# Adoption of Improved Rice Varieties in Sarpang District of Bhutan

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**ABSTRACT**

*The adoption of improved rice varieties (IRVs) is imperative for ensuring smallholder farmers' food security as well as their collective contribution to national food security. It is important to comprehend the adoption rate of IRVs and determine what influences their adoption. This study employed a farmer-oriented approach to understand the current adoption status of IRVs and the factors affecting their adoption in Sarpang district of Bhutan. A total of 264 rice growing households selected through a multi-stage sampling technique were interviewed using structured and semi-structured questionnaires. A binary logistic regression was employed to analyse the data, and the adoption of IRVs was defined from the perspective of whether farmers grow any of the IRVs or not. The result showed that the household-level adoption rate of IRVs was 60.61%, which translated into a coverage of 47.25% of the total cultivated wetland in the district. A total of 18 rice varieties were recorded in the study site with five IRVs; three of which were released officially and two were sourced by farmers through informal channels from India. The IRVs in the area showed a 39.71% yield advantage over the traditional varieties ($p < .001$). The empirical results showed that family size had a significantly positive influence ($p = .023$) on the probability of adoption of IRVs, suggesting that bigger families were more likely to adopt IRVs due to increased labour availability for agricultural tasks. Conversely, total wetlands under cultivation had a significantly negative influence ($p = .01$) on the probability of the adoption of the IRVs. This indicates that farmers who cultivated smaller wetland areas were more likely to adopt IRVs, due to the higher productivity of IRVs meeting their household's food needs.*

**Keywords:** *Adoption; Binary logistic regression; Factors; Improved rice varieties; Varietal diversity*

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# 1 Introduction

Rice (*Oryza sativa* L) is consumed by more than half of the global population, which is produced in more than 100 countries, with Asia accounting for 90% of global production (Fukagawa & Ziska, 2019). In Bhutan, rice is grown by 21,891 households in an area of 22,985 acres (National Statistics Bureau [NSB], 2023) with a total production of 40,563 MT (Department of Agriculture [DoA], 2020). Despite this limited land area, rice holds a pivotal role in Bhutanese agriculture. It is not only a staple food for the Bhutanese but also a significant crop that supports the livelihoods of many farmers across the country. It is cultivated in all 20 districts of Bhutan, at altitudes ranging from 150 meters in the south to 2,600 meters in the north (Chhogyel & Bajgai, 2016). The importance of rice in Bhutan extends beyond sustenance, influencing cultural practices and agricultural strategies within the nation.

The Department of Agriculture is emphasizing self-sufficiency in rice production; however, Bhutan's rice production has been plagued by several setbacks (Chhogyel & Bajgai, 2016). Bhutan is currently 25% self-sufficient in rice production and consumption ($13^{th}$ Five Year Plan, 2024), and the government aims to raise the sufficiency level to 30% within the next five years. India is the main supplier of rice imports, and the country imports an average of around 80,000 MT annually, hence the need to put in more effort to attain a higher level of self-sufficiency in rice.

Bhutan's agricultural sector has undergone a remarkable transformation during the past 112 years, evolving from shifting cultivation-Tseri to sedentary, modern, and increasingly profitable farming, with the transition marked by three distinct phases i.e., subsistence farming (1907–1970), self-subsistence to part commercial (1970–1990), and integrated and semi-commercial farming (1990–2020) (Gurung, 2012). Rice is considered one of the key cereal crops that contribute to the nation's GDP, and since the 1960s, systematic planning, the establishment of legal and policy frameworks, as well as modern technology and machinery, have all helped to boost crop productivity (Ministry of Agriculture and Forests [MoAF], 2021). The MoAF has established systematic plans in every Five-Year Plans for the agricultural sector to meet the requirement and development in particular areas generally to boost the country's GDP. From the start of the planned development in 1961, the RNR sector progressively contributed to the nation's GDP (Economic and Social Commission for Asia and the Pacific, 1961) and to meet rice self-sufficiency. According to Shrestha (2004), the study provided significant insights into the program's impact on Bhutan's agricultural sector and overall economy. This study used rigorous economic assessment approaches such as cost-benefit analysis and impact evaluation, sheds light on the program's success in improving rice production, improving farmer lives, and encouraging sustainable agricultural growth in the country.

The southern foothill of Bhutan, ranging in elevation from 200 to 3,600 meters above sea level (masl), has a subtropical climate with distant wet and dry seasons that support extensive subsistence agriculture via various forms of multiple cropping, with rice serving as the primary summer crop (Dendup et al., 2021). This region accounts for 35% of national rice acreage including the districts of Samdrup-jongkhar, Samtse, and Sarpang (Chhogyel & Dendup, 2020). In Bhutan, 27 modern rice varieties have been released, five of which were released by ARDC-Samtenling for the wet-subtropical zone of Bhutan, namely Bhur Rey Kaap-1, Bhur Rey Kaap-2, Bhur Khambja-1, Bhur Khambja-2, and Sokha Rey-1 (DoA, 2020). According to Dendup et al. (2021), adopting improved cultivars favourably influences productivity and total rice production.

The adoption of improved rice varieties (IRVs) is important for ensuring food security and boosting livelihoods; nevertheless, IRV adoption has remained relatively low in underdeveloped countries (Checco et al., 2023). According to Saka et al. (2005), farmers have responded positively to intervention programs that encourage the use of IRVs, with a 68.7% adoption rate and then a mean yield of IRVs that is significantly higher than the yield of local varieties, with a yield advantage of 38.7%. Thus, one of the important interventions to increase rice production and improve national food security is the promotion of IRVs (Dendup et al., 2021). According to Chhogyel & Bajgai (2016), 68% of farming households in Wangdue and 62% in Punakha districts have adopted IRVs.

The development and acceptance of IRVs and technologies are critical for ensuring contribution to national food security and income security. Furthermore, in order to build policies and programs to assist rice sector growth and boost rice production and efficiency, it is necessary to identify the rate of adoption and factors influencing the limited adoption of IRVs. Thus, the DoA under the Ministry of Agriculture and Forests, haven been initiating technical interventions in major rice-growing districts to boost rice yield and production from 2008 to 2009 (Chhogyel et al., 2015). However, limited empirical research has been undertaken so far to examine the factors influencing IRVs adoption and their adoption rate in the wet subtropical zone of Sarpang district. Therefore, this study attempts to determine the adoption rate as well as key factors affecting the adoption of IRVs by the farmers of Sarpang district.

## 2 Materials and Method

### 2.1 Study site

Sarpang is one of the major rice-growing districts of southern Bhutan. The district's elevation ranges from 200 to 3,600 meters above sea level (masl). This region experiences a subtropical climate with distant wet and dry seasons. During the monsoon season (June to September), it receives significant rainfall ranging from 1,500 mm to 2,500 mm on average, contributing to the fertility of the soil and supports agricultural productivity including rice cultivation.

Farmers are engaged in both rainfed and irrigated rice farming depending on the availability of water resources. A questionnaire-based survey was conducted in five major rice-growing gewogs namely Dekling, Gelephu, Samtenling, Sherzong, and Umling (Figure 1).

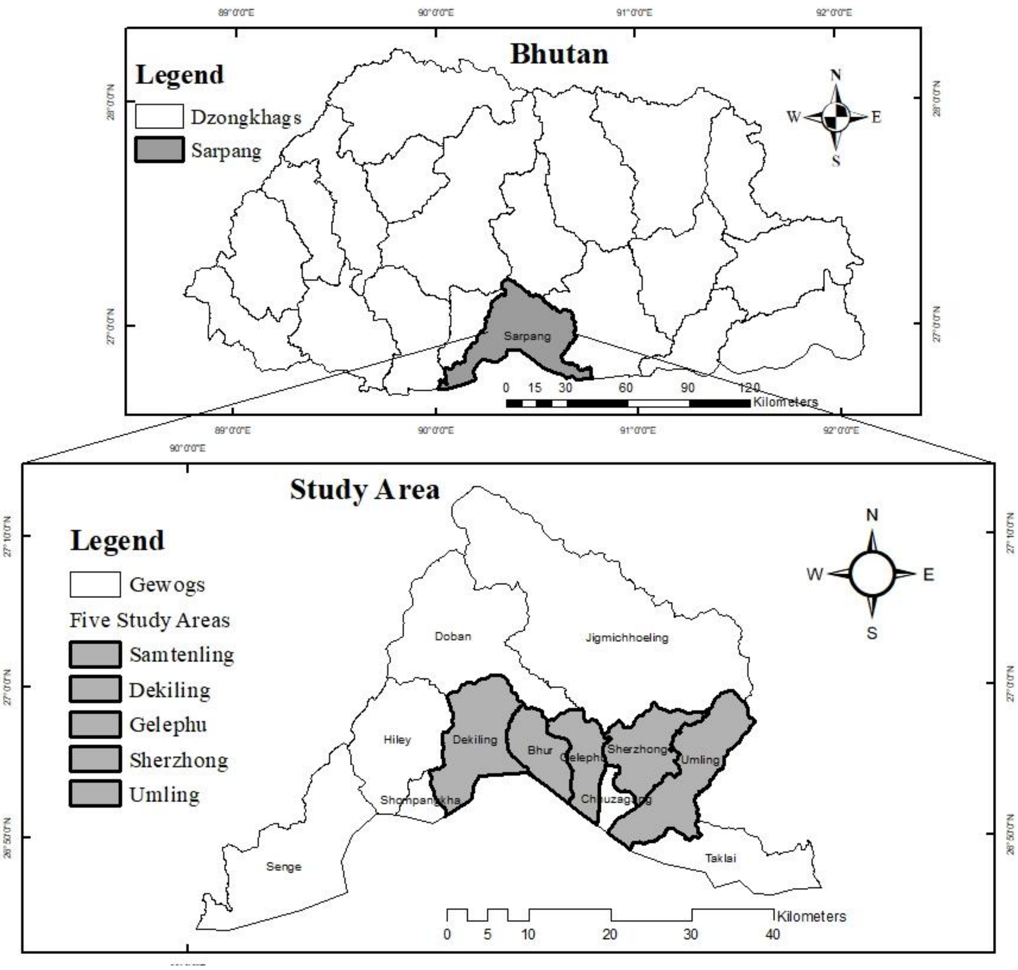


Figure 1. Study Area- Sarpang, Bhutan

## 2.2 Sampling technique

A multi-stage random sampling method was employed to select rice-growing households. In the first stage, five gewogs were selected purposively based on the total number of rice growing households in each gewog as well as the intensity of rice production and accessibility of agriculture technology. In the second stage, three chiwogs from each gewog were selected through the Probability Proportional to Size random sampling method, and only two chiwogs for Gelephu due to the lack of rice cultivators in the other chiwogs. In the final stage, rice-growing households from each gewog were selected randomly. The Raosoft Sample Size Calculator (online software) was used for generating the sample size from the given population with the margin of error (5%), confidence interval (95%), and response distribution (50%) taking into consideration (Raosoft, 2004). Considering the number of households in the selected rice growing areas which was statistically perceived as population ($N$), the sample size ($n$) of 264 households was derived from $N = 317$ (Table 1).

Table 1. Distribution of sample size across the study area

| Study Area | Chiwogs | No. of HHs | Total HHs | Proportion (%) |
|---|---|---|---|---|
| Umling | Dangling | 10 | 61 | 23.1 |
| | Rejoog | 11 | | |
| | Gaden | 40 | | |
| Sherzhong | Barshong | 13 | 43 | 16.3 |
| | Tashiphu | 16 | | |
| | Pemayoedling | 14 | | |
| Dekiling | Chokorling | 31 | 74 | 28 |
| | Jigmeling | 27 | | |
| | Nubgang | 16 | | |
| Gelephu | Pelrithang Khoted | 16 | 27 | 10.2 |
| | Pelrithang Khamaed | 11 | | |
| Samtenling | Samtenling | 48 | 59 | 22.3 |
| | Samtenthang | 7 | | |
| | Khemapang | 4 | | |
| Total | | | 264 | 100 |

## 2.3 Data collection

Between January 10th and February 30th, 2024, primary data was collected from five rice-growing gewogs within the Sarpang district. The data for the study was gathered for the 2023 rice growing season, with the exception of Gaden chiwog, which is situated within the Umling gewog. For Gaden chiwog, data on paddy cultivation was collected from the previous year, 2022. This exception was because of a halt in paddy cultivation due to the reconstruction of their irrigation channel. Data collection involved employing both structured and semi-structured questionnaires. These questionnaires encompassed inquiries regarding respondent demographics, land-holding classifications, the prevalence of farmers cultivating IRVs versus traditional varieties, and factors influencing the adoption of IRVs. The aim was to highlight the adoption rates, traits, yields, and the factors affecting the adoption of IRVs across different regions.

### 2.4 Data analysis

Data were analysed using Jeffrey's Amazing Statistics Program (version 0.18.3, JASP Team, 2024). The analytical techniques that were used in this study comprised simple descriptive statistics and binary logistic regression analysis. Descriptive statistics includes frequency distribution, means, and percentages. Statistical differences in selected variables between adopters and non-adopters were determined using the Chi-square test for categorical or dummy variables and independent t-test/ Mann-Whitney U test for continuous variables. Normality and homogeneity of variance of the data were tested prior to conducting an independent t-test. One-way ANOVA of yield values given by the farmers for traditional, IRVs (Indian), and IRVs (Bhutanese) was performed in order to determine the significant difference in the yield of different rice varieties. The yield data was first log(x) transformed to fulfill the assumption of equal variance. Bonferroni post-hoc test was performed, after the ANOVA result showed significant treatment difference, to determine the difference between each treatment.

Binary logistic regression analysis was performed to determine the influence of socio-demographic variables on the probability of adoption of IRVs in this study, and previous studies (Chukwu et al., 2016). According to Hosmer and Lemeshow (2000), logistic regression is a statistical method used to predict the relationship between one or more explanatory variables (independent variables) and the response variable (dependent variable), which consists of two or more categories, on a category or interval scale. The response variable comprises dichotomous qualitative data, denoted by a value of 1 (one) representing the occurrence of an event, and a value of 0 (zero) indicating the non-occurrence of the event (Rusliyadi et al., 2022). The logit model is specified as follows:

$$\text{Log } Li = \text{Log } (P_i / [1 - Pi]) = \beta_o + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_k X_{ki} + \mu_i \quad (1)$$

Where Log Li is the log of odds ratio for farm i, is called the logit or logit model. It gives the odds ratio of the probability of occurrence of events. $X_i$ is a vector of independent variables; $\beta_o$ is the intercept and $\beta_i$, i=1…k are the coefficients of the independent variables to be estimated, and $\mu_i$ is the error term. The explanatory variables included in the model are listed in Table 2 together with their hypothesized effect on the adoption of improved rice varieties. To assess multicollinearity among the predictors, a Variance Inflation Factor (VIF) test was performed and tolerance values were calculated. The VIF values for all predictors ranged between 1 and 2, and the tolerance values were between 0.5 and 0.9. These results indicate no serious multicollinearity in the model, allowing all factors to be included. All the figures were made using the R statistical software version 4.3.0 (R-Core-Team, 2023) with attached packages: ggplot2, gridExtra, and patchwork.

Table 2. Description of the variables specified in the logistic regression model

| Variable | Meaning | Description | Expected sign |
|---|---|---|---|
| *Dependent variable* | | | |
| Adopt IRVS | Whether a farmer grows IRVs or not | Dummy (grows = 1, 0 otherwise) | |
| *Independent* variables | | | |
| Gender | Gender of the household head | Dummy (Female = 0, Male = 1 | + - |
| Age | Age of the household head | Continuous (years) | - |
| Education | If the household head had any formal education | Dummy (yes = 1, 0 otherwise) | + |
| Household size | Number of people in the household | Continuous (number) | + |
| Wetland size | Total cultivable wetland (owned + leased) | Continuous (acre) | + |
| Family labour | Number of active individuals helping in farming | Continuous (number) | + |
| Extension visit frequency | Number of extensions visits in a year | Continuous (number) | + |
| Farm machinery ownership | If the household owns any type of farm machinery | Dummy (yes = 1, 0 otherwise) | + |
| Farming experience | Numbers of years farming | Continuous (years) | |
| Source of irrigation | Source of irrigation during the rice growing season | Dummy (river/canal water = 0, Rainfed = 1) | + |
| Marketing | If the households sell their produce after harvest or not | Dummy (yes = 1, 0 otherwise) | + |

## 3 Results and Discussion

### *3.1* Socio-demographic features of the surveyed rice farmers

The descriptive statistics of the farmers separated by adoption status and socio-demographic characteristics for the 264 surveyed rice farmers (186 male ad 78 female) from five gewogs of Sarpang district are presented in Table 3. The average age of the household head was 52 and each household had almost 6 individuals on average. However, the active family members i.e., the family members above the age of 15 actively contributing to rice cultivation, were only half of the total individuals in the household on average. The study area had an average wetland size of 2.15 acres. The majority (70.45%) of the respondents were male and formed 42.05% of the adopters in total. This dominance of male leadership within a family could be attributed to the cultural norms of the people where male descendants are often favoured to inherit land and properties, especially in the local communities. Almost 97% of the surveyed individuals had farming as their main occupation and 91% had more than 10 years of farming experience. Just 28.8% of the household heads had a formal education, and only 18.6% of the households owned farm machinery (of any kind). On average, the farmers reported having met the extension agent of the gewog only two times annually. The majority (95.8%) of the households utilized river/canal water for irrigating their paddy field.

The result of the differences in the means of characteristics between the adopters and non-adopters showed a significant difference in the average household size ($U$ = 5756, $p$ < .001), active family members ($U$ = 6227, $p$ < .001), and the wetland size ($U$ = 9971, $p$ < .006, Table 4.1). Specifically, the adopters showed higher means in the household size and number of active family members compared with their non-adopter counterparts. Whereas, the adopters of IRVs had lower area of land compared to the non-adopters of IRVs. These results suggest possible differences between adopters and non-adopters in terms of household structure and family involvement in farming activities.

Other characteristics such as age of the household head, gender of the household head, average contact with an extension agent, occupation of the household head, farming experience of the household head, education level of the household head, farm machinery ownership, source of irrigation, and proportion of males and females, did not differ between the adopters and the non-adopters.

Table 3. Descriptive summary of socio-demographic characteristics of rice farmers by adoption status

| Characteristics | Categories | Pooled data | Adopters | Non-adopters | *p*-value |
|---|---|---|---|---|---|
| Age of household head (years) | | 52 | 52.1 | 51.8 | 0.84 |
| Household size (numbers) | | 5.8 | 6.1 | 5.48 | < .001* |
| Family labour (numbers) | | 3.41 | 3.5 | 3.2 | < .001* |
| Wetland size (area) | | 2.15 | 1.96 | 2.32 | 0.006 |
| Extension contacts (Frequency) | | 2.1 | 2.1 | 2.2 | 0.55 |
| Gender (%) | Male | 70.45 | 42.05 | 28.41 | 0.63 |
| | Female | 29.55 | 18.56 | 10.98 | |
| Occupation (%) | Farmer | 96.6 | 58.7 | 37.9 | 0.22 |
| | Government/Civil service | 1.9 | 0.7 | 1.2 | |
| | Self-employed | 1.5 | 1.1 | 0.4 | |
| Farming experience (%) | >10 years | 90.9 | 55.7 | 35.2 | 0.09 |
| | 6-10 years | 6.1 | 4.2 | 1.9 | |
| | 1-5 years | 3 | 0.7 | 2.2 | |
| Education (%) | Formal education | 28.8 | 15.5 | 13.3 | 0.15 |
| | No formal education | 71.2 | 45.1 | 26.1 | |
| Farm machinery Ownership (%) | Yes | 18.6 | 10.3 | 8.3 | 0.38 |
| | No | 81.4 | 50.4 | 31 | |
| Source of irrigation (%) | River/canal water | 95.8 | 57.2 | 38.6 | 0.14 |
| | Rainfed | 4.2 | 3.4 | 0.8 | |

Note: *significant at $p < .001$

### 3.2 Awareness on improved rice varieties

The results of the study revealed a remarkable level of awareness regarding IRVs, with an impressive 99.24% of the surveyed households demonstrating familiarity with the IRVs (Table 4). This significant percentage underscores a widespread understanding and recognition of the benefits associated with IRVs among the surveyed population.

Further analysis was performed to shed light on the sources contributing to this heightened awareness. Among the surveyed individuals, it was found that 40.84% of the population gained knowledge about IRVs through interactions with fellow farmers. This peer-to-peer exchange underscores the importance of farmer networks in disseminating information and knowledge about agricultural innovations. Similar findings were documented by Lwoga et al., (2011) in Tanzania and Adetimehin et al., (2018) in Nigeria, who attributed these results to the consistent availability, accessibility, credibility, and reliability of information shared within farmer networks, which are deeply trusted by rural communities.

Additionally, the Gewog Agriculture Centre and agriculture extension agent emerged as significant contributors, accounting for a combined total of 59.39% of the population's awareness about IRVs. Also reported by Lwoga et al., (2011), these institutions play a crucial role in delivering agricultural education, training, and support services to rural communities, thereby serving as key conduits for knowledge transfer and technology adoption. However, the lowest number of farmers gained knowledge from the Agriculture Research and Development Centre (ARDCs) which could be due to the functioning of the research centre as it is mainly instituted to conduct research rather than information dissemination. Additionally, a weak linkage between researchers and extension services may have contributed to this gap, suggesting a need for stronger collaboration to enhance outreach and knowledge-sharing.

Overall, the data underscores the diverse pathways through which awareness about IRVs is generated, ranging from informal farmer networks to formal agricultural extension services and research institutions. By understanding these sources of awareness, policymakers, and agricultural organizations can tailor their outreach efforts to effectively reach and educate diverse agricultural communities, ultimately facilitating the widespread promotion and adoption of IRVs and contributing to sustainable agricultural development.

Table 4. Awareness level of the respondents and source of information about IRVs for the respondents in Sarpang district

| Details | Frequency | Percentage |
|---|---|---|
| *Aware of IRVs* | | |
| Yes | 262 | 99.24 |
| No | 2 | 0.76 |
| Total | 264 | |
| *Source of Information** | | |
| Other Farmers | 107 | 40.84 |
| Gewog Agriculture Centre | 97 | 37.02 |
| Agriculture Extension Agent | 56 | 21.37 |
| ARDC-Samtenling | 2 | 0.76 |
| Total | 262 | |

Source: Field Survey, 2024

* Source of information is only for the 262 respondents that were aware of IRVs

### 3.3 Household-Level adoption rate

In this study, a household was considered an adopter if they grew any of the IRVs in any area of land. As observed, regardless of the varieties of IRVs, 60.61% of the sampled households cultivated improved varieties (Table 5). However, the adoption rate of IRVs varied greatly between the study sites with Gelephu having the lowest adoption rate (44.4%) and Umling having the highest adoption rate (68.9%). Further analysis of the households cultivating IRVs revealed that out of the 60.61% of households cultivating IRVs, 72% of the households cultivated IRVs which were released officially in Bhutan while the remaining 27% of the households cultivated Indian IRVs sourced from informal channels (Table 6).

The differences in the adoption rates reported among the study sites show farmers' preferences of specific variety to specific needs and social settings, as seen in Wangdue-Punakha Valley by Chhogyel & Bajgai (2016). They also mentioned that the disparity in adoption rates could also be linked to variations in the levels of support provided by DoA across different gewogs and districts.

The prevalence of Bhutanese IRVs in a significant portion of households indicates the significance of governmental support, research, and development efforts in promoting the adoption of IRVs. The presence of Indian IRVs highlights the impact of farmer-to-farmer knowledge transfer on adoption trends. Farmer networks might have played a key role in this dynamic process, which might have led Bhutanese farmers to seek out Indian IRVs. This could be because they recognized the perceived benefits of Indian IRVs in terms of specific features or qualities offered by these varieties. The presence of Indian IRVs which are not officially released in our country also highlights the diverse sources of IRVs being cultivated and suggests the importance of considering both formal and informal channels in assessing adoption rates and understanding farmers' preferences.

The overall adoption rate of 60.61% for IRVs in this study site was slightly lower than the adoption rate of 65% for Wangdue-Punakha Valley as reported by Chhogyel & Bajgai (2016). This slightly lower rate of adoption in the district suggests the need for more effort to promote the adoption of IRVs, especially considering Sarpang as one of the major rice-producing districts.

However, the adoption rate of IRVs in this region has significantly improved, with the current rate of 60.61% marking a twofold increase compared to the 32% household adoption rate reported in low-altitude zones in 2002 (Shrestha, 2004). This increase in the adoption rate of IRVs underscores the success of the efforts by the MoAL to promote the adoption of IRVs.

Table 5. Household-level rice variety adoption rates in five gewogs of Sarpang district for the 2023 rice growing season

| Gewogs | Number of sampled households | | Total |
|---|---|---|---|
| | Adopters | Non-adopters | |
| Dekiling | 45 (60.8) | 29 (39.2) | 74 |
| Gelephu | 12 (44.4) | 15 (55.6) | 27 |

| | | | |
|---|---|---|---|
| Samtenling | 39 (66.1) | 20 (33.9) | 59 |
| Sherzhong | 22 (51.2) | 21 (48.8) | 43 |
| Umling | 42 (68.9) | 19 (31.1) | 61 |
| Total | 160 (60.61) | 104 (39.39) | 264 (100) |

Source: Field survey, 2024
Note: The values in the parenthesis indicate the percentage of rice growers

Table 6. Adoption rate of Bhutanese and Indian IRVs in terms of the number of households and area under cultivation

| Varieties | No. of adopters | Area (acres) |
|---|---|---|
| Bhutanese | 126 (72) | 161.12 (64.2) |
| Indian | 49 (28) | 90 (35.8) |
| Total | 175 | 251.12 |

Source: Field Survey, 2024 Note: values in the parenthesis indicate the percent of farmers and area under IRVs cultivation

### 3.4 Cultivated area under IRVs

Table 7 shows the total area of wetland, the total cultivated land for the study sites, and the land allocation by adopters and non-adopters. On average, each household in the study site possessed 2.15 acres of wetland, with rice cultivation covering approximately 2 acres of this land, representing 92.3% of the total wetland area. This indicates a high utilization of wetlands for rice cultivation among the surveyed households.

The percent area grown with IRVs was 47.25%, equivalent to 251.12 acres, compared to the total cultivated wetland (566.7 acres) in the surveyed gewogs. Notably, Dekiling, Samtenling, and Umling gewogs had a higher percentage of wetland areas under IRVs compared to areas under traditional varieties. Conversely, in Sherzong and Gelephu gewogs, traditional varieties accounted for 67.5% to 73% of the total cultivated wetland area. This was primarily due to the presence of better-performing local varieties, such as Mama rice in Gelephu and Sipsoo rice in Sherzong, which are well-adapted to the local conditions (Figure 2). Further analysis revealed that out of the 47.25% of land cultivated with IRVs, 64.2% of the wetland was cultivated with IRVs officially released in our country while the remaining 35.8% was covered by Indian IRVs, which were not officially released (Table 6).

The percentage of wetlands cultivated with IRVs in this study area was lower, standing at 47.25%, compared to the findings of Chhogyel and Bajgai (2016) for Punakha (56.7%) and Wangdue (54.5%) district. The area under IRVs in this study represents a significant increase compared to historical adoption rates in the region. For instance, compared to the 17% of the wetland cultivated with IRVs reported by Shrestha (2004) in 2002 in the low-altitude region, the current area under IRVs reflects a substantial improvement of IRV adoption over time.

However, there appears to be no significant change in the total wetland cultivated with IRVs compared to 2011, as noted by Ghimiray et al. (2013) in the same agroecological region. Despite this, the sustained high percentage of area under IRVs observed in this study indicates the continued success of efforts to promote IRVs and enhance farming practices in the region.

Table 7. Land allocation in rice production and the area under IRVs across the study area

| Gewogs | *N* | Total wetland (acres) | Area cultivated to rice (acres) | | | Average area grown with rice per household (acres) |
|---|---|---|---|---|---|---|
| | | | IRVs | Traditional varieties | Total | |
| Dekiling | 74 | 118.9 | 63.35 (56.4) | 48.91 (43.6) | 112.26 | 1.5 |
| Gelephu | 27 | 64.7 | 15.16 (27) | 40.9 (73) | 56.06 | 2.1 |
| Samtenling | 59 | 105.2 | 55.7 (54) | 47.57 (46) | 103.27 | 1.7 |
| Sherzong | 43 | 110.3 | 34.06 (32.5) | 70.85 (67.5) | 104.91 | 2.4 |
| Umling | 61 | 167.7 | 82.85 (53.5) | 72.06 (46.5) | 154.91 | 2.5 |
| Total | 264 | 566.7 | 251.12 (47.25) | 280.29 (52.75) | 531.41 | 2 |

Source: Field survey, 2024

Note: The values in the parenthesis indicate the percentage of land cultivated with rice

### 3.5 Rice varieties grown by farmers

The study found 18 different rice varieties under cultivation in the Sarpang district during the 2023 growing season. A total of five IRVs and 13 traditional varieties were grown by the respondents in an area of 531.41 acres (Table 8). Agriculture Research and Development Center-Samtenling has released six IRVs to date, however, farmers only grew three IRVs (Bhur Khambja-1, Bhur Khambja-2, and Samtenling Rey Kaap-3). Farmers also grew two IRVs (Ranjit and Badhur) from India released by the Assam Agricultural University in 1990 (Dutta et al., 2023). Despite not being formally released in the district, the open border between Bhutan and India allowed the farmers to adopt two enhanced Indian cultivars through informal channels (farmer-to-farmer interaction). Umling and Sherzong gewogs were among those cultivating Indian IRVs.

Bhur Khambja-1 was the most widely cultivated IRV in terms of both the number of cultivators and the area cultivated (Table 8). This variety, characterized as a medium-maturity main-season variety is widely adopted for upland and rainfed ecologies in Bhutan (Chhogyel et al., 2016; Dendup & Chhogyel, 2018; Dendup et al., 2021). This variety was originally bred in

IRRI using IR12979-24-1 and UPL RI 5 as parents and released for the uplands of the Philippines as APO (Ghimiray & Vernooy, 2017).

The high adoption rate of Bhur Khambja-1 was also reported in previous studies, including in Singey gewog by Dendup et al. (2021). Furthermore, compared to the 4% adoption rate for the low altitude zone in 2011 (Ghimiray et al., 2013), Bhur Khambja-1 cultivation has significantly increased, covering an area of 25%. However, its adoption in gewogs like Gelephu and Umling remained very minimal due to the presence of better-performing varieties such as Mama in Gelephu and Ranjit in Umling (Figure 2).

Currently, only the farmers from Samtenling and Dekiling gewogs grew the newly released variety - Samtenling Rey Kaap-3, which is an introduced variety from Lao PDR with an unknown pedigree (Figure 2). This variety was recently released in 2022 by ARDC-Samtenling and to date, 7.6% of the surveyed population grew the variety in a total area of 22.29 acres which corresponds to 4.2% of the total rice area.

Among the 13 traditional varieties, Khamtey was the most popular variety among the surveyed households in the study area. Approximately 27.6% of farmers cultivated Khamtey, covering 127.67 acres of wetland. The popularity of Khamtey can be attributed to the variety's preferred taste and good market price, particularly in Sherzong, Samtenling, and Umling gewogs.

Table 8. The adoption rate of IRVs and traditional rice varieties based on the number of households and areas under cultivation for the 2023 rice growing season

| Varieties | Number of adopters | Total area cultivated (acres) |
|---|---|---|
| *Improved Rice Varieties* | | |
| Bhur Khambja-1 | 101 (38.2) | 132.7 (25) |
| Ranjit | 38 (14.4) | 69.2 (13) |
| Samtenling Rey Kaap-3 | 20 (7.6) | 22.3 (4.2) |
| Badhur | 11 (4.2) | 20.8 (4) |
| Bhur Khambja-2 | 5 (1.9) | 6.1 (1.1) |
| Total | 175 | 251.1 (47.25) |
| *Traditional Rice Varieties* | | |
| Khamtey | 73 (27.6) | 127.6 (24) |
| Champa | 30 (11.3) | 38 (7.2) |
| Mama | 17 (6.4) | 32.9 (6.2) |
| Masinu | 14 (5.3) | 19.7 (3.7) |
| Sipsoo | 14 (5.3) | 20.7 (4) |
| Manjana | 9 (3.4) | 14.1 (2.6) |
| Mouli | 6 (2.3) | 8.3 (1.6) |
| Poudhey | 5 (0.7) | 7.5 (1.4) |

| | | |
|---|---|---|
| Mosuli | 4 (1.5) | 4.6 (0.8) |
| Tsirang Zam | 2 (0.7) | 1.9 (0.3) |
| Apa bara | 1 (0.4) | 3.6 (0.7) |
| Ausaley | 1 (0.4) | 1.1 (0.2) |
| Cerki | 1 (0.4) | 0.2 (0.05) |
| Total | 177 | 280.29 |

Source: Field Survey, 2024

Note: Values in the parenthesis indicate the percentage of farmers for the first column and the percentage of total land for the second column

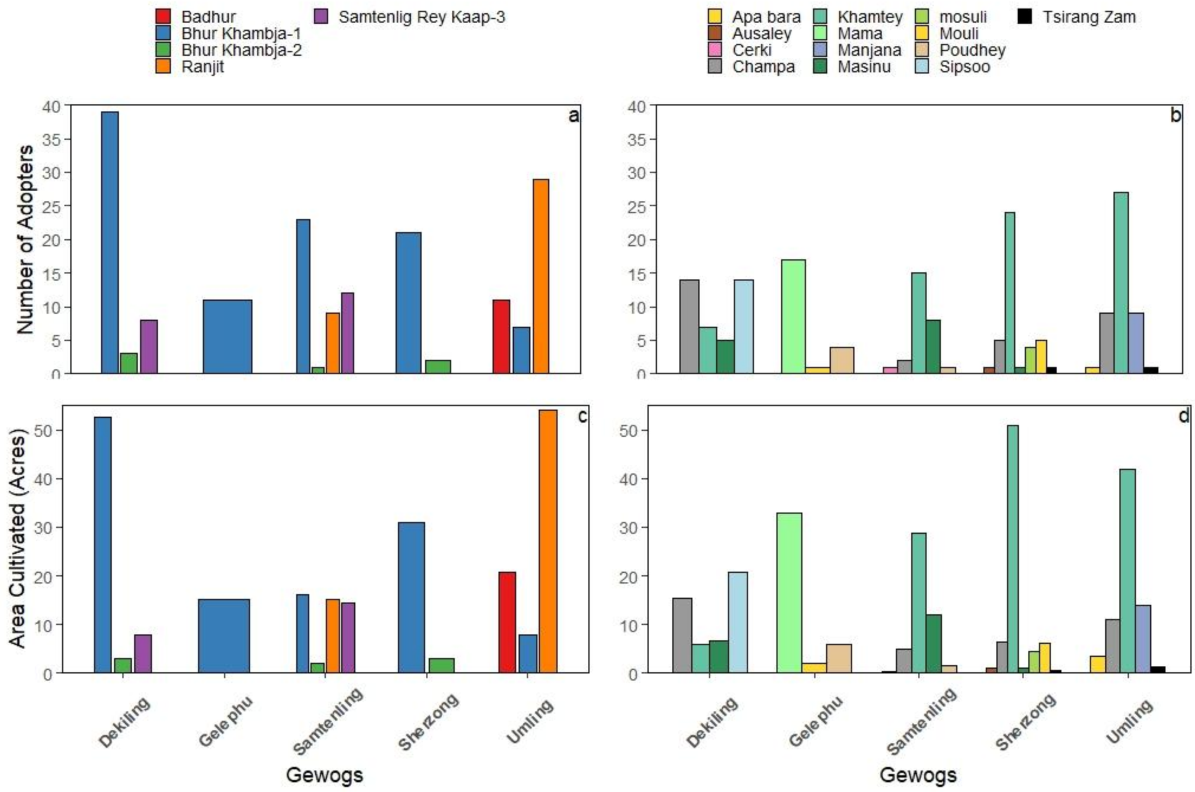


Figure 2. a. Number of households from each gewog adopting IRVs. b. Number of households from each gewog adopting traditional varieties. c. Wetland areas under different gewogs cultivated with IRVs. d. Wetland areas under different gewogs cultivated with traditional varieties

### 3.6 Rice varietal diversity

The findings from the study provided interesting insights about the farmers' diversity of rice varieties. The data showed that a significant portion of the farmers (68.5%) grew only one variety of rice. Upon further disaggregation of the data in this subgroup, 51.9% of them grew IRVs and 48.1% of them grew traditional varieties (Table 9). Moreover, 29.5% of the surveyed households grew a combination of two different rice varieties. Among these households, the majority (62.8%) cultivated a combination of IRVs and Traditional variety. Some households (20.5%) grew a combination of two different traditional varieties, while others (16.7%)

cultivated two different IRVs. A very small proportion of the population (1.9%) grew three different rice varieties. Primarily, they grew one IRV along with two traditional varieties, showcasing a diverse approach to rice cultivation practices.

Farmers claimed that their desire to make use of each type's distinct traits and advantages is what motivates them to plant a diversity of rice varieties. While IRVs are favoured for their higher yield potential, which guarantees enough output till the following harvest, traditional varieties are preferred for their culinary qualities. In order to increase total production, farmers also combine two different IRVs, including both the Bhutanese and Indian varieties because they believe them to be locally adapted. Furthermore, the inclusion of several Bhutanese IRVs, for example, Samtenling Rey Kaap-3 in conjunction with Bhur Khambja-1 and 2, allows performance assessment and testing. As seen in this study and reported by other studies (Chhogyel & Bajgai, 2016; Dendup et al., 2021), rice variety diversification is a common technique in developing nations, especially among subsistence farmers. Farmers may satisfy their household demands through this variety diversification technique while also reducing the chance of crop failures (Almekinders et al., 1994; Gauchan et al., 2005).

Table 9. Varietal diversity of rice in the study area for 2023 rice growing season

| Variety composition | Frequency | Percentage |
|---|---|---|
| Single | 181 | 68.5 |
| *Only Improved* | 94 | 51.9 |
| *Only Traditional* | 87 | 48.1 |
| Double | 78 | 29.5 |
| *Improved and Traditional* | 49 | 62.8 |
| *Traditional and Traditional* | 16 | 20.5 |
| *Improved and Improved* | 13 | 16.7 |
| Triple | 5 | 1.9 |
| *1 Improved and 2 Traditional* | 4 | 80 |
| *2 Improved and 1 Traditional* | 1 | 20 |
| Total | 264 | 100 |

Source: Field Survey, 2024

### 3.7 **Yield differential among rice varieties**

The yield data from farmers were collected in terms of their local unit called Muri (which is equivalent to 40 kg) and converted to kg acre$^{-1}$ (Dendup et al., 2021). The study found significant differences ($F(2, 349) = 48.972$, $p < .001$) in the mean yield of different rice varieties. Both the Indian and Bhutanese IRVs had higher yields compared to the traditional varieties (Table 10). On average, IRVs demonstrated a remarkable yield advantage of 39.71% over traditional varieties. This finding underscores the genetic superiority of IRVs and highlights their potential to enhance agricultural productivity and food security.

Interestingly, the analysis showed just a little yield disparity of 43 kg acre$^{-1}$ between Indian and Bhutanese IRVs. This suggests that both Bhutanese and Indian IRVs perform comparably well in terms of yield in the proposed study site. Samtenling Rey Kaap-3 was the best-performing IRV, with the highest yield per acre (993.21 kg acre-1, Figure 3). Badhur, Bhur Khambja-1, Ranjit, and Bhur Khambja-2 came next, demonstrating the wide range of high-yielding choices for the farmers. When compared among traditional types, some of the varieties—namely, Sipsoo, Champa, Cerki, and Mosuli—showed higher yields. This demonstrates how important traditional varieties are to preserving agricultural diversity and satisfying specialized consumer wants or preferences.

The yield advantage of IRVs in this study area was similar to what was reported by Dendup et al. (2021) in the neighbouring area of Singey gewog (37.9%). Punakha (33%) and Wangdue (25%) districts in central Bhutan also reported similar findings of yield advantage of IRVs (Chhogyel & Bajgai, 2016). Similar findings were also reported internationally by Tsinigo et al, (2017) in Ghana, Bello et al. (2020) in Nigeria, and Hossain et al. (2006) in Bangladesh. This indicates that IRVs are a promising strategy for raising agricultural productivity and tackling global food security issues because they are consistently effective in increasing rice yields.

Overall, these results highlight how critical it is to encourage the use of IRVs to increase rice yield and support food security. Furthermore, identifying the performance of certain varieties, both traditional and IRVs can help guide focused initiatives meant to improved rice growing techniques and maximize yields for Bhutanese farmers.

Table 10. Mean yield difference between the Bhutanese IRVs, Indian IRVs, and the traditional varieties grown by the farmers

| Type of variety | Mean yield (kg acre$^{-1}$) |
|---|---|
| Improve Rice Varieties (Bhutanese) | 919.6 ± 25.02 a[1] |
| Improve Rice Varieties (Indian) | 876.8 ± 40.51 a |
| Traditional Varieties | 642.8 ± 24.81 b |

[1] Means followed by the same lowercase letters within a column indicate no significant difference between treatments ($p < .05$) as established by the Bonferroni post-hoc test. Values are means ± standard deviation.

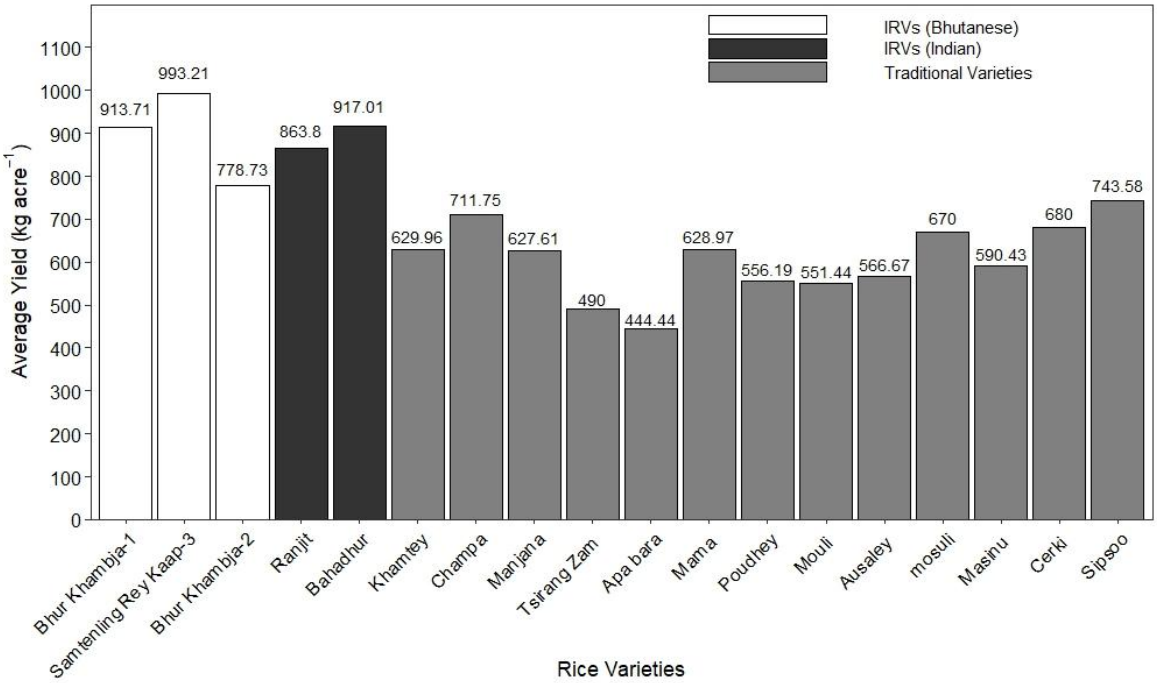


Figure 3. Average yield of Bhutanese IRVs, Indian IRVs, and traditional varieties recorded in the Sarpang district

## 3.8 Source of paddy seeds

The study showed that the seed sources differed among the varieties. The Bhutanese IRVs were mostly distributed from the Gewog Agriculture Centre which is free of cost (Figure 4). Also, the ARDC-Samtenling was one major seed source for the newly developed rice variety (Samtenling Rey Kaap-3). The 14% of the farmers sourcing seeds from ARDC were mainly those who were selected as a trial for the variety Samtenling Rey Kaap-3. As for the Indian IRVs, some farmers sourced it from the Indian farmers and most of them availed it from their fellow farmers. The traditional varieties were all sourced from informal channels including fellow farmers and self-saved seeds.

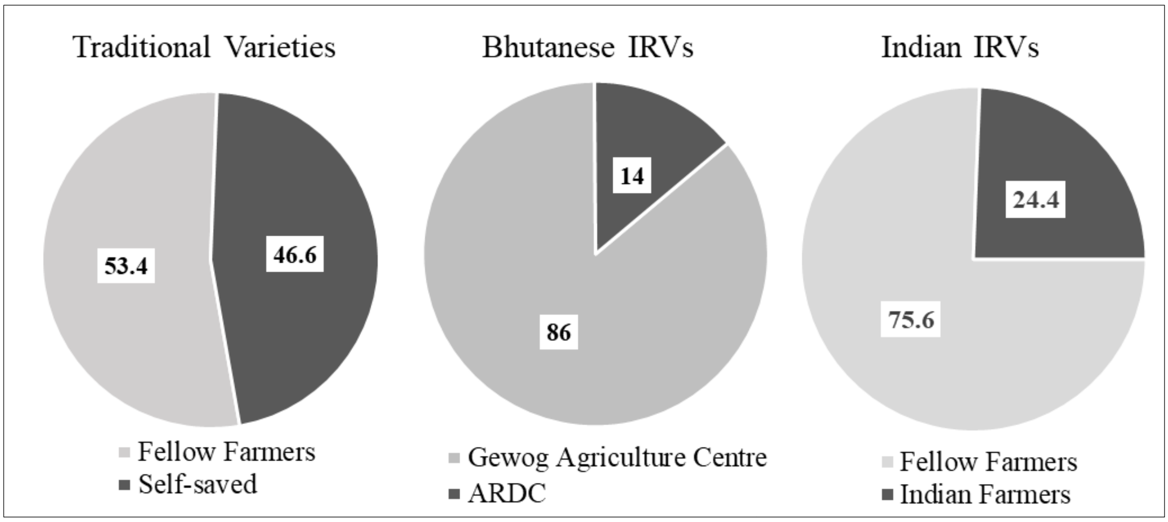


Figure 4. Sources of Bhutanese IRVs, Indian IRVs, and traditional varieties

### 3.9 **Positive and negative traits of IRVs**

The adopters of IRVs highlighted a range of benefits compared to traditional varieties (Figure 5 (a). Foremost among these advantages was the capacity of IRVs to yield significantly higher quantities of rice, a factor that resonated strongly with respondents. Additionally, a notable proportion of adopters acknowledged IRVs for their enhanced resistance to lodging, mitigating the risk of crop damage and yield loss. Furthermore, some adopters appreciated the early maturity of IRVs, facilitating timely harvesting and potentially reducing susceptibility to adverse weather conditions. While a minority of respondents noted IRVs' improved traits such as drought resistance, preferred taste, resistance to pests and diseases, and uniform maturity compared to traditional varieties, these attributes still contributed to the overall appeal and adoption of IRVs among farmers seeking improved agricultural outcomes.

The surveyed individuals predominantly identified poor taste as the primary negative traits associated with IRVs (Figure 5 (b). This finding indicates that despite the numerous advantages of IRVs, concerns regarding sensory qualities persist among a significant portion of adopters. Additionally, a minority of respondents expressed concerns over other negative traits, including low market price, early maturity, and an increased incidence of pests and diseases. The problem with early maturity was that the paddy would mature before the monsoon season ends hence complicating the process of drying and storage. Also, an increased incidence of bird attacks was noted as IRVs mature first compared to the traditional varieties. These concerns highlight various challenges faced by adopters of IRVs, ranging from economic considerations to environmental vulnerabilities and pest management issues. Understanding and addressing these negative traits are crucial for the continued adoption and sustainable cultivation of IRVs in agricultural practices. Researchers must prioritize these issues as part of the variety development process, ensuring that future IRVs are not only high-yielding but also resilient to local challenges and well-suited to farmers' needs. By incorporating feedback from farmers and addressing specific shortcomings, researchers can enhance the overall acceptance and long-term viability of IRVs in diverse agricultural settings.

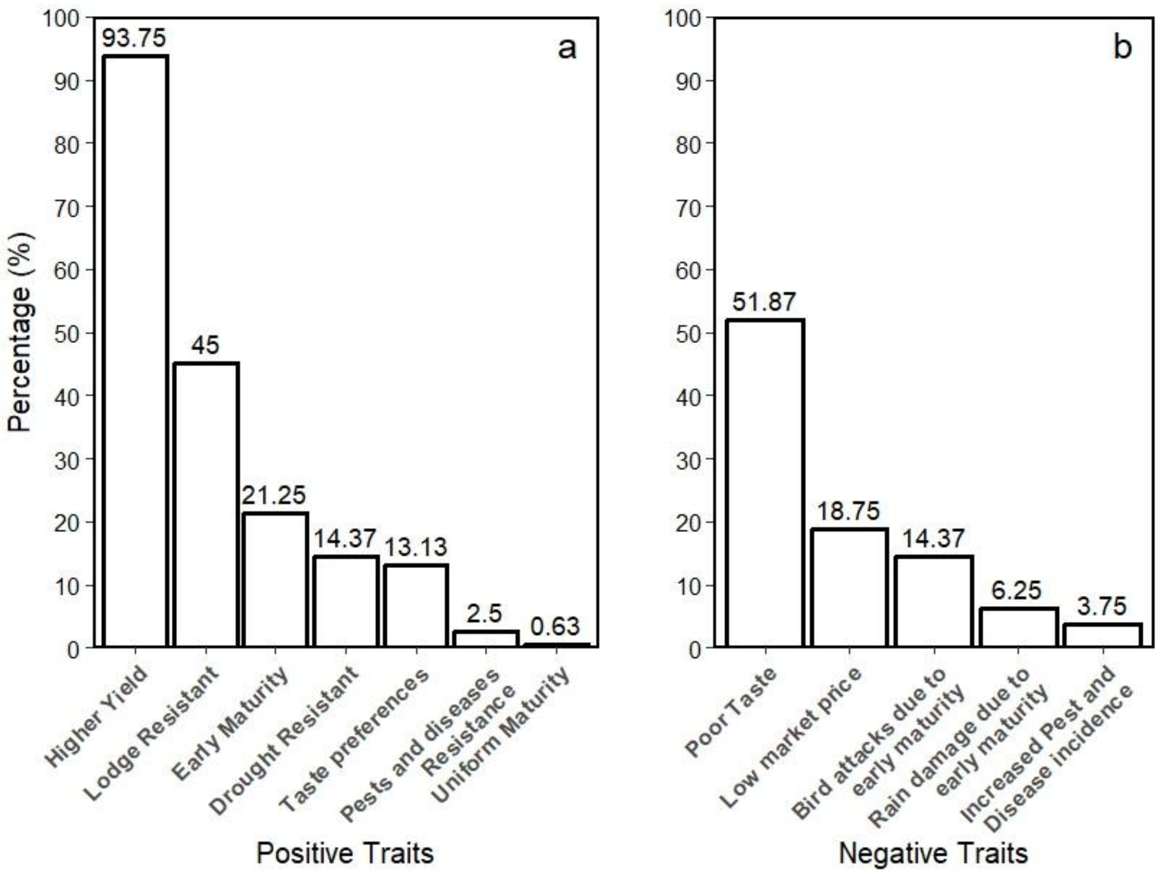


Figure 5. (a) Positive and (b) negative traits of IRVs according to the IRV adopters ($n$ = 160)

### 3.10 **Factors affecting the adoption of IRVs**

The surveyed data were analysed using the maximum likelihood estimation of a logistic regression model to assess the factors affecting the adoption of IRVs in the wet subtropical zone of Bhutan. The factors that influence the adoption of IRVs are presented in Table 4.8. The model had a correct prediction rate of 67.045%. Given that the model's primary goal was to determine the main factors that influence the adoption of IRVs, its -2 Log Likelihood and substantial model chi-square (p <.001) support its suitability for the purpose (Table 11).

The results indicated that the family size and total wetland (owned + leased) were the

Table 11. Logit estimates of coefficients of various determinants affecting the adoption of improved rice varieties in Sarpang district, Bhutan, 2023

| Variables | Coefficient estimate (β) | Standard error | Odds ratio | *p*-value |
|---|---|---|---|---|
| Constant | -1.609 | 1.149 | 0.200 | .162 |
| Age | -0.002 | 0.013 | 0.998 | .895 |
| Family Size | 0.212 | 0.098 | 1.237 | .023 * |
| Total Wetland | -0.325 | 0.125 | 0.723 | .010 * |
| Extension visit frequency | 0.007 | 0.177 | 1.007 | .970 |
| Gender (male) | -0.188 | 0.312 | 0.828 | .547 |
| Education (yes) | -0.272 | 0.313 | 0.762 | .385 |
| Total Family labour | 0.143 | 0.127 | 1.154 | .259 |
| Farm machine ownership (yes) | -0.208 | 0.353 | 0.812 | .556 |
| Farming experience (6-10 years) | 1.455 | 1.032 | 4.283 | .158 |
| Farming experience (More than 10 years) | 1.385 | 0.856 | 3.996 | .106 |
| Source of Irrigation (Rainfed) | 0.966 | 0.855 | 2.629 | .258 |
| Marketing (Yes) | 0.222 | 0.480 | 1.248 | .664 |
| Model $\chi^2$ | | 34.409 | | < .001*** |
| -2 Log likelihood | | 319.603 | | |
| Overall cases correctly predicted (%) | | 67.045 | | |
| Sample size | | 264 | | |

Note: * significant at $p < .05$, *** significant at $p < .001$

significant factors that influenced the adoption of IRVs. However, the variables such as the age of the household head, extension visit frequency, gender of the household head, education of the household head, farm machinery ownership, farming experience, source of irrigation, marketing their produce, and total family labour did not have any significant effect in their influence on the adoption of the IRVs.

### 3.10.1 The influence of family size

The model's results showed that family size significantly increased the likelihood of adopting IRVs. More specifically, the positive coefficient estimate showed that families with greater family sizes were more likely to adopt IRVs than families with fewer members. This result is consistent with previous research (Ruzzante et al., 2021; Garba et al., 2019; Chukwu et al., 2016), which frequently uses family size as a proxy for labour availability in agricultural contexts. The greater labour availability for farming tasks in bigger families might be the reason for the positive correlation seen between family size and IRV adoption. There is more ability to do rice cultivation activities, such as planting, weeding, and harvesting, when there are more family members available to help in agriculture.

According to the findings of Bahiru et al. (2023), there is a negative relationship between household food security and family size, meaning that larger families are more likely to experience food insecurity. Considering that larger households typically have higher food requirements, this correlation is very noteworthy. Households may utilize IRVs as a practical solution in response. According to research done by Hossain et al. (2006); Chhogyel & Bajgai (2016); Tsinigo et al, (2017); Bello et al. (2020); Dendup et al. (2021); Osei et al. (2022); and also seen in this study, IRVs usually yield more than traditional types. Households can increase rice production using IRVs and better match it to the nutritional needs of families.

### 3.10.2 The influence of total wetland

To assess the effect of farm size on the probability of adoption of IRVs, the total wetland cultivated by the household was included in the model. The results of the analysis showed that the probability of adopting IRVs was negatively and significantly impacted by the total wetland area. This implies that compared to families with lower wetland areas, those with bigger wetland areas were less likely to adopt IRVs. This negative effect of land size was contrasting to what was proposed. The result of this study also contrasted with the following studies: Oyekale and Idjesa, (2009); Ghimire et al. (2015); Chukwu et al. (2016); Chandio and Yuansheng, (2018); Rahaman et al. (2020); Loko et al. (2022). They reasoned that since they have the means and space to test and apply new methods on their farms, farmers with greater land holdings are more likely to embrace improved rice production technology.

Households with smaller wetland sizes showed a higher probability of adoption of IRVs in this study. The trend might be probably caused by the IRVs' higher yielding potential than traditional varieties, which allow farmers with smaller areas of land to produce more food. This result is consistent with that of Bahiru et al. (2023), who observed a positive relationship between land size and household food security. They emphasised that in order to meet yearly food and nutritional needs, higher agricultural output is required because smaller landholdings are more vulnerable to food insecurity. Furthermore, the fact that smaller landholders choose IRVs emphasizes how crucial technology is to promote sustainable farming practices.

## 4 Conclusion

This study assessed the awareness, adoption rate, yield difference, and factors affecting the adoption of IRVs in the Sarpang district. A remarkably high level of awareness regarding IRVs was recorded in the study area. A majority (60.61%) of the farmers adopted IRVs which included both the Bhutanese and Indian IRVs, reflecting a positive trend towards embracing these varieties. However, the area cultivated with IRVs remained relatively low compared to the traditional varieties. The Gewog Agriculture Centres and fellow farmers were the most prominent sources of Bhutanese and Indian IRVs, respectively. A diverse range of rice varieties was recorded, with Bhur Khambja-1 emerging as the most widely cultivated IRV and Khamtey as the most cultivated traditional variety in terms of both the number of cultivators and the area cultivated. Importantly, IRVs in the study area demonstrated a significant (39.71%) yield advantage over traditional varieties. The most acknowledged positive characteristic of IRVs was their higher productivity, whereas their poor cooking quality was recognized as a negative attribute. The empirical results on factors affecting the adoption of IRVs showed that family size had a significant positive influence on the probability of adoption of IRVs, whereas, the total wetland had a significant negative influence on the probability of adoption of IRVs. This study recommends that Bhutanese rice researchers need to consider the farmers' preferences for rice varieties and specific traits, their socio-demographic characteristics such as family size and land size, while considering the development and release of IRVs in the region, in order to enhance and promote the adoption of the IRVs. Further studies should be taken up to better understand the factors other than those included in this study, affecting the adoption of IRVs in multiple locations.

## 5 Acknowledgment

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## 6 Authors' contribution statement

The research work was in partial fulfilment of the BSc Organic Agriculture programme of Ms. Yangchen Ghishing, which was supervised by Dr. Mahesh Ghimiray, Faculty of Agriculture at CNR. The study was conceptualized and designed jointly by the two authors, with ideas and relevant literature provided to the supervisee. The proposal was then vetted by a committee within the faculty and suggestions for improvement were incorporated. The supervisee was responsible for implementing field work including data collection, validation, analysis, and interpretation with intermittent guidance and supervision. Mr. Pema Tamang helped with field data collection, data analysis, and provided constructive feedback. Ms. Yangchen Ghishing drafted the manuscript and Dr. Mahesh Ghimiray provided critical comments and feedback for improvement.

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