

Varietal Diversity, Seed Security and Adoption Dynamics of Rice Farmers in Eastern India

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Abstract Rice in Indian state Odisha can contribute more to the agrarian economy if existing low productivity is ameliorated through varietal diversity, improved seed security, and a higher varietal turnover. This exploratory study has found 63% of farmers acquire seeds from farm-managed seed sources. The rice area is dominated by only four mega varieties and a low level of varietal diversity (0.311) was observed. In low land flood-prone areas, such diversity is relatively low (0.25) whereas upland areas have shown higher diversity (0.349). The diversity level increases with the increase in farmers' landholding size. Inter-region variation in varietal diversity is also noticeable indicating gaps in choices and access across regions. Farmers who participated in the varietal demonstration adopted varieties as indicated by increased acreage under those varieties in subsequent years. Farmer to farmer knowledge and seed sharing was found to be strongly present. In respect of varietal traits yield, grain quality, cooking quality, and diseases and pest tolerance are most considered by farmers for variety adoption. Even though seed availability is satisfactory in the state, the seed security dimensions like access, quality, varietal choice, and seed system stability need improvement to better the overall rice seed security at the farm level.

Keywords Varietal Turnover, Seed Replacement, Varietal Diversity, Seed Security, Seed System Stability

1. Introduction

Odisha state has a 4.19 crore population with a decadal growth of 14.05% and 32.6% of people still live below the poverty line [1]. Odisha produces 8.4 million tons of rice contributing, about 7% of India's total production but registering 2.1 ton/ha productivity as against the national average of 2.7 tons/ha [2]. Such low productivity should be seen in the context of only 35% area under irrigation coverage and merely 15% area is sown with rice in the dry season because owing to limited irrigation facilities [3]. The average monthly income of an agriculture household in Odisha is just Rs 5112 just half of the national average [4]. Such prelude reaffirms that the progress in the status of farmers is possible through better rice farming in Odisha.

Rice is grown in all 30 districts of the state, majorly in the wet season. Mayurbhanj has the highest coverage of 3.13 lakh, followed by Ganjam (2.81 lakh) and Bargarh (2.3 lakh). Bhadrak, Balasore, Subarnapur, Sambalpur, and Sundargarh are other major rice-producing districts [5]. Rice assumes a special significance in the agrarian economy of Odisha as the rice-based cropping system is an important growth driver of the state's economy [6]. The recently released state's agriculture policy (2018) says rice contributes 24.4% of 7500 crore agriculture GDP besides employing a vast workforce. Share of Gross State Value Added (GSVA) of Agriculture and Allied Sector in Total GSVA of State at Current Prices stands at 19.35% (2017-18) [7]. Therefore, any endeavor to overhaul the farm sector in the state needs substantial focus on rice and

its growers. However, the poor seed replacement and low varietal turnover, institutional challenges of farmers to access quality seeds are major rice development impediments in the state [8]. These are the major challenges in boosting rice productivity and making it poorly comparable with other agriculturally progressive states in India.

Study Objectives

In view of the aforesaid context, the study had following four objectives to attain.

- (a) To profile rice farmers with regard to land resource endowment, currently grown varieties and incidence of abiotic stresses.
- (b) To assess farm level varietal diversity across districts, ecologies, and farmers' category.
- (c) To analyze the seed source, adoption dynamics and varietal trait preference of farmers.
- (d) To evaluate the rice seed security at farmer's level.

2. Materials and Methods

2.1. Farmers' Profile

Simple descriptive statistical tools were used for the basic profile of the farmers using data on gender, caste landholding size, rice varieties they grow, and occurrence of abiotic stress at the farm level.

2.2. Determination of Varietal Diversity

There are a quite few methodical tools to evaluate concentration (specialization) or diversification of a component in a specific space and time. Herfindal, Ogive, entropy, and Simpson index are some of the popular indices widely used in agriculture to measure crop diversification [9]. The most often used Simpson diversity index which is essentially a derivation of the Herfindal index was employed in this study to numerically assess the diversification of rice varieties in the state [10].

Diversity in varieties at the farmer level indicates the adoption and spread of varieties by individual farmers [11]. A higher diversity index reflects a wider choice of varieties of the farmers. This can be further disaggregated at the ecology level to understand how the varietal diversity index differs across ecologies. Simpson diversity index (SDI) assesses the degree of concentration of varieties at farm level in different ecologies [12]. The same index is often used to measure the extent of diversification. An SDI of 0 measures no varietal diversity whereas the value towards 1 tells a higher degree of diversity meaning the farmer is growing a large number of varieties in his land of different ecologies. The mathematical expression for this index is

$$SDI = 1 - \sum_{i=1}^n p^2$$

P_i is the proportionate area of the i^{th} variety and total cultivated area; n is the total number of varieties grown by the farmers in a particular ecology.

2.3. Seed Source, Adoption Dynamics, and Varietal Trait Preference of the Farmers

Major seed sources data were analysed and graphed to show the distribution of different seed points from where farmers meet their requirements. In comprehending the adoption dynamics, farmer to farmer seed sharing/exchange data was examined to infer how a farmer with tested experience of an improved variety can play a catalytic role in the dissemination of that variety. With a frequency analysis on the most preferred channels to acquire knowledge about a new variety, the best route for varietal dissemination was inferred and presented with a graph. The varietal trait preference was studied with data on farmers' best three trait choices about a variety. These data were categorized and visualized using a tree map that shows the concentration of different trait choices of farmers when they are in search of a new variety. The required primary data were collected from about 3000 farmers, sampled proportionately from 20 districts.

2.4. Seed Security of the Farmers

The seed security of a farm family exhibits direct bearings on food and nutrition security. Seed security is a critical enabler in building a more food secure farm community. However, unlike measuring food security, the domain of seed security has some computational difficulties [13]. The household-level of seed security in this study has employed the measurement framework proposed in the consultation workshop on seed security assessment by FAO in 2013. Seed security is vital for farm growth in Odisha [14].

2.5. How is Seed Security Defined?

Building on the seed security framework of FAO, a household can be said seed secure when it has sufficient and uninterrupted access to quality seeds of its choices and the seed system is adequately resilient to serve the farmers even in the context of shocks and vulnerability. Thus a resilient system should meet seed demand even when seed production or crop season is hit by climatic or non-climatic shocks. This further implies seed security of a farmer needs to be counted on five interlinked parameters—seed availability, seed access, seed quality, varietal suitability, and stability of the seed system. These indicators as defined and included in the study can be understood from the tabulated brief below. The definition and concepts of these parameters are largely derived from the internationally recognized food security framework. Worthwhile to mention here is that, in this study, the seed security analysis is conducted for rice seed only.

Each respondent was asked to score their attainment of these five indicators (**Table 1**) using a 10-point scale with 0 being lowest and 10 the highest. Such rating for all indicators was a memory-based perceptual assessment of farmers. The mean scores of each parameter plotted in a radar diagram to create a seed security pentagon depicting how seed secures the farmers are in the study area.

Table 1. Key Parameters of Seed Security

#	Parameter	Description
1	Seed Availability	It implies, adequate quantity of seed is available in the form of farm-saved seeds, stock of fellow farmers, local seed outlets (both private and public) in close proximity of the farmers. This availability however may not be always accessed by farmers because of knowledge deficit, poor purchasing power
2	Seed Access	Ability of a farmer to acquire quality seeds of the preferred variety, either through exchange, purchase, social networks etc.
3	Seed Quality	Quality seed encompasses—Physical purity (clean and free from inert materials), assured germination level (at least 85% germination observed), Varietal purity (not a mixture of varieties), Good seed health (seed is free from insects and plant pathogens)
4	Varietal Suitability	It exists, when a variety meets a range of farmers preferred desirable traits
5	Stability of Seed System	This indicator essentially measures the strength how the first four parameters are ensured when the seed system experiences shocks like drought, flood or a major system inefficiency.

3. Results and Discussion

3.1. Basic Demographic Details of the Farmers

Gender and Age: In the survey, 61% farmers were male and 39% were women, representing a satisfactory gender representation. Age-wise, respondents were mostly in the age bracket of 19-59 years and only 14% of farmers aged 59 years or above. The mean age of the farmers was estimated to be 45 years. The average years of schooling of sampled farmers were 5.69.

3.2. Farmers' Category

Keeping with state and national level trends, marginal and small farmers have a high concentration in the study. These two together constitute around 73% of all farmers. Medium and large farmers owning more than 4 ha land have less than 1 percent representation among all farmers (**Table 2**).

Farmers who are in possession of less than a hectare constitute 67% of the total farmers, merely 7% of farmers

reported to have owned two hectares or more land. Smaller landholdings with an average family size of 4.2, induce the incidence of poverty as indicated by 80% of farmers listed as BPL cardholders. The ST (91%), SC (89%), and OBC (72%) farmers were reported to be poorer than general category farmers.

Table 2. Share of different categories of farmers

Category of farmer	Frequency	Percent	Cumulative %
Marginal (less than 1ha)	1,960	66.87	66.87
Medium (4-10 ha)	21	0.72	67.59
Semi Medium (2-4 ha)	181	6.18	73.76
Small (1-2 ha)	765	26.10	99.86
Large (more than 10 ha)	4	0.14	100
Total	2,931	100.00	

3.3. Types of Varieties

Age of the variety has a significant bearing on crop performance because of progressive genetic erosion and susceptibility to plant pathogens over time. The study followed a simple notion to classify the farmers-grown varieties based on their age calculated using the year of their notification. A variety of fewer than 10 years from the date of notification is considered a modern variety and others are categorized as older varieties. The emphasis here is to probe how different categories of farmers have been growing these two classes of varieties. Notably, the cultivation of MV among marginal farmers is the highest (40.92%) among all other categories even though their farm size is smaller. The proportion of farmers other than marginal, who have grown MV ranges from 31.49% (Semi-medium) to 38.1% (medium). When all categories of the farmer are combined, 61.85% of them still are growing older varieties (**Table 3**).

Table 3. Varietal share among various categories of farmers

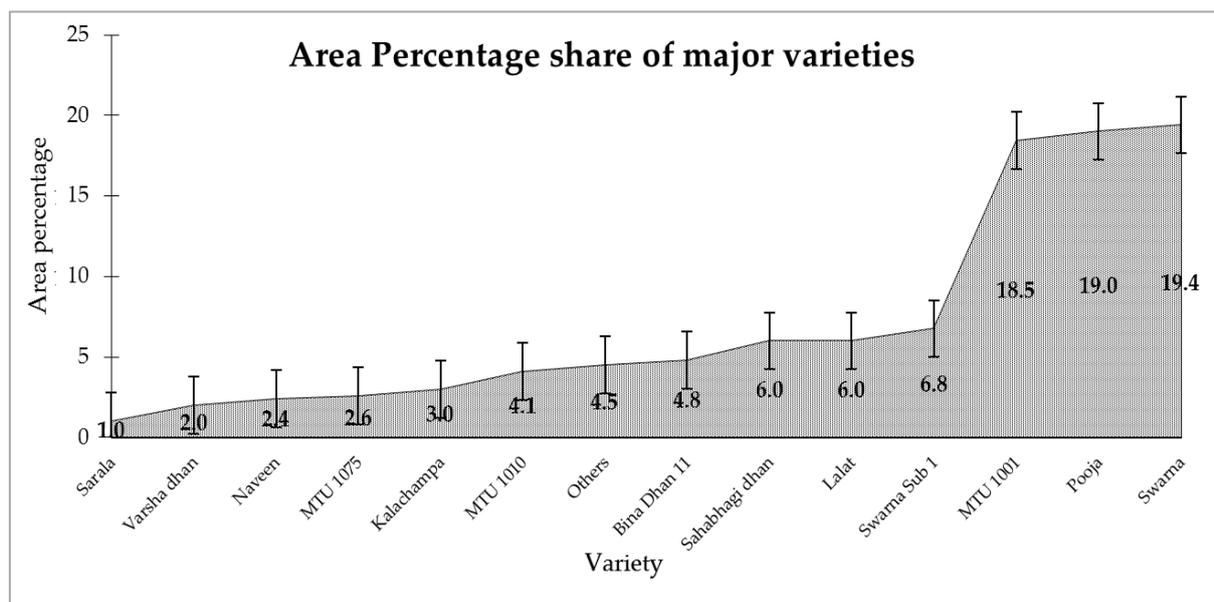
Category of farmer	Modern varieties (MV)	Older varieties (OV)	Total
Marginal (<1 ha)	802 (40.92%)	1,158 (59.08%)	1,960
Medium (4-10 ha)	8 (38.10%)	13 (61.90%)	21
Semi Medium (2-4 ha)	57 (31.49%)	124 (68.51%)	181
Small (1-2 ha)	251 (32.81%)	514 (67.19%)	765
Large (>10 ha)	0	4 (100%)	4
Total	1,118 (38.15%)	1,813 (61.85%)	2,931

3.4. The Extent of Abiotic Stress

Abiotic stress in Odisha is an important impediment to rice farming. Drought and flood are the major such abiotic stresses farmers face frequently [15]. Of all 2931 farmers, 1175.

Table 4. Different abiotic stress and its prevalence

Land type	Drought	Flood	None	Salinity	Total
Low land	162	109	229	10	510
Medium land	506	383	623	1	1513
Upland	507	20	381	0	908
Total	1175 (40.09%)	511 (17.43%)	1223 (41.73%)	11 (0.38%)	2931

**Figure 1.** Major rice varieties in Odisha

(40.09%) reported that their land is vulnerable to drought. However, only 17.43% respondents (majorly from coastal districts) said flood has hit at least one in last three years. Salinity which is an adverse phenomenon in sea shore, is not a major abiotic stress as revealed in the study (**Table 4**).

3.5. Rice Varieties Grown in Wet Season

It was observed that farmers have grown as many as 107 varieties in Kharif season. In the same year, state seed corporations had sold only 44 varieties, suggesting there are many varieties not being in the seed chain but being cultivated by farmers. These varieties could be farmers-saved local varieties and varieties being sold by private seed companies. However, 13 major varieties have the maximum coverage (95.5%). Only 4.5% area in kharif season is sown with other than these 13 varieties. Pooja, Swarna, Swarna sub 1, Lalat and Sahabhangi are the major rice varieties covered maximum acreage under rice (**Figure 1**).

3.6. Intra Farmers' Adoption Dynamics

Adoption of a variety is to be understood by farmers' consistency in growing it in post-demonstration seasons. The selected varieties were demonstrated in 2017 and

farmers were asked if they will keep growing it in 2018 and 2019. In the year 2017, when new varieties farmers were given new varieties on-farm trials, a farmer on average used 80.06 decimal land the cultivation. 460 (60.05%) of these farmers stated to continue growing these varieties in 2018. Interestingly, in the following year (2019) adoption rate shows a further upward trend as 67.75% of farmers decided to cultivate the varieties. Out of 248 unwilling farmers in 2018, 12.9% changed their minds and grew those varieties in 2019.

Table 5. Varietal adoption dynamics

Year	% of farmers grown the variety	Average acreage under the varieties (decimal)
2017	100.00	64.30
2018	60.50	70.10
2019	67.75	74.10

When analyzing acreage under varieties, in 2017 when farmers' first-time grew these varieties through demonstrations, the average acreage of a farmer for these varieties was 64.3 decimal that went up to 70.1 decimal and 74.1 decimal in 2018 and 2019 respectively indicating a fair varietal adoption (**Table 5**). Farmer's average landholding appropriate for introduced varieties was estimated to be 165.33 decimals and 74.1 decimal is now planted with newer and best-evaluated varieties which

accounts for 44.9% areas of all farmers are under new varieties which by any standard, presents an encouraging adoption trend.

However, there is a variation in variety wise adoption pattern. The highest adoption was noticed for Swarna sub 1, where 84.68% of farmers have reported having adopted this variety by 2019. This was closely followed by CR 1009 sub1 (85%), DRR dhan 42 (77.42%), and Bina dhan 11 (70.14%). These four new varieties except DRR dhan 42, have sub 1 gene and can tolerate water submergence for at least two weeks. This feature along with good yield is an adoption enabler in submergence hit areas, especially in the coastal region. Sahabhagi dhan and DRR dhan 44—suitable for drought-prone areas have gained acceptance of farmers as 68.18 and 66.66% of the farmers have adopted these varieties respectively.

3.7. Inter Farmers Spread Varietal Knowledge

The experiment was undertaken with 707 on-farm trial (OFT) participants and it strives to understand how these farmers diffuse the varietal knowledge and induce adoption among farmers who have not been part of the OFT experiments. Turned out, farmer (OFT)-farmers (non-OFT) spread of varietal knowledge is a catalyst to trigger the adoption of suitable varieties. In all, 707 farmers (**Figure 2**) have grown a new variety in the experiment, and 273 of them shared the varietal information with others, majorly among the fellow farmers in his village. The mean number of fellow farmers who become aware of new varieties through an OFT-farmer is 1.9. Thus 273 farmers have shared the varietal knowledge with 519 farmers. However, of these, only 164 (23.2%) such farmers have adopted the varieties in the next season.

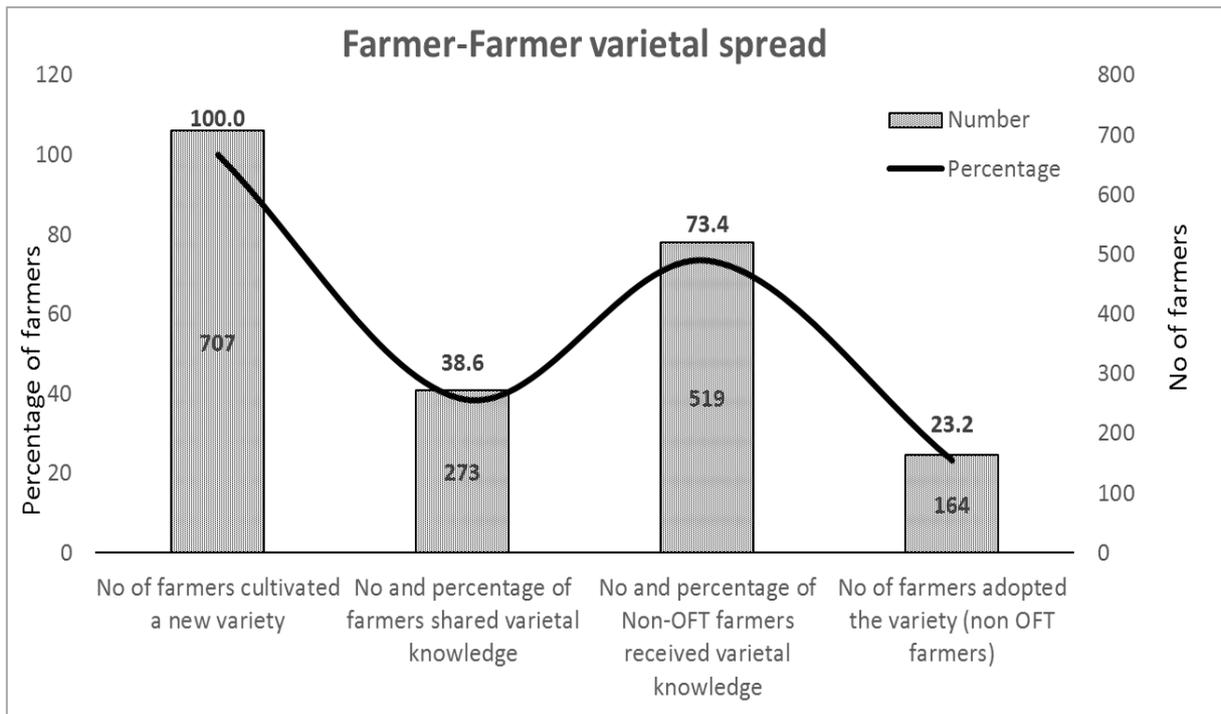


Figure 2. Farmer to farmer spread of varietal knowledge

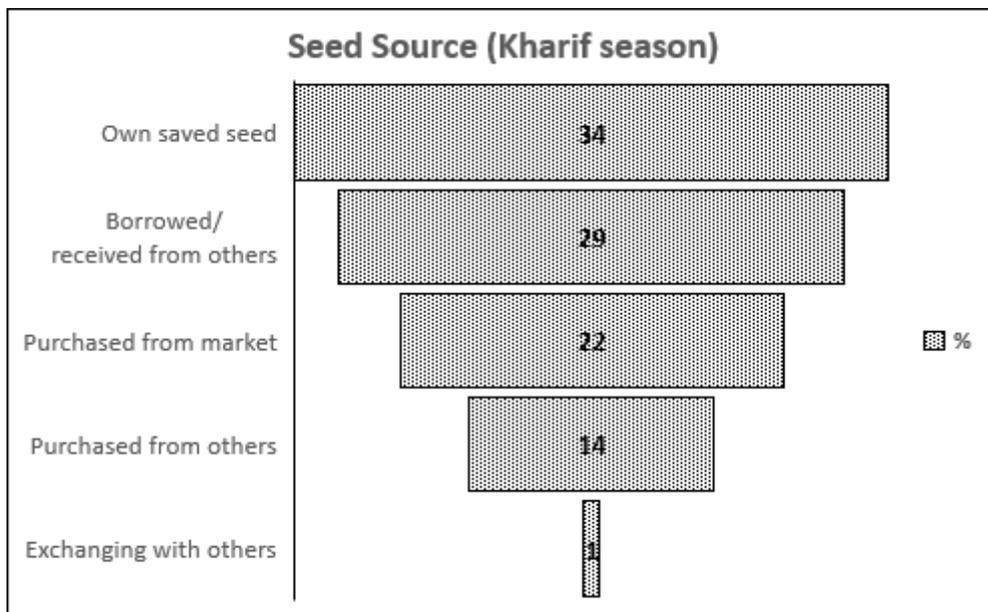


Figure 3. Farmer to farmer varietal dissemination

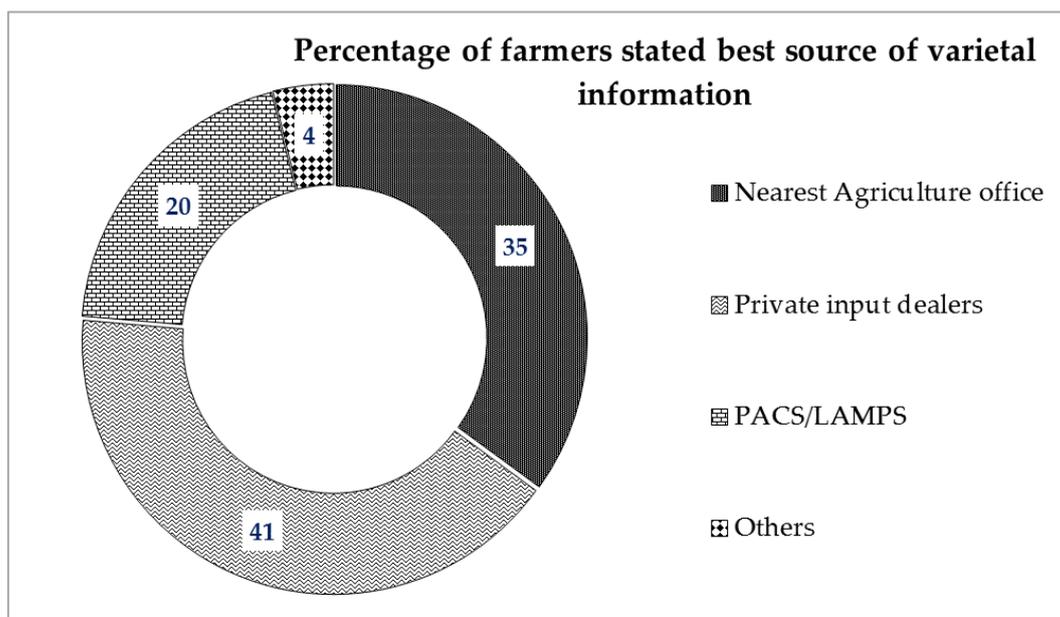


Figure 4. Farmers preferred source of varietal information

3.8. Seed Exchange/Sharing

Farmers saved seeds and share from fellow farmers and relatives are the two major seed sources. 63% of farmers have reported having acquired seeds either of these two ways. 29% of farmers used the seeds received from other fellow farmers. Merely 22% of farmers reported that they purchased it from the market. Thus seed exchange mechanism plays a vital role in diffusing seeds of a new variety at a faster pace. This study also elicited that in 2018, the average seed saving by a farmer is 49.45 kgs in Kharif season and 12.22 kg (24.66%) is either shared with or sold to other farmers in the neighbourhood farmers for

cultivation (Figure 3).

3.9. The Best Route to Know about a New Variety

Communication about a new variety to the target group is critically important for the dissemination of the innovation. The channels through which messages get transmitted appropriately are therefore of importance to reach farmers with a potential variety. As depicted in Figure 4, the nearest assistant agricultural officers and block agriculture officers(AAO/BAO), private input dealers, Primary Agriculture Societies (PACS) outlets are the major communication ports for such purposes, however,

such communication channels need to be approachable, farmer-friendly, and trustworthy. This study sought to understand which is the most convenient channels for a farmer in accessing information about a new variety. Notably, it has been found that 41.32% of farmers think private input dealers are the best source of varietal information. The local AAO and BAO offices are also a preferred port for varietal communication as stated by 35.03% of farmers. Interestingly, PACS—the largest network of seed sale for paddy, are chosen by only 19.76% of farmers as a favored communication source. Such findings lay more emphasis on private dealers and nearest agricultural offices for the diffusion of new varieties. Similarly, the PACS and Large Area Multipurpose Societies (LAMPSs) can be revamped to be used as a conduit for varietal information dissemination. Exploring the potential of these channels assumes high significance to enhance farmers’ uptake of new varieties.

3.10. Variety Trait Choices of Farmers

Farmers choose varieties based upon a set of prioritized

traits. These preferred traits are essential from the research perspectives of developing new varieties. Such trait intelligence aligns research priorities with farmers’ requirements and preferences. The study attempted to synthesize (Figure 5) different such preferred traits of the respondents. The farmers were asked to make three choices (first, second and third) of trait qualities that they always look for in a variety before the adoption. Frequencies of these three choices when plotted in a treemap, it deciphered that yield, grain type, biotic resistance are the most cited under first choice. Cooking quality, yield, and biotic stress resistance are the major considerations as the second choice. Furthermore, yield, cooking quality, and abiotic stress tolerance were considered as major traits under the third choice. This essentially postulates yield, cooking quality biotic stress tolerance are the most decisive considerations that need alignment with a varietal development program. Notably, variety duration which is otherwise an important trait has not been mentioned strongly by the farmers. This can be explained by the farmers’ assumption that any new variety released should have an appropriate duration in the target geography.

Farmers' trait choices in a variety

■ First choice ■ Second choice ■ Third choice

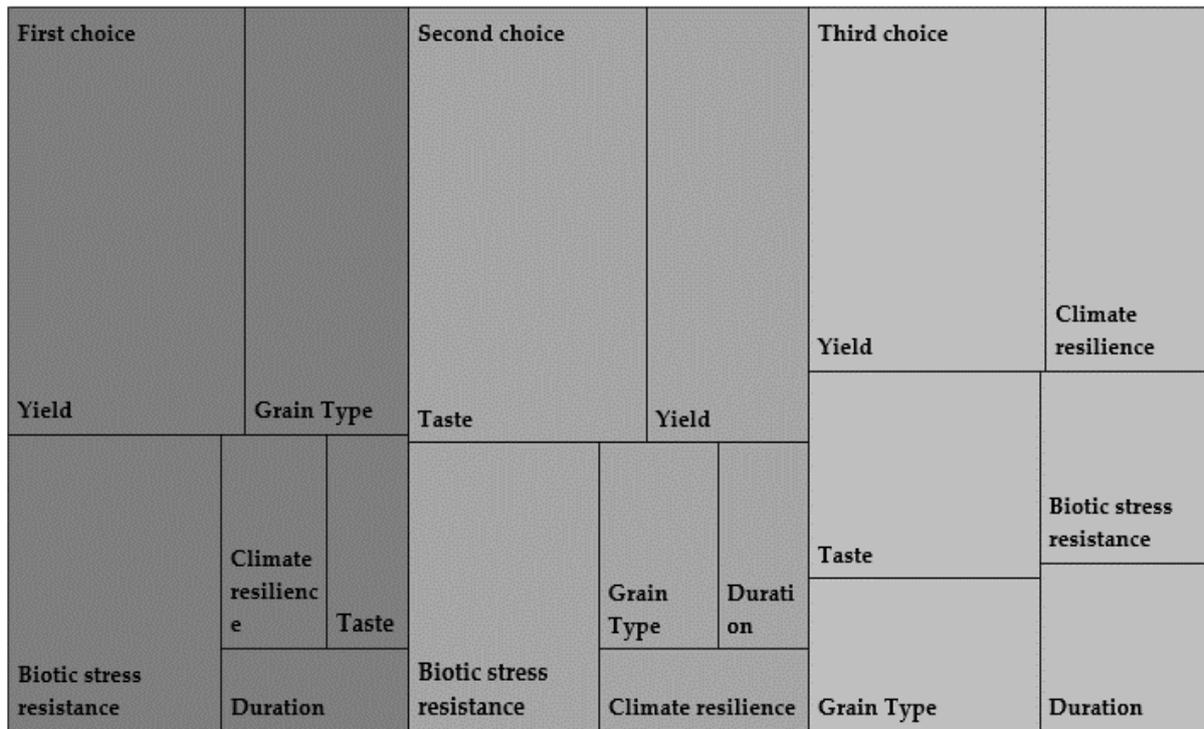


Figure 5. Farmers trait preference in a variety

3.11. Varietal Diversity

The computed variety diversity index (VDI) was plotted (**Figure 6**) to understand the frequency of farmers under different levels of the index [16]. As many as 1192 (40%) farmers have reported growing a single variety, thus registering a perfect 0 index. This can either be due to non-adoption (this itself may be determined by a range of factors) of more suitable varieties or farmers are satisfied with currently grown varieties. In this sense, only 60% of respondents have stated some degree of varietal diversity. The highest frequency (1362) was observed for diversity index ranging from 0.41-0.6 (**Table 6**). A considerably higher incidence of diversity index (0.61 and more) was reported by 362 farmers. Farmers have also been classified based on their calculated VDI and only 58.82% of farmers are found to have a moderate degree of diversity. About 41% of farmers are in the category of poor and low level of VDI and 12.35% of respondents scored a high level of diversity.

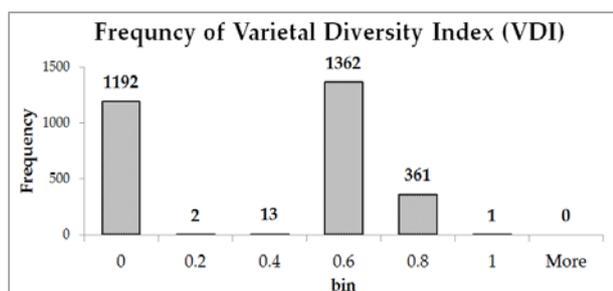


Figure 6. Frequency of VDI

Table 6. Level of varietal diversity among farmers

Level of diversification	Class	No of farmers	Percentage
0-0.20	Poor	1194	40.74
0.21-0.40	Low	13	0.44
0.41-0.60	Moderate	1362	46.47
0.61-0.8	High	361	12.32
0.81-1	Very high	1	0.03

3.12. Varietal Diversity by Category of Farmers

There is a distinctive variation in terms of how farmers of different categories adopt more than one variety (**Table 7**). Farmers with relatively smaller landholding, for obvious reason, resist growing multiple varieties and this is confirmed by their low diversity index of 0.298. On the other side, medium and large farmers exhibited a higher magnitude diversity of 0.402 and 0.403 respectively. A moderate degree of diversity has been reported from semi medium farmers. Overall, the varietal diversity index is estimated to be 0.311, reflective of a high concentration of few varieties and this can be validated by a high density of few varieties in the total rice area. This is important to note here that these indices of diversity have been calculated for the same type of land (e.g medium, upland, etc) and therefore show how farmers plan to grow multiple varieties in the same ecology, thus nullifying the variation in varieties because of land type and other factors.

Table 7. Varietal diversity among different categories of farmers

Farmer category	Variety diversity index
Large (more than 10 ha)	0.403
Medium (4-10 ha)	0.402
Semi Medium (2-4 ha)	0.371
Small (1-2 ha)	0.328
All Farmers	0.311
Marginal (less than 1ha)	0.298

3.13. Diversity across Districts

District wise performance in terms of VDI is presented in following map (**Figure 7**). A stark variation in the diversity index among districts is observable. Districts like Keonjhar, Mayurbhanj, and Sampalpur have measured 0.5 on the diversity scale but again there are districts such as Kandhamal, Koraput, and Malkangiri, where index is reported to be very low (<0.15), much below the average figure of 0.311. Interestingly, Bhadrak, Bargarh, Jajpur, Balangir, which are otherwise ahead in rice farming have a low degree of diversity index.

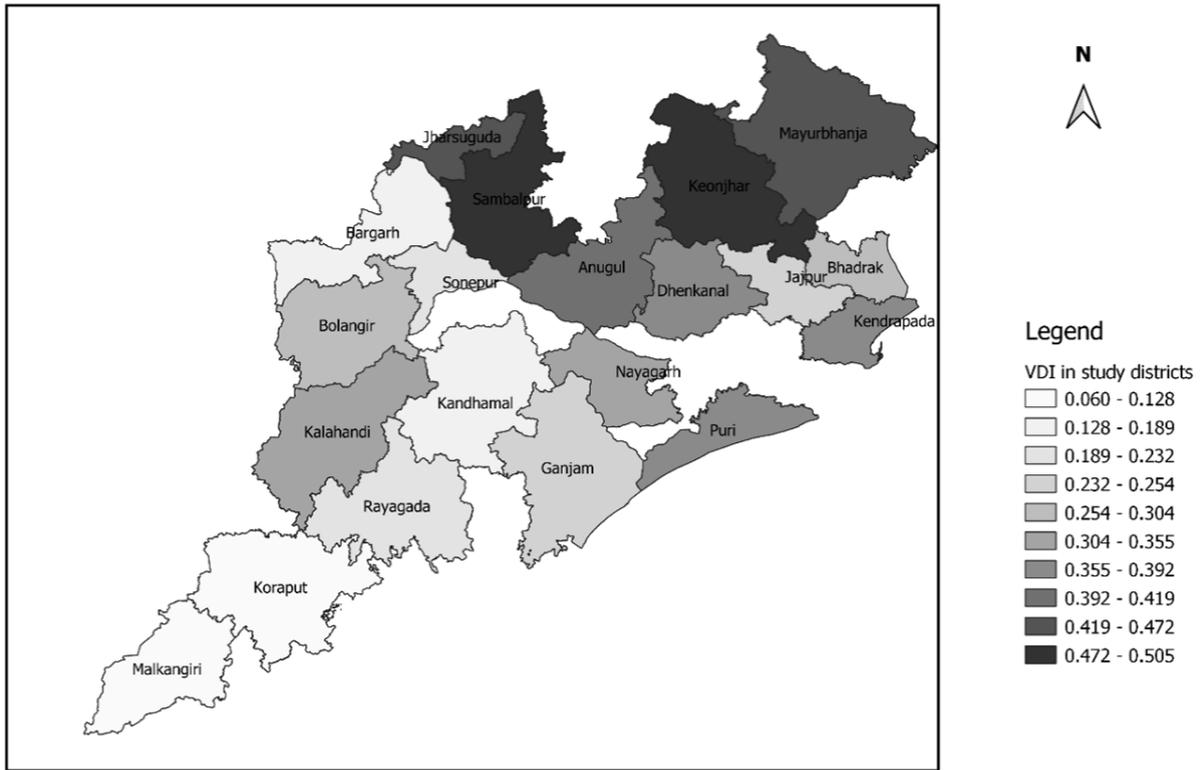


Figure 7. Variedal diversity inde (VDI) across study districts in Odisha

3.14. Diversity across Rice-Growing Ecologies

Variation in the diversity index has also been seen across different rice-growing environments (Table 8). Low and Upland—both are frequently faced with extreme weather conditions during crop growth in the wet season. Water scarcity in drought-prone areas and inundation in low-lying districts are the state's chronic phenomena Therefore, these two ecologies demand more choices of varieties that can potentially exhibit resilience to these abiotic stresses. However, the index for low land is estimated to be 0.35 whereas it is 0.349 in upland indicating low varietal choice and adoption of multiple varieties in both of these ecologies. Notably, medium land that is relatively stress-free has revealed very low magnitude diversity (0.276). Farmer's reservation for few well-performing mega varieties, little urge to adopt newer and more varieties, partially explain this low varietal diversity in this ecology.

Table 8. Varietal diversity across rice ecologies

Ecology	Variety diversity index
Low land	0.250
Medium land	0.276
Upland	0.349
All	0.311

The variety diversity map for major abiotic stresses when generated (Table 9), it was found that farmers who

confront drought have an index of 0.307 and for flood-affected areas, it is only 0.245. This elucidates either choice and adoption of multiple varieties are limited in areas flood-vulnerable areas. In salinity-prone areas (particularly the coastal districts), the index was found to be 0.374.

Table 9. Varietal diversity in different stress prone rice ecologies

Abiotic stress	Variety diversity index
Drought	0.307
Flood	0.245
None	0.343
Salinity	0.374
All	0.311

3.15. Varietal Diversity and Farmers' Education Level

The extent of varietal diversity is positively correlated with the years of schooling of the farmers. Seemingly, farmers with more education levels tend to diversify varietal buckets. This corroborates the general notion that with more years of schooling, farmers are usually in a better place to access relevant information and knowledge about agricultural activities. The simple correlation estimated between education level and diversity in varieties is 0.54 reflecting a stronger association of these two variables. Therefore, any policy measures relating to varietal diversity need to consider this association.

3.16. Seed Security at the Household Level

Seed security thus measured illustrates several insights around the selected indicators. The ideal and expected score of each indicator is 10, signifying the highest possible achievement and it is visualized with the help of a radar chart (**Figure 8**). The seed availability, starting point to reinforce seed security, scored 8.2 out of 10 and it can be termed as a reasonable degree of security. This score also underlines that the current system including formal and informal seed channels is quite efficient to offer seeds to the farmers in a time-bound manner. However, a low seed access score (7.3) explains farmers cannot always access those seeds available in the system. A host of reasons may trigger such scenarios like farmers wanting to buy seeds from public and private outlets but cannot reach them because of information gaps and other challenges [12]. Those farmers who grow hybrid varieties may not always be able to afford the pricey hybrid varieties mainly being marketed by private companies. On several occasions, as stated by farmers, some common farmers face hardship to access seeds through the farmer-farmer exchange because of tilted community power dynamics [4]. The domain of seed quality with a mean score of 6.4 suggests that seed security is weakened by the quality issue and it brings forth the dissatisfaction of farmers about the available and accessed seeds. The quality control measures for both farm-saved and seeds sourced from formal channels are found to be vital here. When the approach is to skilling farmers to meet quality seeds on their own, capacity

development initiatives can be fruitful. Since 63% of farmers acquire seeds from farm-saved stock (as analysed above), making farmers self-reliant through capacity building holds reasonable importance.

The flexibility and a wider varietal choice boost the seed security of the farmers. The estimated score of this indicator is just 5.2 and it explains farmers have a very limited choice range in choosing the variety of their preferences. This choice of varieties however reflects farmers' preferences, not necessarily the selection of expert-recommended varieties. The poor outcome of this indicator also suggests a possible extension gap in popularizing many of those newly bred varieties suitable for the state. The correct positioning of those new varieties aided by trait-based market segmentation supposedly can help improve this indicator.

Seed system stability, which incumbents upon the other four indicators during a crisis, has attained a score of 6.6. Such a moderate score explained that in the event of an unlikely situation (such as flood, drought, or any other exigencies, etc.), seed availability, access, quality, and variety choice are adversely impacted to a greater extent. This indicator, therefore, highlights bringing in the system more resilience to improve the seed security. In a flood or drought year, many seed growers suffer crop loss and seed availability is shrinks. In such a situation, the seed quality aspect is also diluted. Appropriate contingency measures both for formal and informal seed channels are therefore indispensably required.

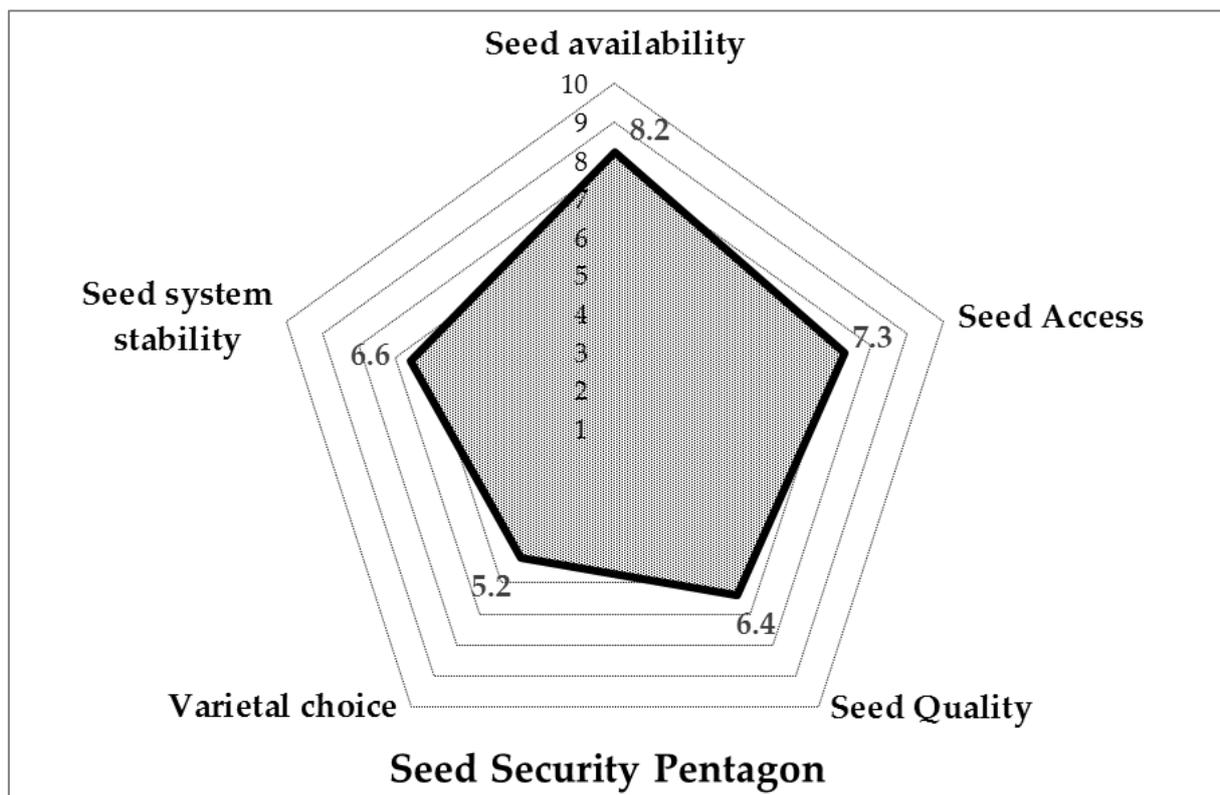


Figure 8. Farmers seed security as visualized in radar chart

4. Conclusions

There are scopes and options to boost both the productivity and production of rice in Odisha. A large proportion few older varieties need to be substituted with recently developed better options. The extension functionaries can consider the large-scale demonstration of those newer varieties through on-farm trials as the findings of the study found reasonable strength of the farmer-farmer seed exchange to fast-track the diffusion process. This measure supposedly will create demand for the varieties that need to be primarily aided by a formal seed system. Since seed security dimensions are poorly rated, the policy environment needs to expand the scope of seed access, varietal choice, and seed quality. Poor varietal diversity at the farm level is reflective of farmers' restricted choice of variety selection particularly among marginal farmers and in marginal environments (drought and flood-prone areas). Therefore, strategic measures to broaden farmers' choice of appropriate varieties in specific ecology will go a long way to improve varietal turnover in the run-up to enhance rice productivity in the state.

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