Infestation
1	Purple nut sedge	*Cyperus rotundus* L.	Mothe	I
2	Bermuda grass	*Cynodon dactylon* L.	Dubo	II
3	Jungle rice	*Echinochloa colona* L.	Rato banso	III
4	Goat weed	*Ageratum houstonianum* Mill.	Nilo Gandhe	IV
5	Crab grass	*Digiteria sanguinalis* (L.) Scop	Chetre banso	V

Table 10. Frequency of weeding practiced by the farmers in 2023

S.N.	Number of weeding	Frequency
1	2 weeding by hand	38 (63.3)
2	1 weeding by daade plus 1 weeding by sohorne	11 (18.3)
3	3 weeding (2 hand weedings plus 1 sorne)	11 (18.3)
	Total	60 (100)

The most commonly identified weed species were purple nut sedge, goat weed, jungale rice, bermuda grass, crab grass, gallant soldier, paracress, dayflower, hairy beggarticks, and goose grass. Among these, the top five most problematic weeds ranked by Garrett values and infestation severity (Tables 8 and 9) were purple nut sedge (Rank I), Bermuda grass (II), jungle rice (III), goat weed (IV), and crab grass (V).

Study data showed that 63% of farmers relied on two rounds of hand weeding using a *kute* (a small hand hoe). Another 18.3% used a combination of one round with a *daade(*wooden rake drawn by bullock*)* and another round with *sohorne* (selective hand pulling). Similarly, 18.3% of farmers conducted three weeding sessions: two rounds of hand weeding using *kuto*, followed by one round of selective hand pulling just before panicle emergence—a practice locally known as *sohorne*. On average, effective weed management in one hectare required 53 laborers, resulting in a total expenditure of approximately NRS 32,000 (Table 14).

Insects pests and diseases

The common belief that local landraces possess strong resistance to insects and diseases has diminished after years of continuous cultivation using the same varieties.More than 90% of farmers reported not applying any control measures against prevailing pests and diseases, primarily due to limited knowledge and financial constraints.Among insect pests, stem borer (63.3%), gundhi bug (25%), and nematodes (11.7%) were the most prevalent. The major diseases identified included rice blast (61.7%), brown spot (21.7%), and false smut (16.7%) (Table 11).

Table 11. Overall insects and disease occurrence faced by the upland rice farmers in the study areas in 2023

S.N.	Particulars		Frequency (%)
1	Disease	Brown spot	13 (21.7)
		Rice Blast	37 (61.7)
		False Smut	10 (16.7)
		Total	60 (100)
2	Insect	Stem borer	38 (63.3)
		Gundhi bug	15 (25)
		Nematodes	7 (11.7)
		Total	60 (100)

Harvesting, post-harvest and storage

Harvesting is done manually by women and men, while men are responsible for threshing. Labor charges for women range from NRS 600 to 800, whereas for men, the cost is between NRS 1,000 to 1,200.During maturity, crops are often damaged by birds and wild animals, causing some farmers to harvest rice prematurely to avoid further losses.This practice leads to an estimated yield reduction of about 10%. After harvesting, the rice is spread on the terrace for sun drying for about 4 to 5 days. Once dried, men thresh the rice using a bench or a large hard stone. The threshed rice is then cleaned by winnowing. After cleaning, the grains are sun-dried again for 1 to 2 days to reduce moisture content to 12–13%, ensuring good storability.Storage is typically carried out using traditional methods, with grains stored in bhakari (bamboo basket) and jute sacks. The average yield among farmers ranges from 1.6 to 2.8 tons per hectare.

Nutritive value of the upland rice grains

The landraces were richer in nutritional value compared to the improved varieties. Notably, the crude protein content was significantly higher in the Chobo (10.79%) and Chhote (12.34%) landraces, surpassing that of the popular mid-hill variety Khumal 4 (Table 12). Chhote also showed higher crude fiber (3.90%) and iron content (3.27%), enhancing its nutritional value (Table 13). Additionally, the brown rice recovery rate was highest in Bhutte (82%), exceeding that of the improved variety Khumal 4.

Table 12. Physical and proximate analysis of upland rice genotypes obtained from the study areas along with one improved variety in 2023

Genotypes	1000 kernel wt. (g)	Total Carbohydrate (%)	Crude Fat (%)	Crude Protein (%)	Crude Ash (%)	Brown Rice (%)
Chobo	23.06	74.26	0.99	10.79	0.61	77.87
Gorkhali	20.13	75.0	0.85	9.89	0.56	75.04
Chotte	23.46	72.6	0.90	12.34	0.56	79.37
Bhutte	19.60	73.8	1.14	10.18	0.68	82.09
Khumal 4	20.10	73.68	0.92	10.63	0.58	76.59

Table 13. Chemical analysis of upland rice genotypes obtained from the study areas along with one improved variety in 2023

Gen otypes	Crude fibre(%)	Amylose (g/100 g)	Iron (mg/100 g)	Phosphorus (mg/100 g)	Calcium (mg/100 g)	Total Carbohydrate (%)
Chobo	0.71	38.12	1.03	78.65	99.01	74.26
Gorkhali	1.60	26.59	2.40	81.85	57.47	75.0
Chotte	3.90	21.17	3.27	56.49	91.95	72.6
Bhutte	1.48	21.85	2.39	82.94	50.12	73.8
Khumal 4	1.80	23.31	3.26	104.14	71.03	73.68

Economics of dry direct seeded rice

The costs involved in cultivating upland rice on one hectare were as follows: field preparation cost NRS 12,000 (13.7% of total cost), seed expenses NRS 4,000 (4.6%), manure application NRS 10,000 (11.3%), weeding NRS 32,000 (36.3%), harvesting NRS 12,000 (13.7%), and threshing NRS 16,000 (18.2%). The total production cost was approximately NRS 88,000. The total income generated from the crop was NRS 120,000, resulting in a net benefit of NRS 32,000 (Table 14).

Table 14. Costs and Income from different activities in upland rice cultivation in 2023.

Activities	Cost per Ropani (500 m2)	Cost per ha (NRS)	Costs incurred (%)
Field preparation	600	12000	13.7
Seeds procurement	200	4000	4.6
Seed sowing	100	2000	2.2
Organic manures	500	10000	11.3
Weeding	1600	32000	36.3
Harvesting	600	12000	13.7
Threshing	800	16000	18.2
Total cost	4400	**88000**	
Income rice grain (2.5 t/ha)	5000		
@Rs 20/kg		100000	
Straw (4 t/ha) @ Rs 5 per k	1000	20000	
Total Income	6000	120000	
Benefit (Total income -total cost)	**1600**	**32000**	

DISCUSSION

The ethnic minority communities such as Sarki, Magar, Kumal, Tamang, Gurung, Chhetri, and Brahmin—dominate dry direct-seeded upland rice cultivation.These resource-poor communities inhabit hill slopes and tars, where they traditionally grow rice under rainfed conditions on marginal lands. Upland rice cultivation is closely associated with socially and economically disadvantaged groups farming in challenging environments (Joshi et al 2001).

Due to the rolling topography, field sizes are generally small in the hills. Small average field sizes were also reported by Bajracharya et al (2010). Farmers prepare the land using bullocks with a traditional plough called a *halo*. The number of ploughings varies between two and three, depending on soil type and land slope. Sowing typically takes place at the onset of the pre-monsoon season, between the months of Chaitra and Baisakh (March–April).Farmers use seeds saved from their own harvests or purchase from neighbors, as these seeds are resilient to the local environment. Seeds are sown by broadcasting at a rate of 80–100 kg per hectare, which is usually higher due to low germination caused by reduced soil moisture in upland conditions. Mogiso (2020) reported that 80 kg/ha gave the optimum yield under upland conditions.

Upland rice cultivation is dominated by diverse local landraces.This diversity results from varying altitudes that create diverse agro-ecosystems in the mid-hills (Sthapit et al 2002). Low yield of local landraces is a major constraint in direct-seeded upland rice. Improved varieties like Sukha Dhan-2 are cultivated by only 6.7% of farmers. Even improved varieties such as Sukha Dhan-2, Makwanpur-1, and CH 45 yield below their potential. The low yields from local landraces were also reported by Bajracharya et al (2010).This decline in productivity is attributed to low-quality seeds, moisture stress, poor soil fertility, weed infestation, pest and disease problems, and limited adoption of modern agricultural technologies.

Low yields are also linked to farmers primarily depending on organic manures for crop nutrition, which they apply in reduced quantities due to decreasing livestock populations. Common manures include cow dung, goat manure, buffalo manure, and poultry manure. The amount applied varies across districts depending on livestock holdings.Chemical fertilizers, mainly urea, are used by few farmers due to limited purchasing capacity and unavailability in time. Sutardi et al. (2022) reported increased grain yields with combined use of inorganic fertilizers and organic manures. Higher grain yields were also observed with high doses of organic manure (Bhattarai et al 2020; Siavoshi et al 2011).

Major constraints in dry direct-seeded upland rice include soil quality, seed availability, irrigation, weeds, diseases, and low yield. Weeds pose a significant challenge, accounting for 36.3% of total production costs. They are identified as major biological constraints to rice cultivation by smallholders (Johnson, 2025). Timely weeding is difficult for farmers growing this traditional aerobic rice variety due to the labor-intensive nature of the task. Rising labor costs and labor shortages caused by out-migration further discourage many growers from continuing this cultivation system. Similar findings were reported by Hagos (2015). The predominant weed species identified include Purple nut sedge, Goat weed, Jungle rice, Bermuda grass, Crab grass, Gallant soldier, Paracress, Dayflower, Hairy beggarticks, and Goose grass. Oyebanji et al (2022) also reported these weed species in upland rice fields in Nigeria.

The five most problematic weeds are Purple nut sedge, Bermuda grass, Jungle rice, Goat weed, and Crab grass. Due to their C4 photosynthetic pathway, these weeds are highly competitive against rice and difficult to manage (Singh 2012). Farmers control weeds through two to three rounds of weeding each season, using a combination of hand pulling, hand hoeing, and a traditional local tool called the *daade*. Selective hand pulling, known locally as *sohorne*, is practiced to remove mature weeds that outgrow crops during later growth stages. The use of small hand tools and manual hand weeding is common for weed management in upland rice cultivation (Kato 2010).

The high level of resistance to insects and diseases once seen in local landraces has diminished over years of continuous cultivation using the same varieties. Stem borer and gundhi bug were the major insect pests, while rice blast and false smut were the main diseases affecting upland rice. Hashim (2020) also reported severe blast infestations in upland rice, resulting in substantial yield reductions.

Harvesting is mostly performed by women, while threshing is done manually by men. Although women carry out a larger share of the work,they receive lower payments, highlighting gender disparity. Singh (2015) reported women's contributions in upland rice cultivation and the disparities they face. Yield losses are high due to birds, wild animals, and premature harvesting. Traditional methods are commonly used for seed storage, with no modern storage techniques applied.

The nutritional values of landraces—including protein, crude fiber, and iron content—are comparable or superior to improved varieties. Prasad et al (2021) found that local rice varieties exhibited high protein, fiber, and ash content. Upland rice provides greater satiety, as meals prepared from these traditional varieties keep people full longer. Farmers also noted that livestock prefer straw from these landraces, attributing this preference to higher energy content and a cooling effect during work periods.

The cost of production for direct-seeded upland rice is relatively higher than transplanted rice, with weed control costs taking the largest share. Productivity in direct-seeded upland rice can be increased through the use of improved varieties and better agronomic practices.

Livelihood and system sustainability

Upland rice serves as a vital source of livelihood for resource-poor ethnic communities living in the hills and tars. Besides rice, these farmers cultivate a limited range of subsistence crops such as maize and legumes.To meet basic needs, they often sell rice and straw in local markets or to neighbors.Due to widespread poverty and limited education, engaging in larger-scale business activities remains challenging.However, this traditional farming system plays a crucial role in maintaining the ecological balance of the hills and tars by avoiding the use of high-yielding seeds, modern technologies, and machinery.Farmers believe that their longstanding rice cultivation practices help preserve the natural environment, ensuring sustainability over decades.

Future concern

The sustainability of upland rice cultivation faces numerous challenges including low rainfall, soil fertility decline, reduced productivity of traditional landraces, weed infestations, pest and disease pressures, and rural-to-urban migration. Increasing threats from wild animals such as monkeys, wild hogs, and birds further jeopardize upland rice farming in Nepal's hills. To secure the future of this cropping system,focused research is urgently needed to improve landrace quality and develop effective soil management practices.

Limitations of the study

The study was conducted in the mid-central hills with a limited sample size. A more detailed survey with increased sample size covering more upland districts is needed for comprehensive analysis.

CONCLUSION

Dry direct seeded upland rice is a vital component of the rice production system, significantly contributing to food security in the hills of Nepal.This system is predominantly practiced by smallholder farmers and disadvantaged ethnic groups, who have cultivated local landraces for generations using traditional knowledge adapted to local conditions.

While these landraces are valued for their superior grain quality, slow digestibility, and good taste, as well as for producing straw that serves as an important fodder resource during lean periods, their productivity has declined in recent years. Farmers often prefer these traditional varieties over improved ones due to their resilience and adaptability to changing rainfall and weather patterns.However, major constraints such as weed infestation and low yields threaten the long-term sustainability of upland rice cultivation.

Addressing these challenges through the improvement of existing landraces, as well as better soil and water management practices, is crucial to ensure the continued viability of this important rice system.

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Authors' Contributions

Rajendra Kumar Bhattarai, Bishnu Bilas Adhikari and Mina Nath Paudel conceived and design the study ; Rajendra Kumar Bhattarai performed the study; analyzed, interpreted the data and wrote the paper. Bishnu Bilas Adhikari, Lal Prasad Amagain, Mina Nath Paudel and Jagat Devi Ranjit assisted in interpretation of the data and improvement of the manuscript. Rajendra Kumar Bhattarai wrote the final draft.

Conflicts of Interest

The authors have no relevant conflict of interests.

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