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Farmer-led conservation of paddy landraces in Western Odisha

Preeti Yadav[a], R N Padaria[a,*], R R Burman[b], Sujit Sarkar[a], Rajbir Yadav[a], Ankur Biswas[c] & Soora Naresh Kumar[a]

[a]ICAR-Indian Agricultural Research Institute, New Delhi 110 012
[b]ICAR- Division of Agricultural Extension, Krishi Anusandhan Bhawan, New Delhi 110 012
[c]Indian Agricultural Statistics Research Institute, New Delhi 110 012
[*]E-mail: padariarabindra@gmail.com

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Despite the Green Revolution's impact, many small-scale farmers continue cultivating landraces for their agronomic, culinary, and cultural values. This study, conducted in Odisha, focuses on region-specific on-farm conservation practices employed by farmers for landraces. Five focused group discussions were conducted in five villages, involving 15 landrace custodian farmers in each village of Western districts of Odisha. The Four-Square Analysis, a participatory approach, was utilized to evaluate landrace conservation practices in five villages. Principal Component Analysis and Biplot visualization were employed to analyze the relationships between practices, varieties, and conservation scores. Focused group discussion revealed that a total of 30 paddy landraces were cultivated and conserved in the sampled villages. The study identified diverse landraces such as *Kalabati*, *Katia*, and *Kusum kali*, each valued for unique traits and cultural significance. Paddy landraces with disease resistance, medicinal value, and economic significance were commonly cultivated in households or on a larger scale. Important agronomic practices involved organic farming, reduced fertilizer use, biological pest control, System of Rice Intensification (SRI), and bacterial culture for landrace conservation. Management practices comprised seed banks, diversity blocks, seed exchanges, and community cultivation. The findings highlight the importance of farmers' indigenous knowledge, their beliefs and cultural practices in conserving landraces. Landraces which were rare and cultivated due to cultural or social importance require special attention in conservation efforts. Incentivizing community involvement and implementing tailored strategies would be crucial for effective landrace conservation initiatives.

Keywords: Conservation, Landraces, Paddy, Participatory, Practices, Seed

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India, with its vast biological diversity, is home to nearly 49,000 plant species, including around 17,500 higher plant species. It boasts about a wide range of crops, both in terms of species diversity and individual variations. The country houses 5,725 endemic species of higher plants, encompassing approximately 141 endemic genera, over 47 families, and approximately 11.9% of the world's flora[1]. Within the 12 global mega-gene centers, the Indian gene center holds a prominent position[2]. Crop diversity encompasses a range of genetic resources like modern cultivars, landraces, and wild relatives which is vital for global food security. Landraces represent an important category of these crop genetic resources and India is home to approximately 15,658 rice landraces, is the largest exporter of Basmati rice, and cultivates numerous indigenous and local varieties of wheat, pulses, and millets that possess high nutritional value[3]. However, the transition from landraces to modern varieties, exemplified by the "Green Revolution," has significantly narrowed the genetic foundation of modern crop varieties[4]. In the past century alone, over 90% of crop varieties have vanished, with just nine plant species accounting for 66% of the world's crop production[5]. Despite this trend, many farmers, particularly small-scale ones, continue to cultivate diverse and well-adapted farmers' varieties/landraces due to their preferred agronomic, culinary, quality, or locally significant cultural values. The dynamic management of landraces, including exposure to different production systems, environments, farmers' selection, and seed exchange practices, maintains a reservoir of continuously evolving genetic variability. Landraces are vital for farming communities' agricultural and food security, serving as survival assets and a kind of "currency" for bartering or market exchange[6]. Farmers, who have direct contact and interaction with the natural ecosystem at the farm level[7], can contribute to the conservation of genetic resources on

*Corresponding author

their agricultural lands and surrounding areas[8]. Therefore, it is essential to understand the region-specific best on-farm conservation practices practiced by local farmers and their cultivation practices. In this context, the current study aims to evaluate and document the methods employed by farmers to conserve landraces using a participatory approach.

Methodology

Sampling plan

The study was conducted in Odisha, which is the secondary centre of origin of cultivated rice. Odisha has the distinction of possessing about 15, 000 traditional rice varieties out of 50,000 found in the world[9]. Odisha ranks first for maximum registration of landraces and farmer varieties in India[10].

The investigated area selected for landrace conservation practices are the three western districts of Odisha, namely Jharsuguda, Sundargarh and Bargarh. Despite urban encroachment, certain communities in these districts continue to cultivate and preserve landraces. The preliminary investigations revealed a notable absence of studies that explicitly detailed conservation practices related to the maintenance of genetic diversity and the preservation of landraces in this area. This emphasis allows our study to fill an important void in the existing literature, shedding light on practices that were region-specific. Five villages practicing landrace conservation were selected based on membership in a formal seed bank. Kattipali, Pandemal, Kaintara, Katikhela, and Baghdihi villages were chosen as study sites as they were the members of *Desi Bihan Surakhya Samiti*, a formal seed bank situated in Bargarh district of Odisha with 1200 farmers associated in different districts of Odisha. Exploratory surveys and five focused group discussions with 15 landrace custodian farmers in each village were conducted to analyze landrace varieties and associated conservation practices.

Four square analysis

The four-square method is a research tool specifically designed to facilitate the collection of data and generate evidence regarding seed system diversity[11]. The data collection process involves a participatory approach, utilizing focus group discussions (FGDs) guided by questions aligned with the study's objectives. These objectives encompass exploring local crop diversity, assessing the economic viability of crop varieties, establishing breeding goals, formulating plant breeding programs, evaluating the effects of seed interventions on crop varieties, and monitoring changes in crop variety diversity over time[12].

The process of *Four-Square Analysis* is elucidated below

A four-square design was made on the ground with lines and circles with each quadrant representing one of the categories of landraces as discussed in the scoring pattern below.

Scoring of Conservation practices and their relationship with varieties

Operationally defined, a good practice for the conservation of landraces is a system, organization or process that, in a given space from the local levels of resolution, and over time, maintains, enhances or creates landraces and ensures their availability to and from farmers for improved livelihoods. The scoring pattern of the conservation score is mentioned below:

1. Grown by few households on small areas (high importance) 3
2. Grown by few households on large areas (high importance) 1
3. Grown by many households on small areas (high importance) 1
4. Grown by many farmers on large areas (not considered threatened) 0
5. Practice of normal or low importance 0

Conservation Score of Practices

For calculating the conservation score, the practices are listed in the left-hand column. The varieties for which the practice is very important are then listed in the second column and conservation scores are calculated using the following formula

Conservation scores for practices by variety = Score of variety X Priority of practices for specific varieties Equation (*1*)

The total conservation score of a practice is a function of the importance of the practice to keeping individual landraces, the number of landraces thus maintained, and the rarity of these varieties (Table 1).

Principal component analysis and biplot

To perform PCA in R software, the following steps were followed:

1. Scores for best practices and landraces were normalized to a range of 0 to 1.

2. Codes were provided to landraces nomenclature (1,2,3,4) for better visualization of plots (Table 2).
2. PCA was conducted and biplot was obtained.
3. A biplot was created to visualize the relationships, with arrows representing best practices and varieties labeled by serial numbers. The orientation of arrows indicated the importance and direction of practices, and varieties were positioned based on crucial practices for their survival.

Result and Discussion

Extent and distribution of landraces

During the Four-Square Analysis, the extent and distribution of landraces in the sampled region were

Table 1 — Conservation scores of practices used for conserving landraces based on priority

	List of practices (Agronomic)/Villages	Kattipali	Kaintara	Pandemal	Baghdihi	Katikhela
1.	No fertilizer application	6	16	10	11	13
2.	Jeevaamrit	7	3	1	4	7
3.	Organic farming	15	8	1	12	1
4.	Fertilizer based on soil color	14	1	7	NA	NA
5.	Harvesting in submerged condition	3	1	3	NA	NA
6.	SRI	4	1	NA	7	NA
7.	Conventional farming	NA	2	6	NA	1
8.	Green manuring	NA	NA	NA	7	NA
9.	Summer ploughing	NA	NA	NA	10	NA
10.	Biological pest control	NA	NA	NA	13	NA
	List of practices (Management)/ Villages	Kattipali	Kaintara	Pandemal	Baghdihi	Katikhela
1.	Community cultivation	13	7	2	7	7
2.	Diversity block	10	4	1	17	7
3.	Seed exchange	19	16	5	20	23
4.	Proper storage	20	13	5	11	NA
5.	Seed bank	33	2	4	20	23
6.	Mass selection	10	1	3	7	3
7.	Mixing seeds	10	3	1	6	4
8.	Natural out-crossing	9	13	7	NA	NA
9.	Nucleus seed production	10	NA	NA	10	NA
10.	Demonstration plot	7	NA	NA	9	NA

NA: Not Adopted

Table 2 — Code for landraces used in Biplot (Landrace-specific practices for conservation of landraces)

Village: Katikhela	Code	Village: Kaintara	Code	Village: Pandemal	Code	Village: Baghdihi	Code
Landraces							
Kalabati	• 1	• *Kalabati*	• 1	• *Kusumkali*	• 1	• *Bahal dhan*	• 1
Katia	• 2	• **Katia*	• 2	• *Sonakhati*	• 2	• **Chini Chira*	• 2
**Kala maliphul*	• 3	• **Brahma Black*	• 3	• *Machhakanta*	• 3	• *Pratiksha*	• 3
**Brahma Black*	• 4	• *Jalgudi*	• 4	• *Brahma Black*	• 4	• **Bathras*	• 4
**Madabaru*	5	**Bahal*	5	*Kalabati*	5	*Kalabati*	5
**Megadabral*	6	**Bojni*	6	**Bojna*	6	**Jalgudi*	6
**Karaini*	7	*Bhajna*	7	**Purutin*	7	Village: Katikhela	Code
**Kalasu*	• 8	• **Kalahans*	• 8	• **Manipuri black rice*	• 8	• *Kalabati*	• 1
**Sonagathi*	• 9	• **Annapurna*	• 9	• **Katia*	• 9	• **Kala maliphul*	• 2
**Kusum*	• 10	• *Kandhsagar*	• 10	• **Barumai*	• 10	• **Karaini*	• 3
Talmuli	• 11	• *Pratiksha*	• 11	• **Kushika*	• 11	• **Kalasu*	• 4
Barumai	• 12	• *Jagbandhu*	• 12	• *Kurumandal*	• 12	• *Sunakathi*	• 5
**Kushika*	• 13	•	•	•	•	• **Talmuli*	• 6
Kurumandal	• 14	•	•	•	•	• **Kusumkali*	• 7
Kusum kali	• 15	•	•	•	•	• **Bahal*	• 8
**Bathrash*	• 16	•	•	•	•	• **Bojni*	• 9
**Congvani*	• 17	•	•	•	•	• *Bajna*	• 10
**Congdemay*	• 18	•	•	•	•	• **Annapurna*	• 11
Jalgudi	• 19	•	•	•	•	• **Kandhsagar*	• 12

• *Rare varieties

assessed, showing varying results across different situations and villages (Table 3). During discussions with farmers, it became evident that there has been a notable shift towards modern cultivars over the years. This transition is primarily attributed to the convenient availability of modern cultivars in nearby markets. The major decision-making factor behind this shift is often influenced by market demand for specific varieties or landraces and loss of interest of farmers in conserving traditional landraces and farming system. Traditional knowledge was greatly influenced by the modernization of region[13]. However, it was noteworthy that some farmers continue to conserve landraces for various reasons. A significant motivation for this conservation was the ancestral legacy, with forefathers having preserved these traditional varieties. Additionally, cultural significance plays a crucial role, especially during festive occasions, and the unique culinary habits associated with these landraces contribute to their conservation. It was noticed that in all five villages of western Odisha, *Kusumkali* and *Talmuli* landraces were cultivated on a large scale due to their resistance to the Brown Plant Hopper. In Baghdihi village, *Kusumkali* gained popularity among many households due to both high market demand and its ability to withstand pest attacks. Some landraces were grown by a few households on a smaller area, classified as rare in the four-square analysis, driven by cultural and social significance. *Sonagathi* was cultivated by only a few households due to its recognized efficacy in eye treatment, while *Kusum* was grown specifically for joint pain relief during pregnancy. *Kalabati* was cultivated by a few households over a large area due to its health benefits, resistance to diseases, and growing demand in the state market (Table 4). Landraces like *Kalabati* and *Kusumkali* commanded favorable market prices, ranging from Rs 150-250 per kg in retail markets. Notably, the paddy landrace *Kusumkali* was sold at Maximum Retail Price in state markets (*mandis*). Farmers reported cost savings in cultivating *Kalabati* and *Talmuli* landraces, attributed to reduced expenses on pest control and the adoption of organic farming practices. In the case of *Kalabati*, the benefit-cost ratio was observed to be 5:1, outperforming the modern cultivar Ganga, which had a ratio of 2:1, as informed by farmers of Kattipali village. The discussions with farmers resulted in a list of conservation practices, which were divided into two components: "on-field agronomic practices" and "management practices."

Landrace-specific conservation practices

In the biplot of Kattipali village (Fig. 1), certain varieties like *Katia, Kalamaliphul, Madabaru* (*sub*)*, Megadabral,* and *Karaini* are grouped in the first quadrant, indicating their similarity in required conservation practices. Fertilizer based on soil color and organic farming was identified as important practices for conserving these varieties. In the second quadrant, varieties such as *Kalasu, Barumai, Kushika, Kurumandal, Kusumkali, Bathrash, Congvani, Congedemay,* and *Jalgudi* show closer association with each other compared to the varieties in the first quadrant. Conservation practices for this group include chemical-free farming and harvesting in submerged conditions. In the third quadrant, *Sonagathi* and *Talmuli* are located at significant distances from each other, despite both responding well to the practice of using bacterial culture (*Jeevaamrit*) for cultivation. Regarding management and improvement practices, *Kalabati, Brahma Black, Sonagathi, Barumai, Kushika, Kurumandal,* and *Kusumkali* are grouped in the same quadrant. Conservation practices for this group include community cultivation, nucleus seed production, diversity block, mass selection, and demonstration plots, with community cultivation standing out as the most crucial based on the length of the vector arrow. Similar interpretations were conducted for other biplots, which have been discussed in subsequent sections (Fig. 1, 2, 3, 4 & Fig. 5).

Table 3 — Result of Four-Square Analysis: Distribution (frequency) of landraces in sampled villages of Western Odisha

S. No.	Sampled villages	Rare landraces	Intermediate landraces		Common landraces
		Few Households Small area	Few Households Large Area	Many Households Small Area	Many Households Large Area
1.	Kattipali	13	4	2	0
2.	Kaitara	7	2	2	0
3.	Baghdihi	6	2	3	1
4.	Pandemal	3	0	2	0
5.	Katikhela	9	0	3	0
	Total landraces	38	8	12	1

Practices for landraces (Agronomic)

Chemical-free farming

One of the major specialties of many of the landraces is that they do not require much fertilizer doses for growth. Farmers are avoiding the use of fertilizers in the field while growing the landraces such as *Kalasu, Barumai, Kushika, Kurumandal, Kusumkali, Bathrash, Congvani, Congedemay* and

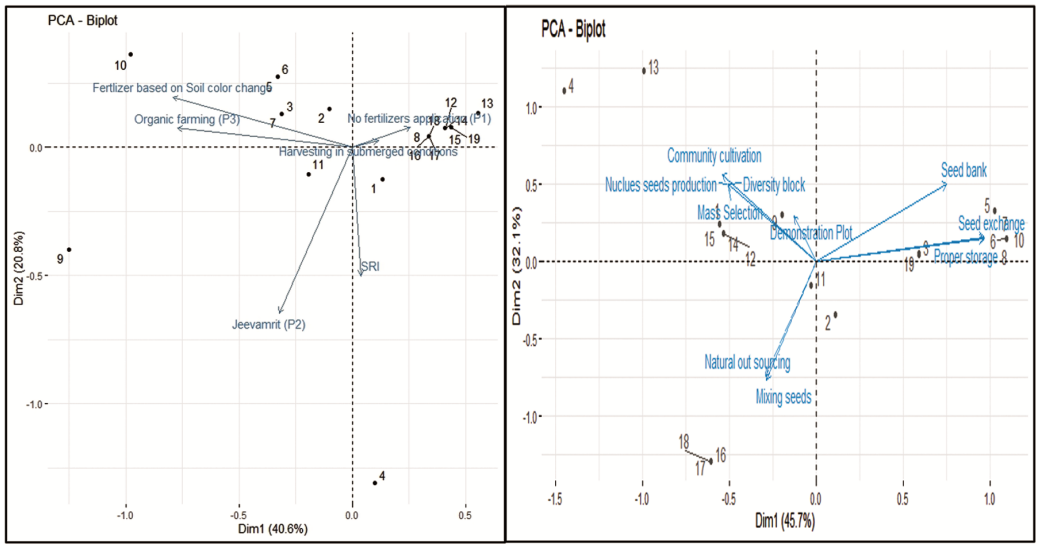

Fig. 1 — Relationship between best agronomic and management practices for landraces in village Kattipali

Table 4 — List of landraces and their characteristics conserved in western Odisha

S.No.	Varieties	Prominent characteristics perceived by farmers
1.	*Kalabati*	78% Carbohydrate but 100% Sugar-free; Black rice; Continuously grown in the field without getting destroyed (6-7) years
2.	*Katia*	Black rice; Rich in calcium and iron,
3.	*Kala maliphul*	Black rice; Rich in calcium and iron; 100% bran
4.	*Brahma Black*	Black rice; Rich in calcium and iron
5.	*Madabaru (sub)*	Black rice; Rich in calcium and iron; unique flavor, aroma,
6.	*Megadabral*	Black rice; Rich in calcium and iron
7.	*Karaini*	Cooking time is less
8.	*Kalasu*	Cooking time is less
9.	*Sonagathi*	Use in eye treatment, thick grains
10.	*Kusum*	For pregnant women; Joints pain
11.	*Talmuli*	Free from the attack of Brown Plant hopper
12.	*Barumai*	
13.	*Kushika*	Cannot give fertilizers otherwise lodging, good taste
14.	*Kurumandal*	
15.	*Kusum kali*	Resistant to the attack of Brown Plant Hopper; No fertilizer application, good taste
16.	*Bathrash*	Red rice has, a good taste
17.	*Congvani*	Red rice
18.	*Congedemay*	Red rice
19.	*Jalgudi*	Red rice, more tillers, harvesting in submerged conditions
20.	*Bahal*	Jagannath *boj*, good taste, preferred for *Pakkhal bhat*
21.	*Bojni*	Taste, low input required, *Pakhala bhat*
22.	*Bhajna*	*Jaggannath boj*, good taste, *Pakhala bhat*
23.	*Kalahans*	"*Kanika*" (a sweet rice dish) and "*Pakhala*" (fermented rice), a pleasing aroma
24.	*Annapurna*	Home consumption
25.	*Kandhsagar*	Home consumption
26.	*Pratiksha*	Good yield
27.	*Jagbandhu*	Rice cake
28.	*Machhakanta*	Medium-sized and possesses a good cooking quality, Scented, suitable for rice pudding
29.	*Manipuri Black rice*	Unique black/purple color and nutty flavor, the short duration can be grown thrice in a year
30.	*Purutin*	Home consumption

Jalgudi; Bahal, Bojna, Bhajnaand Kalahans. It is a common observation among farmers that certain landraces, particularly those with taller plant heights, are prone to lodging when exposed to excessive fertilizer doses. Landraces and tall varieties with lower harvest indexes absorb and transport more nitrogen to grains than modern cultivars in nitrogen-limited conditions[14]. Farmers note that excessive fertilizer use can disrupt landraces' natural nutrient interactions and uptake mechanisms. The use of fertilizers has been shown to reduce the adaptability of crop genetic resources[15].

Organic farming

Farmers in various villages have recognized the importance of organic farming practices for certain landraces. Organic farming practices have enhanced the market value and consumer appeal of these landraces which are organically produced while ensuring a balanced and environmentally friendly farming system. In villages like Baghdihi and Katikhela (Fig. 4 & Fig. 5) farmers particularly prefer organic farming and SRI, as they provide good yields and meet the high demand for black rice varieties like *Barumai, Kushika, Kurumandal, Kala maliphul, Sonagathi*, and *Talmuli*. The landraces, such as *Kalabati, Katia, Brahma Black, Bahal dhan and Kalabati*, are highly sought-after for their unique qualities, and medicinal properties. Farmers for the cultivation of landraces followed the old saying *"Apni mitti apni khad, apne beej aur apna swaad"* ("Our soil our food, our seeds and our taste").

Soil color change

Soil colour changes over time and can indicate the availability of nutrients. Farmers have informed that it

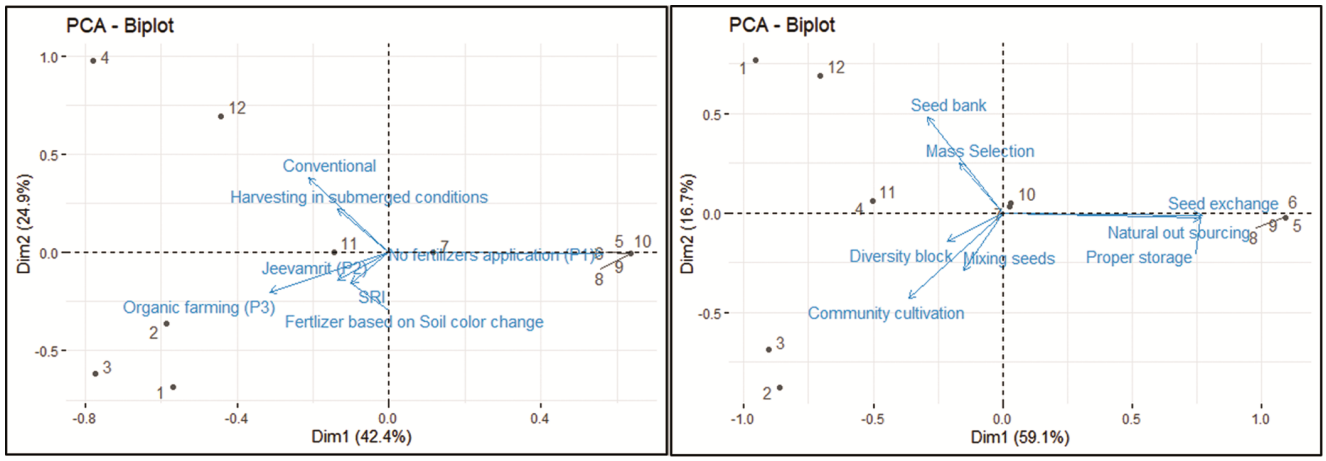

Fig. 2 — Relationship between best agronomic and management practices for landraces in village Kaintara

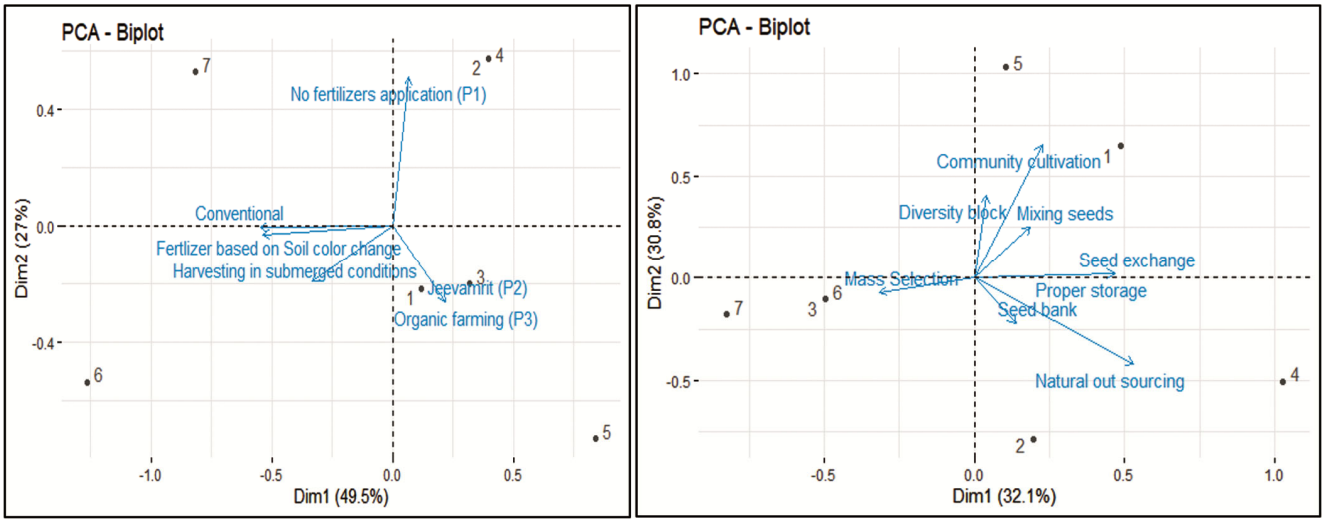

Fig. 3 — Relationship between best agronomic practices for landraces in village Pandemal

is important to note that if the soil color does not change or remains stagnant, it may indicate an unhealthy soil condition, possibly lacking in essential nutrients. The following diagram describes the relationship between soil color and nutrient application:

Soil Stages		Soil Color		Nutrient Application
Banjar	→	Dull or Pale	→	Nil/Ploughing
After Light Rain	→	Changes from Dull	→	Vermicompost is applied
Heavy Rain	→	Black or Brown	→	Cow dung mixture is applied
Plain Layer	→	Brownish-Green	→	Healthy soil

Farmers believe that enriching the soil leads to healthy and active roots in plants, particularly in landraces. They emphasize the importance of listening to the soil's needs; "*Hum sunegye Dharti ki awaz*" (We will listen to soil's voice) and providing nutrients accordingly, as landraces primarily rely on natural sources (90%) rather than external ones (10%) for nutrients. Unlike modern cultivars with static red roots, landraces have vibrant and robust roots that contribute to their dynamic and resilient nature against diseases and pests.

Harvesting in submerged conditions

In submerged conditions, farmers harvest the crop with the help of boats to help retain their genetic potential which otherwise would have submerged. Here *Jalgudi* is one such variety, grown almost by all farmers in flood-prone and water-logged areas. Landraces cultivated in flood-prone areas have naturally evolved adaptations to cope with submerged conditions. As informed by farmers under waterlogged conditions persisting for a month, plants exhibit an adaptive response where the shoots bend sideways, resulting in an increased number of branches emerging from the bending point. This response ultimately leads to enhanced tillering. Such traditional rice landraces grown elsewhere in Koraput district, Odisha, displayed higher antioxidative enzyme activity and ascorbate levels than the

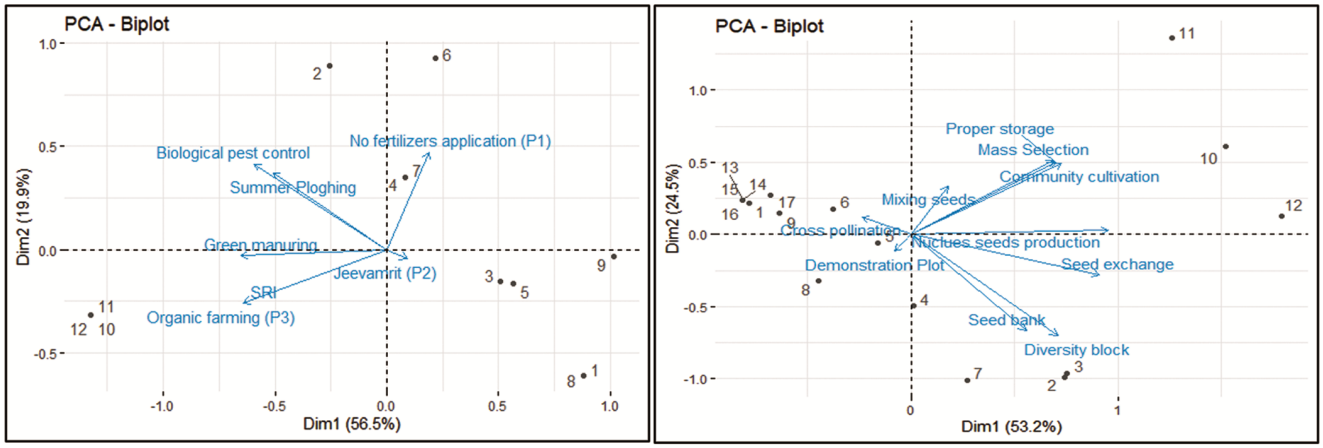

Fig. 4 — Relationship between best agronomic practices for landraces in village Baghdihi

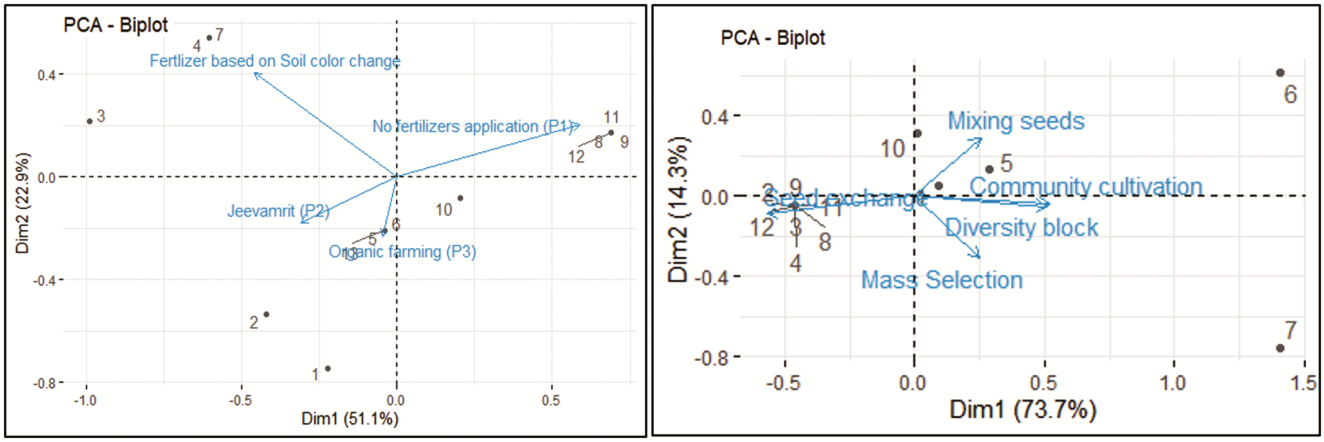

Fig. 5 — Relationship between best agronomic practices for landraces in village Katikhela

tolerant check variety, leading to improved photosynthetic activity[16].

SRI

The System of Rice Intensification (SRI) is an innovative approach to paddy rice cultivation that focuses on improving productivity while minimizing the use of external inputs. The paddy cultivation process involves careful seed selection and targeted seeding. Seedlings are nurtured using the raised bed method and transplanted with adequate spacing. Timely transplantation height is crucial for optimal yield. Farmers prefer to transplant seedling when it is at a height of 6 inches. According to them even a one-inch difference in height at transplanting can reduce paddy yield by 30 to 33%. Organic fertilizers like compost and manure are favored. *Kalabati, Brahma Black, Kalabati, Katia, Barumai, Kushika, and Kurumandal* are the varieties being conserved agronomically by SRI.

Bacterial culture

The use of bacterial culture, commonly known as Jeevaamrit, is an important practice of natural farming for the farmers of western Odisha, even for farmers who may not fully adhere to principles of natural/organic farming. *Jeevaamrit* is essentially a fermented microbial culture made from locally available organic materials. It typically includes a combination of cow dung, cow urine, jaggery or molasses, gram flour, water, and beneficial indigenous microorganisms. These ingredients are mixed and left to ferment for a specific duration, usually around 7 to 10 days. The fermentation process which occurs in culture increases nutrient availability, improving soil structure, and suppressing harmful pathogens in soil[17]. The farmers in Kattipali village are utilizing a novel formulation of *Jeevaamrit*, which they refer to as "*Jeevanoshakti*" locally. This formulation is created by combining litter and twigs from 8-9 tree species, cow dung, ghee, yoghurt, extract from pulses, seeds, rice powder, and water. The mixture is then allowed to ferment for 45 days. In Baghdihi village, farmers created *Ganjeevaamrit* (*sukhi khand*), a solid form of *Jeevaamrit*, in various proportions. Due to tall landraces (4-5 feet), spraying bacterial culture is challenging. Instead, solid *Jeevaamrit* is applied to soil every 3rd day for 20 days.

***Summer Ploughing* (*Kharatiya Chasa*)**

Summer ploughing also known as pre-monsoon ploughing helps control pests and diseases, as it exposes insects and their larvae to the hot sun and high temperature, which kill them[18]. It also helps reduce the risk of soil-borne diseases, as the soil is thoroughly turned over and aired out. The idea that ploughed land can receive natural fertilizer from thunder and lightning during the first rain is a common belief in some farming practices. Summer ploughing is common for indigenous paddy cultivation by tribal farmers in Tamil Nadu during April[19].

Green manuring

This practice is considered an important agronomic conservation strategy by the farmers of Baghdihi village. For cultivating landraces *Barumai, Kushika, Kurumandal*, organic farming, SRI and green manuring practices are considered the important ones by the farmers. Green manuring using *Dhaincha* (*Sesbania rostrata*) in paddy cultivation is a common practice in some regions. *Dhaincha* seeds are sown in the field in April and May before a few weeks (40-45 days) the intended paddy planting. After harvesting *Dhaincha*, it is incorporated into the soil by ploughing; it decomposes and adds organic matter to the soil.

Biological pest control

In Baghdihi, farmers implement a traditional method of insect control by utilizing a “T-shaped wooden structure” in their fields. This structure serves as a perch for crows and other birds, which feed on a variety of insect species such as grasshoppers, beetles, and caterpillars. The presence of crows is beneficial in reducing insects and pests’ populations naturally. In addition to the wooden structures, farmers are adopting the use of yellow sticky cards to trap insects and small pests in the fields.

Conservation practices (Management)

Mass selection

Mass selection has been used widely to improve traditional landraces that have been passed onfrom one generation of farmers to the next over long periods[20]. In Pandemal village landraces; *Jalgudi*, and *Jagbandhu* are conserved through mass selection. In Kattapali village landraces; *Kalabati, Brahma Black, Sonagathi, Barumai, Kushika, Kurumandal* etc are selected through massselection.The process of mass selection involves growing a large number of landrace plants together and allowing them to pollinate naturally. Afterwards, the farmers select the best-performing individuals based on desired traits, such as yield, disease resistance, flavor, or adaptability to

local conditions. The selected plants are then used to produce the next generation of seeds. Farmers try to maintain and improve locally adapted landraces, ensuring their availability for future generations. Conducting six rounds of mass selection in a local variety successfully preserved the "low nitrogen requirement trait" in a Brazilian village[21].

Mixing seeds

The mixing of seeds for landrace conservation is generally not a common practice due to the potential loss of genetic purity and uniqueness, there are instances where it is employed to address specific challenges. In situations where a particular landrace is at risk of extinction or has limited genetic diversity, farmers may mix seeds from different populations or sub-varieties to enhance genetic diversity and increase resilience to environmental changes. Rare landraces such as *Bathrash, Kaintara Katia, Kushika, Barumai, Talmuli*, and *Bajna* are conserved through seed mixing. Farmers have also observed unintentional mixing of seeds, as seen in the case of *Bahal dhan*, where seeds from different landraces got mixed with *Bahal Dhan* paddy varieties in the field. This accidental mixing can lead to the development of new genetically diverse paddy varieties with traits from different landraces[22].

Seed bank

The *Desi Bihan Surakhya Samiti* seed bank in the Bargarh district plays a vital role in preserving native landraces and the cultural heritage associated with these landraces. Farmers can book seeds in advance, ensuring availability when needed. The seed bank focuses on two essential conservation practices: proper seed storage and seed exchange. These practices are particularly important for preserving specific landraces like *Kalamaliphul, Kalasu, Kusum, Jalgudi, Talmuli, Chini Chira, Bathrash* etc. In Pandemal village, seeds are preserved in earthen pots lined with cow dung and turmeric paste, dried in the sun, and covered with neem leaves to repel insects. The three villages of Kattipali, Pandemal, and Baghdihi are connected through the seed banks and collaborate to conserve and promote traditional landraces (Fig. 1, Fig. 3 & Fig. 4). The seed bank employs two approaches, namely diversity blocks and demonstration plots, to maintain landrace diversity. They believed "*Aaj samay ki yahi pukar, Beej par krishak ka adikar*" (This is the call of the times today, farmer's right on seeds).

Diversity block

Diversity block is used to conserve *Kalabati, Brahma Black, Sonagathi, Barumai, Kushika, Kurumandal and Kusumkali* in the village of Kattipali. The conservation of the landraces namely, *Brahma Black* and *Kalabati* diversity blocks are employed to further maintain the genetic purity of the landrace due to their desirable traits and high demand in the market. The diversity blocks essentially function as small nurseries where seeds from the central panicles are germinated and grown into seedlings. This allows for the cultivation of the different landraces in a protected environment. Once the seedlings have reached an appropriate growth stage, they are transplanted into different small patches of land. This step expands the cultivation area while maintaining the integrity of the landrace. These small patches are referred to as diversity blocks. In this method, different blocks are designated for conserving specific landraces. Each block is dedicated to maintaining the genetic purity of a particular landrace. A specific procedure is followed within the diversity block. The central panicle of the landrace in each block is selected, and seeds are saved from that panicle. By carefully selecting and saving seeds from the central panicle, farmers and seed banks aim to preserve the genetic purity and integrity of the landrace for future cultivation and conservation. The described procedure is repeated for each landrace in its dedicated block to ensure the conservation of diverse landraces within the overall cultivation system.

Demonstration plot

The practice of maintaining a demonstration plot with a mix of high-yielding varieties and landraces/traditional varieties is a valuable approach used by seed banks to assess and promote different varieties among farmers. Both Kattipali and Baghdihi have well-operated seed banks in their respective regions. A demonstration plot is set up featuring multiple rows, with one row dedicated to a high-yielding variety and others to traditional types. The seed bank continually assesses performance factors like yield, disease resistance, and pest tolerance throughout the season. Landraces excelling in these traits are identified and selected seeds are then distributed to regional farmers.

Seed exchange

The seed exchange is a vital conservation method where farmers swap seeds with seed banks, neighbors, and local markets. This fosters diversity, preserving

traditional varieties and genetic richness. In this case, a barter system facilitates seed exchange to conserve landraces like *Kalamaliphul* and *Megadabral*, historically common in villages like Kattipali. A barter system between farmers and seed banks is employed: a farmer giving 1 kg of seeds can receive 2 kg in return from the seed bank when needed. Urban farmers join via informal contracts, aiding long-term landrace conservation in Kattipali village. Festivals also play a role in a seed exchange, like Odisha harvest festival popularly known as *Nuakahi*.

Natural outcrossing

Natural outcrossing is pivotal for conserving landraces, and safeguarding genetic diversity, adaptability, and traditional traits. In Kattipali village, *Bathrash, Congvani,* and *Congedemay* landraces have been preserved by naturally crossing seeds with traditional or wild/weedy rice. Similarly, Kaintara conserves *Bahal, Bojni*, and others via natural introgression, seed exchange, and proper storage (Fig. 2). The village Pandemal protects *Chini Chera* and *Bathrash* through outcrossing, proper storage, and a seed bank (Fig. 3).

Community cultivation

Community cultivation is collaborative farming where a group shares land, resources, and crop management. Its aim is local cooperation, knowledge exchange, and sustainable agriculture. Farmers jointly plan, work on shared or designated plots, and collaborate on tasks like planting, irrigation, and harvesting. This fosters communal engagement and supports efficient agricultural practices.

Nucleus seed production

Nucleus seed production" refers to a seed multiplication system that involves the controlled and standardized production of seeds from a selected group of plants. This method begins with the careful selection of superior landraces, and a representative group of plants is established as the nucleus. This nucleus is cultivated in an isolated and controlled environment, such as a greenhouse, to prevent cross-pollination and maintain genetic purity. Seeds are then collected from the nucleus, with a focus on specific panicles showcasing the desired traits of the landrace. The obtained high-quality seeds are used to establish multiplication plots, where the landrace is systematically cultivated to produce a larger quantity of seeds. The resulting seeds become available for distribution to farmers, researchers, and stakeholders, contributing to the conservation of landrace diversity and providing a reliable seed supply for future cultivation. It usually requires more capital and resources and was practiced by the formal seed bank in Kattipali village where a full-fledged seed bank is being operated on a small scale.

Conclusion

The research provided valuable insights into the complex interplay between landraces, conservation practices, and the socio-cultural context in western Odisha. The study emphasized the role of traditional practices, cultural significance, and farmers' knowledge in the conservation of landraces. The results revealed varying patterns across villages and landraces, with certain landraces being more prominent in specific regions.

Policy implications

Policy makers could support traditional farming practices like chemical-free, organic, and System of Rice Intensification (SRI) through incentives and subsidies, recognize local communities' rights to save, exchange, and sell seeds, promoting seed banks and community-driven conservation, develop policies for rare landrace conservation with special incentives. Implement capacity-building programs for farmers in traditional conservation, prioritize nutrient-rich landraces and integrate them into school meal programs for diverse and nutritious diets.

Future prospectus

Future research prospects could involve participatory studies in farmers' fields, comparing landraces with widely used modern cultivars. Implementing cognitive mental modeling techniques for understanding of farmers' perceptions toward conservation of landraces.

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Conflict of Interest

There are no conflicts of interest among the authors as this study is based on evidence-based learning

and the collection of traditional knowledge from the farming community and elderly individuals. No confidential information was involved in the research process.

Author Contributions

PY: Investigation, data collection, writing original draft; RNP: Conceptualization, methodology, review and editing; PY: Data analysis, methodology, review and editing.

Declaration

The authors confirm that they obtained prior informed consent from all the participants before collecting data for the current research study.

Data Availability

The collected data will be available through a request from the corresponding author.

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