Diversity of local rice genetic resources in marginal semi-arid of East Nusa Tenggara: Status and conservation

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Abstract. In a marginal semi-arid environment, the cultivation of local upland rice is important as a staple food. However, climate change impacts genetic erosion, which can ultimately disrupt farmers' food security and sovereignty. This study aims to understand the status of existence, cultivation methods, and conservation management by farmers in semi-arid areas. This study used primary data collected through interviews to determine the status of local upland rice and primary data on cultivation and conservation management. The location and respondents were selected purposively. The results showed that ENT Province has 81 varieties of upland rice: 20 accessions from Southwest Sumba, 22 from Ende, 15 from Ngada, and 24 from North Central Timor. All respondents stated that local upland rice is essential for food security, as 95% of the production is consumed as a staple food. Farmers' interest in cultivating local rice is due to its advantages such as drought resistance, pest resistance, low production costs, and good taste. Farmers carry out traditional seed conservation, such as placing them in woven buri palm leaf containers. This requires integrating and considering technological interventions in regional agricultural development policies.

1 Introduction

Indonesia is a country that is very rich in terms of genetic resources study (GRS) [1], where each region has unique GRS characteristics and is different from other regions [2]. This characteristic has the potential to be of high value for regions to utilise location-specific genetic resources so that in supporting national development, conservation must be carried out by collecting GRSs.

East Nusa Tenggara (ENT) is one of the provinces that is included in the semi-arid area category, which consists of small islands and is part of the Wallace line, which consists of

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specific flora and fauna. Some of them include endemic and drought-tolerant floristic elements [3,4]. This makes the marginal semi-arid region of ENT very rich in the diversity of drought-tolerant plants [5], and many are still cultivated or conserved in situ by farmers, especially local upland rice varieties.

The economic structure of the ENT region depends on its agricultural sector. Based on ENT statistical data [5], the total area of paddy fields is 194,471, of which 45.7% is the area harvested for upland rice. This proves that the farming system of dryland farmers, including upland rice farming, contributes to regional economic development. However, the production results are in contrast to the area where field rice production is 232,631 tons, less than the lowland rice production of 929,822 tons [6]. This low-field rice production probably occurs because farmers are still cultivating local upland rice varieties using traditional farming systems and the impact of climate change like extremes in weather conditions, changes in rainfall patterns, heat waves, droughts, and flooding, all of which negatively affect crop yields on several scales. Nevertheless, local rice is still superior because of its ability to adapt to the local climate for a long time.

Based on agro-climatic conditions, the dominant rainfall pattern in ENT is the IIA pattern, with the number of dry months being 5–8 months and the number of wet months being less than four months [7]. The average rainy day is 145 days, with the highest average temperature being 32.80 °C and the lowest being 16.20 °C. In general, the ENT area is classified as hot, with an average temperature of 27–28 °C [8].

Dryland farmers only plant rice for one planting season per year because they rely on rainfall. If crop failure occurs due to climate change and/or low seed quality because of poor storage systems, the socio-economic conditions of farmer households and seed conservation will be disrupted. This has an impact on the existence of local rice, which is increasingly threatened by extinction [9,10]. Therefore, if efforts are not made to preserve GRSs, genetic erosion will occur [11].

Considering the important role of the agricultural sector in the rural economy as the key to the welfare of small farmers, in this case, small farmers who still cultivate upland rice, attention to the upland rice agricultural system needs to be reviewed from social and economic aspects in the role of small farmers. Therefore, it is supported by the large diversity of local rice genetic resources in ENT and has aspects that are very important to maintain. This paper aims to This study aims to understand the status of existence, cultivation methods, and conservation management by farmers in semi-arid areas.

2 Methodology

This study used primary and secondary data. Secondary data were collected from literature studies by relying on Genetic Resources Study (GRS) reports, THT Statistics data, research results, and observations regarding local rice diversity in ENT. Primary data were collected from interviews with local upland rice farmers in ENT using a questionnaire (Google form). Twenty local upland rice farmer respondents were selected purposively based on the location of origin of the local upland rice that had been explored. Data regarding local rice that has been explored, cultivation management, social and economic, and conservation of upland rice seeds of local varieties by farmers that have been collected are presented in the form of tables and documentation and then analysed descriptively.

3 Results and discussion

3.1 Brief description of the study area

East Nusa Tenggara Province is one of the provinces in Indonesia consisting of 566 islands with a land area of 46,452.38 km^2. The ENT region consists of five main islands (Timor, Flores, Sumba, Lembata, and Alor) and several small islands (Sabu, Rote, Ende, Solor, and others). Based on the climate classification [7], ENT Province is included in the semi-arid region with the dominant rainfall pattern in the IIA pattern with a number of dry months of 5–8 months and several wet months for less than four months [8]. The average rainy day is 145 days, with the average high temperature being 32.80 ˚C and the lowest being 16.20 ˚C. In general, the ENT area is classified as hot, with an average temperature between 27–28 ˚C [12].

The lowest rainfall was found in the southern region of South Central Timor District (Polo Village, Bena to Kuanfatu) and the northern region of North Central Timor District (Wini Village, to Kobele), while areas with relatively high rainfall were found in highland areas, such as in Manggarai and Bajawa Districts (Flores Island). In addition, there are areas in the south of Malacca District, namely the Betun and Besikama areas, which have two rainy seasons a year and a known bi-modal rainfall pattern, namely December-March and April-June.

The most common type of soil in ENT Province comes from rock sedimentation [8,16]; therefore, the specific type of farming developed by farmers in this region is known as the dryland farming system. The main characteristic of this agricultural system is that plants are planted irregularly in the form of mixed cropping.

From agricultural statistics data for 2017–2021 (Fig. 1), it can be seen that the districts that produced the largest upland rice were the Island of Flores, namely in 2017 (47,775 tons), 2018 (63,689 tons), 2019 (103,960 tons), 2020 (64,582 tons), and 2021 (75,554 tons), followed by the Island of Sumba, namely 2017 (33,391 tons), 2018 (62,727 tons), 2019 (76,793 tons), 2020 (58,810 tons), and 2021 (73,845 tons).

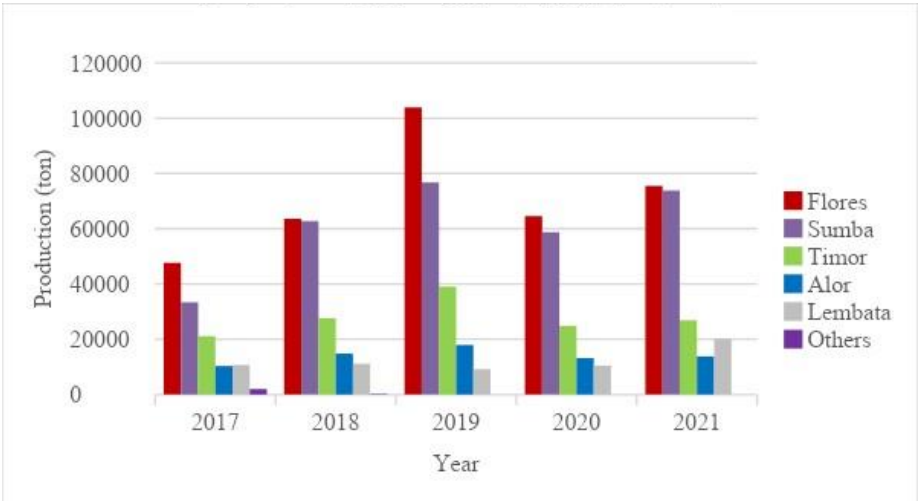

Fig. 1. Field rice production by the main island in ENT Province in 2017–2021.
*) Others: Rote Ndao and Sabu Raijua Districts.
Source: [5,6,13–16]

The cultivation of upland rice depends on the climatic and cultural conditions of the local community. Upland rice cultivation is not well-developed because farmers often experience a shortage of seeds for planting in the next growing season. Upland rice has the opportunity to be developed more widely or to increase its productivity in the future with the application of good technology practices to provide food, especially rice, to support food security and sovereignty in ENT.

3.2 Status of local rice varieties in ENT

The germplasm of local rice varieties consists of rice plants that have been grown for generations in specific areas so that they have genetic advantages as a result of adaptation to the agro-climatic conditions of an area. Usually, local rice is naturally resistant to pests and diseases, tolerant to abiotic stress, and has a good taste quality; therefore, it is liked by many consumers in every location where it grows and develops. Therefore, local varieties with superior characteristics need to be preserved as national genetic resource assets and utilised in breeding programs.

The local rice variety often found in ENT is upland rice, better known as field rice, which is one of the main food crop species in ENT. It is estimated that this plant has been cultivated since 1500 BC, so farmers today do not know for sure the origin of the rice plants they have planted so far. The genetic resources of local agricultural plants in ENT include a diversity of plant species cultivated by the community or farmers in ENT for generations over a relatively long period, so that the morphological characteristics of the plants are well known by the local community with certain local names. Some of these local plant species may be quite widespread in ENT but are still developed in limited areas in certain areas in ENT. This distribution is correlated with the ability to adapt to biophysical environmental conditions in ENT, its agronomic benefit value, or its economic value (either because of the superiority of the results and/or the quality of the results).

The ENT Agricultural Technology Assessment Center (BPTP), Agricultural Research and Development Agency, from 2013 to 2015, also carried out another collection of local ENT upland rice germplasms, and Southwest Sumba District is one of the regions that has the most accession to upland rice, with 20 accessions. [17] and research results [18], 22 accessions from Ende District, 15 accessions from Ngada District [19], and 24 accessions from the North Central Timor District [19]. Based on data on local rice genetic resources [17] and the results of research on local rice diversity in ENT, the following are the types of local rice that can be found among farmers in these areas.

Local upland rice varieties known in Ende District include Pare Mar-Mar, Pare Sera, Girl Dara, Pare Laka, Pare Maro, Pare Ero, Pare Iku Lapa, Are Mera, Kora Tuna, Bu Meng Putih, Jumba, Bu Menge Red, Bu Meng Putih, Bu Meng Campur, Koratuna, Are Nggodo, Are Ndota, Are Kea, Pare Muta Sema, Pare Kedo Lo'o, and Eko Ena [18]. Local upland rice varieties from Ngada District are generally named after their regional origin and partly based on their characteristics, such as Mamakeso, Sewikoka, Soa, Wea Lodha, Wea Ghuhu, Gollewa, Tumu Lena, Nio Dhole, Danga, Mama Wangi, Jerebun, Boawae, Pae To, Pae To Lo'o, and Pipi Toro [19]. Local upland rice varieties known in Southwest Sumba District with names based on the character of the grain or other plant characters, namely b: Pare Rara Kaletes, Kalunmbo Ngoro, Bintang Ladang, Pare Rara, Pare Mete, Pare Pembulu Kere, Goga Renci, Pare Kalenggo, Pare Mee, Pare Kanuro, Pare Mangata, Pare Toro, Pare Gogo, Pare Katonda, Wuluh Kawimbi, Kalengga Rara, Pare Cashew Kawicho, Gogo Wangi (Loyte Laka), Pare Bhokot, Pare Lipu Uta, Pare Keta, and Pare Nangga [17], Pare Habunga Kuhi, Pare Kiku Lapale, and Pare Panenggo Ate [20]. Hosang et al. [19] also stated that local upland rice is also found to be quite varied in the North Central Timor District. The names of local upland rice that are known include Ane Mui Noek, Ane Ulkamus, Ane Ikole, Ane Fafurun,

Ane Muti, Ane Mutifuanoek, Aen Muti, Aen Mukufuamnulu, Aen Bintang, Aen Muti Noek, Aen Muti Fuamana, Aen Nuti, Aen Nolo, Aen Nolo Fuamnulu, Aen Molonoek, Aen Molo Ana, Ane Molo Natane, Ane Okam, Ane Metan, Aen Metan, Aen Amtasa, Ane Oemata Fuamtasa, Aen Metam, and Aen Moe. Furthermore, the amount of local upland rice in East Flores District is found in relatively smaller quantities compared to the districts mentioned above. Some local upland rice known in East Flores District include Ula Ipek Kecil, Labe, Ula Ipek Bele, Mare, Mengi, Proga, Nobo Bisara, Lako Ikang, Muko Ubung, and Here.

Genetic diversity among local varieties illustrates the potential for use in plant breeding activities and supports national development to maintain food security and sovereignty. Genetic diversity in local rice plants can be observed in their morphological characteristics [21]. Local rice characters can be seen visually between accessions in the shape of leaf length, leaf surface, flag leaf angle, leaf midrib colour, grain colour, epidermis colour, number of productive tillers, and rice productivity.

Characterisation of 20 local rice accessions from the Southwest Sumba District by Arsa and Lalel [22] showed that the most dominant variations in agronomic characteristics were average leaf length and leaf width. The leaf length is 49.1 cm, the average leaf width is 1.3 cm, and the leaf surface looks 90 cm. 90% slightly hairy to hairy, 70% of accessions have a flag leaf angle of 45° while the rest are upright, 75% of accessions have white midrib, 60% of accessions have yellow grain colour, 55% of accessions have white epidermis, and 70% of accessions have long grain <1 cm. From these accessions, the average productivity was 2.5 tons/ha. Based on research by Hosang et al. [19], grain colour characteristics of 60% of accessions from Ngada were dark yellow, 64% of accessions were bright yellow; 43.3% of accessions from Ende were dark yellow, and the rest were bright yellow, red, and black; 35.72% of accessions from East Flores were red and black, and the rest were yellow.

Apart from this, one of the unique genetic variations is the aroma of local rice varieties. The results of a literature study showed that upland rice of the Pare Wangi variety from Ende is known to have quite good quality rice with a fluffier rice taste and quite fragrant aroma resembling the aroma of pandan leaves [22]. Previous research [23] also found other characteristics and advantages that the local upland rice, Ende, Pare Laka, and Are Ndota, had the highest anthocyanin content. Meanwhile, Bu Menge Merah rice has the advantage of having an amylose content of 32.24% [18], which is higher than the national variety with an amylose content of 22.3–27.6% [24].

3.3 Farmers' management and consideration of local upland rice cultivation

The important role of local upland rice for farmers in the semi-arid areas of ENT has been proven by the continued maintenance of local upland rice from generation to generation. Apart from being a staple food, this plant also plays an important role in the social and economic aspects of small farmers.

There are two types of upland rice-planting patterns: monoculture and intercropping. Upland rice planted using a monoculture cropping pattern is usually done alternating between lowland rice and upland rice, while that planted using an intercropping cropping pattern is usually planted for subsistence purposes, such as intercropping with corn, pumpkin, cucumber, sorghum, millet, peanuts, green beans, sweet potatoes, or cassava. Apart from this, it is also common to find field rice planted using a sequential planting pattern with corn and lowland rice. Relay cropping patterns are also found between upland rice and plantation crops, and alley cropping patterns between forestry crops.

Table 1 shows that the planting area for local upland rice varieties ranges from 0.03 ha to 1 ha. This land area is relatively narrow for running a farming business. To increase farming income, land area is very influential; the larger the land, the higher the chance of increasing economic income [25]. Land is a source of income for farmers. Therefore, land area and

income are positively correlated [26]. In general, land preparation is carried out using a slash-and-burn system to clear weeds. This process is carried out before the rainy season, that is, from September to November. Planting was carried out in December during the rainy season using seeds saved during the previous planting season. Seeds are planted directly (without seedlings) using random sticks of wood without spacing. During the cultivation process, some pests and diseases attack, but farmers only carry out mechanical control without using chemical or vegetable pesticides. Manual harvesting is done using a sickle/knife. Rice yields from the planted area were very low, ranging from 200 kg to 1,000 kg or 1 tons/ha. Low production affects farmers' income because the higher the production, the greater the income received by farmers [27].

Table 1. Management of local upland rice cultivation in the semi-arid ENT area.

No	Stages of activity	Local upland rice varieties
1	Land area	0.03–1 ha
2	Land processing	Land preparation is carried out using a traditional system including the slash-and-burn clearing of land before planting using wood.
3	Seed preparation	Carry out direct planting without seeding
4	Planting	Random method
5	Maintenance and control of plant pests and diseases	Maintenance without using pesticides
6	Production	200–800 kg
7	Harvest	Using a sickle

Based on the data in Table 2, it can be seen that there are seven factors that cause farmers to continue to plant local upland rice varieties. Local upland rice is resistant to drought and only depends on rainfall. Therefore, climate change greatly influences the sustainability of upland rice agricultural systems. The seeds used are those passed down from generation to generation, which are still preserved today. In the process of cultivating local upland rice varieties, 100% of respondent farmers answered that they did not use labour. Apart from the small planting area, the cooperation system of farmers is still implemented as a tradition so that farmers generally work alone or together. Apart from that, farming is still done manually, so the input costs for farming are low without the use of fertilisers, pesticides, and herbicides. Some farmers answered that the input costs used were only for purchasing machetes, hoes, and crowbars.

The existence of upland local rice is influenced by taste and aroma factors. All respondent farmers answered that the advantage of local upland rice is that it has a delicious taste and fragrant aroma. Even though all respondent farmers answered that their production results were not sold, where 95% of production was used for consumption, 2.5% of production was used for seeds, and 2.5% was used for traditional events or harvest thanksgiving, in some cases, farmers sold their rice if they had economic difficulties. The selling price of upland local rice is more stable than introduced rice, where the price is quite high, around IDR 15,000 to IDR 30,000.

Table 2. Farmers' considerations of local upland rice.

No	Types of consideration	Description
1	Adapts well to the environment	Drought resistant, so it is suitable for planting on rainfed land.
2	Seed source	The seeds used are seeds passed down from generation to generation so farmers do not want to replace them with other varieties.
3	Small production capital	Production costs are very low or non-existent. The cooperation work system is still applied so that it does not require labour costs. Do not use fertilisers, pesticides, and herbicides. There are no land processing or machinery costs.
4	Time efficiency	Harvested after four months planted
5	Consumer demand	The choice of local upland rice varieties is based on delicious taste and fragrant aroma.
6	The selling price is quite high and relatively stable	The selling price ranges from IDR 15,000 to IDR 30,000
7	Production use:	
	a. Consumption	95% is used for consumption
	b. Traditional event	2.5% is used for traditional or harvest Thanksgiving events
	c. Seed	2.5% is kept for seeds
	d. Sale	Not selling

3.4 Management of local upland rice varieties conservation

Seed conservation is an action for the preservation and storage of seeds for various purposes, including ecosystem restoration, maintaining high-quality seed stocks, and conserving plant genetic diversity. It plays a crucial role in ensuring the availability of seeds for large-scale restoration projects and acts as a buffer against crop failures and natural calamities. The seeds that are stored do not receive any special treatment; the seeds are only dried in the sun for approximately four days, cleaned of empty seeds, and then stored in a storage container made of woven buri palm leaves or stored in a sack (Fig. 2).

a) Local upland rice seed storage container made from woven buri palm leaf b) Storage container made of sacks

Fig. 2. Seed storage container.

The data in Table 3 show that the storage patterns of local upland rice farmers in ENT are 40% of respondent farmers storing in huts or garden houses, and 60% of respondent farmers storing in the attic near the stove (Fig. 3). In general, seed storage in ENT is placed in the attic near the stove so that automatically through fumigation, this method of storing seeds is used to speed up the drying process to obtain low water content. Nino [28] stated that the

smoking process which is carried out continuously can cause more and faster evaporation of water from the material [29].

The stored seeds will be planted in the following planting season, so it is known that the storage capacity of the seeds is 1–2 years. This storage method or pattern is a pattern passed down from generation to generation, so it has become a habit or tradition. Therefore, although 65% of respondent farmers wanted to replace this storage pattern with the latest method, 35% of respondent farmers refused to replace this pattern.

Table 3. Seed conservation patterns implemented by rice farmers in the ENT.

No	Methode Conservation	Description
1	Seed storage location	40% of respondent farmers store seeds in huts at home or gardens, 60% store seeds in the attic near the stove
2	Seed treatment before storage	Store seeds after cleaning and drying
3	Duration of seed storage	1–2 years
4	Reasons for choosing a storage method	a method passed down from generation to generation that has been commonly used
5	Pests and diseases in storage	70% of farmer respondents answered that the damage was caused by rats, and the rest did not experience any damage.

During the storage process, the pests that often cause damage are mice, but so far, no control has been carried out. The model for storing seeds and fumigating in the kitchen can be seen in (Fig. 2).

a) The hut where the seeds are stored

b) *Ume Bubu* (roundhouse/Timorese traditional house) seed storage using the smoking method

Fig. 3. Seed storage.

Since ancient times, farmers have carried out conservation in a traditional way, which is still maintained today. Ten per cent of rice production is saved for seed needs, and this is done because farmers are accustomed to the taste of upland rice, high prices, and low production costs, so the conservation of local rice seeds is still being carried out. Considering that its existence is very important for dryland farmers, upland rice is planted to support food security during the dry season. For example, the Southwest Sumba District, which has rain-fed rice fields, is irrigated; therefore, cultivating lowland rice is an agricultural business that must be carried out to maintain household food security.

These seeds have been used for generations to ensure that local rice varieties do not become extinct to be planted in the next year's planting season. This proves that local ENT rice conservation is still being carried out by farmers. So far, the government has paid

attention to but is limited to, suggestions for land expansion and efforts to control pests and diseases. Therefore, special attention is needed for small farmers to increase their rice production for local rice sustainability.

As local rice cultivation is quite limited and it is difficult to extrapolate beyond the place of origin, there is a need for local governments through agricultural extension officers to train local farmers to maintain simple best practices in local seed rice self-sufficiency. Besides, preserving the specific ecosystem where the local rice is normally grown also needs to be considered.

4 Conclusions

ENT has been identified as having 81 local upland rice accessions spread across four districts: Southwest Sumba District with 20 accessions, Ende District with 22 accessions, Ngada District with 15 accessions, and North Central Timor District with 24 accessions. Among the local upland rice accessions, some have been shown to have distinctive genetic diversity, namely rich in anthocyanins, high levels of amylose, and strong pandan aroma. Therefore, research on the advantages of local upland rice from ENT still needs to be done.

Cultivation and conservation management of local upland rice use a traditional method that has been around for generations. The method relies on slash-and-burn for land preparation, direct seeding without nurseries, random planting without pesticides and fertiliser, and manual harvesting with sickles. The seeds are stored in storage made of woven buri palm leaves or sacks and then placed in huts in the home garden or attic near the stove so that they are fumigated automatically.

The impact of climate on yield loss or crop failure and storage patterns that are susceptible to damage from rats mean that conventional management may not be applied to preserve local upland rice genetics. Therefore, cultivation and conservation management technology interventions in rural agricultural development policies need to be considered.

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