

Understanding rice innovation needed for smallholder farmers in semi-arid area of East Nusa Tenggara, Indonesia

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Abstract. Rice is grown in various environments across semi-arid areas of ENT province. This paper elaborates agricultural innovations delivered to the smallholder rice farmers and highlights their responses/adaptability. The research conducted in the state boundary of Indonesia-Timor Leste as part of AIAT-ENT program. The study showed that farmers having more access to rice innovation sources tend to adopt better and willing to purchase for external inputs. By adopting introduced rice innovations, co-operatives farmers in state boundaries were able to improve rice productivity from 1 – 2 ton/ha to 5 – 7.2 ton/ha. After 3 years of AIS implementation, almost all farmers have been continuously HYVs of rice. However, the sustainability of the innovation's adoption has commonly disrupted by the availability of external inputs. Numerous rice-related innovations have been introduced; however, smallholder farmers were keen to adopt only limited ones that suitable with their specific environment and household circumstances. The study concluded that rice innovations delivered to improve rice productivity in semi-arid areas should be focus on specific target groups that suitable their environments and household' circumstances. Rice-related innovations should be delivered in the broader context not merely to increase rice productivity, rather to improve smallholder semi-arid farmers' resilience for food security.

1 Introduction

Rice is the second staple food after maize in semi-arid areas of East Nusa Tenggara (ENT) province. Government programs to boost rice production have been done since 1960s, however, the rice production in ENT was remain stagnant around 750,000 tons/year in the last 10 years which is far below rice demand for almost 5.5 million of ENT population in 2019. Rice production in the last ten years have slightly increased (778,000 tons in 2008 - 811,700 tons in 2019) due to the increase in harvested rice field areas; nevertheless, the rice productivity remained between 3.4 – 4.05 ton/ha [1,2].

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Total rice field area in NTT was 210,773 ha; however, it was only 57,789 ha or 27 % of that are arable for twice a year [3]. This figure showed that most of the rice field in ENT is considered as rainfed lowland rice mainly due to water availability constraints. Rice farming systems in ENT are scattered in different environment in semi-arid areas and grown in various production system/management. Within these circumstances, various rice innovations were delivered. Rice field with more than 1000 ha was distributed only in few locations, while majority of rice field were scattered into less than 100 ha.

Water constraints and adoption of agricultural innovations have limited rice productivity in ENT. While more and more people depended on rice as staple food, present rice production in ENT is no longer enough to meet the local (provincial) demand. To meet the local demand, ENT imported rice around from other Islands in Indonesia, particularly from Java and Sulawesi Islands.

Dominant smallholder rice farmers depend on external inputs, particularly subsidy chemical fertiliser for rice production. Although, some rice productivity in some rice fields were already above 5 tons/ha, the average rice productivity in general was only 3.0 ton/ha or below average national productivity, therefore domestic rice supply is not meet the rice demand. Rice domestic deficit was fulfilled from inter-island trade from Java and Sulawesi Island.

To meet the growing demand of rice as staple food, government have developing some dams and improving/upgrading current irrigated some rice fields. Central government have overseen 26 irrigation areas in NTT to irrigates 106,689 ha agricultural land [4]. In the same time, rice-based innovation has been continuously introduced, particularly in main rice fields.

As part of central government policy to make State Boundary as a “front porch” of the State, Indonesian Agency for Agricultural Research and Development (IAARD) responded it by introducing various agricultural innovations in order to boost agricultural production/productivity in the State Boundary. Rice is one of the commodities that first taken into consideration to be developed/improved in State boundary of Republic of Indonesia and Republic Democratic Timor Leste RI-RDTL. Various innovations related rice farming has been introduced since 2013.

This paper aims to elaborate agricultural innovations delivered to the smallholder rice farmers in semi-arid areas and highlights their responses/adaptability strategies. The study was mainly based on the Assessment Institute for Agricultural Technology – East Nusa Tenggara (AIAT-ENT) research on Rice carried-out in State Boundary of RI-RDTL during 2017 – 2020 and “Identification of Agricultural Innovation Needed (IAIN)” of farmers in East Nusa Tenggara. The first research aimed to deliver rice innovation in order to boost rice productivity in State Boundary, while the second research aimed to identify farmers’ needs before farming system research/activities conducted. Baseline data of the recent study of Precise Technology of Rice (PIR) was also used to strengthen the narratives.

2 Methodology

2.1 Research sites

Rice field in three research sites were considered as small rice fields with only around 100 ha or less and scattered in small valley, corridor along the river and coastal plain areas. Tohe and Maumutin villages of Raihat Sub-district – Belu have boundary with Maliana District of RDTL, while two other District of RI (Kupang and TTU) have boundary with Oecusse enclave of RDTL. All ricefields in the research sites have natural boundary with the RDTL by rivers or creeks.

Research sites were selected purposively based on the rice distribution areas in the State Boundary of RI-RDTL. Three Districts have rice-field in the State Boundary such as: Kupang District (Oepoli rice field), Belu District (Tohe and Maumutin rice field) and TTU District (Tasinifu rice field). The rice field areas were chosen after discussed with District Agricultural Offices and the research were carried-out as collaborative program with extension workers at Sub-district Agriculture Extension Office or *Balai Penyuluhan Kecamatan* (BPK). The research was conducted during 2017 – 2019 in three Districts, however earlier rice program in Belu district (started 2013) was also considered to enrich rice development trajectory in State boundary.

All rice fields were categorised as “simple irrigation” rice field. Due to water constraints, except small part of Tohe village, other rice fields were considered as rainfed lowland rice field which farmed only once a year during the rainy season. Conversely, small part of rice field in Oepoli (Netemnanu village) of East Amfoang sub-district could not be farmed during rainy season due to the river as a main source of water block the primary water channel and therefore it farmed only during dry season after the materials that block the water channel cleared-up. Description of research sites is shown at Table 1.

Table 1. Description of rice research sites in State Boundary of RI-RDTL

District	Ricefield area	Area (Ha)	Irrigation type
Belu	Tohe	747 (3.7 ton/ha)	Irrigation and rainfed
TTU	Tasinifu	24 ha (exist:3.8 ton/ha)	Irrigation and Rainfed
Kupang	Oepoli	1,450 (3.1 ton/ha)	Rainfed

Source: Sub-district (Raihat, Mutis and East Amfoang) Statistical Bureau, 2018 and P3K.

2.2 Data collection and analysis

A baseline survey in all research sites were conducted before rice farming research program carried-out. Secondary data collected mostly from BPK and Sub-district Agricultural Extension Program or *Programa Penyuluhan Pertanian Kecamatan* (P3K) where the rice program being carried-out. Baseline data collected consist of general information (farmer group, village, sub-district, agro-ecological), respondent/farmer’ characteristics and crops and livestock farming’ characteristics.

Trained AIAT-ENT’ technician in collaboration with village agriculture extension worker have responsible for collection of agronomic related data. Socio-economic data were collected using Farm Record Keeping (FRK) and Survey method. Technician have supervised farmers in FRK which consist of land preparation, fertiliser application (time, dosage), pest and diseases control (time, dosage, frequency), weeding, harvest and post-harvest. Most of the data were analysed descriptively.

3 Result and discussion

3.1 Semi-arid ecology of rice farming

Rice field ecosystems in State boundary of RI-RDTL are precious ecosystem/areas which cover only around 3% total land area; however, it plays important roles as productive lands, main source of rice and other food crops. The rest of the State boundary regions are dominated with rocky and hilly landscapes that considered marginal lands that limited food crops production.

Tohe and Maumutin villages in Belu District receive water from the springs and from the Malibaka River which divided or as a natural boundary between Belu district of RI and Maliana District of RDTL. Most of the rice fields scattered along the river banks into several

villages. Before RDTL independent, the region was quite isolated and therefore agricultural innovation very limited reached local communities. Although most of the Raihat areas are dominated by hilly and rocky land up to 900 m asl, the rice field area of Tohe and Maumutin is located in corridor valley lowland around 200 m asl.

Almost all rice field in Tohe and Maumutin villages of Raihat sub-district were planted with rice during rainy season, however it only around 20% of the rice field can be planted during dry season due to limited water source. During dry season, most of the rice field is simply fallowed or used for extensive cattle rising. Farmers informed that they have willing to plant with horticultural crops during dry-season, but extensive cattle rising is limiting to do so.

TTU District of RI has borderline with Oecusse enclave around 104.5 km and it includes 23 villages and 8 sub-districts. Tasinifu village of Mutis Sub-district was one the villages that have rice fields around 24 ha at the borderline with Oecusse enclave. Although, it was just small portion of the village area, this rice field play important role as main source of rice of Tasinifu village. Most the village area was the hilly and dominated with rocky land and therefore it was not suitable for rice.

Tasinifu village has diverse landscape and altitude from the lowland (rice field site: \pm 100 m asl) up to the highland (dominated eucalyptus forest: $>$ 1000 m asl). Small flatland area along the creeks used for rice field land, while the majority of the land in the slopes were used for dry farmland and in the highland ($>$ 1000 m asl) mainly for forestland and grazing land.

Tasinifu village of Mutis Sub-district have only small rice field area (24 ha) or the smallest from the three research site. The average of land ownership and cultivated area of ricefield was only 20 acres (ranged: 10.0 – 50.0 acres). The rice field in Tasinifu village was considered as the most intensive and productive rice field in the State boundary due to water available enough and small size of rice land ownership.

Oepoli rice field herewith refers to the plain coastal areas in East Amfoang Sub-district. Oepoli rice field distributed mainly into three villages such as Netemnanu, North Netemnanu and South Netemnanu. Oepoli plain area in East Amfoang Sub-district of Kupang District is considered the most extensive rice field in borderline of RI-RDTL.

Oepoli region of Kupang district was closer geographically to Kupang town, however due to poor infrastructure it takes almost 12 hours to reach the area from Kupang town compare to only 6 – 7 hours to reach Tohe village of Belu District. So far, infrastructure development in general was bias to State Boundary mainland, while in Oepoli that have land borderline with Oecusse enclave was lack-behind. Present provincial government have trying to close the gap of infrastructure development in State Boundary of RI-RDTL in order to unlock physical isolation of the region by developing/ improving basic infrastructures – especially main road connecting to Oepoli region.

The ecosystem of rice farming in semi-arid areas are various, however it dominated by rainfed lowland rice. Different zone agro-ecosystem and rice growing environments needs to be considered in elaborating development policies [5]. For traditional farmers in semi-arid areas, beside for staple, rice farming is also a way of life and “integral part of cultural tradition” [6]. Agricultural innovation, particularly on rice is very limited introduced, however, improvements of irrigation infrastructure and introduction of HYVs after RDTL’ independent have significant implication for ecology environment of flatland areas and traditional rice farming practices in State boundary.

3.2 Existing practices and exposure to agricultural innovation

Early agricultural innovation in ENT were generally brought by foreign traders, started from the early trade of Sandalwood by Chinese and Indian traders [7,8] and continued by Dutch

colony that introduce some horticultural crops [9, 11]. Although some grain crops were also introduced during colonial period [9, 11] by considering the semi-arid environment and swidden cultivation practices, rice crop seems a minor crops during colonial period [12] up to early Indonesian Independent period.

All research sites were considered as isolated or “neglected” areas and therefore rice innovation exposure and agricultural innovation in general was very limited. Farmers keep practicing their traditional farming with no or less outside interventions. Data from baseline survey and field observation showed that majority rice farmers in Raihat was keep practicing direct seed sowing and almost no weed control.

Existing practice of traditional rice farming in ENT have dictated more on their experience on harvest failure due to water constraints and pest and diseases problems. Within semi-arid environment constraints, farmer prefers to implement “low but secure” strategy for rice production and for food crops in general. They also develop traditional social networks in accessing natural resources [13, 14].

During first decades of Independent era, major policy in Agricultural Department of Indonesian was to ensure food availability and food security for the people and the main commodity to be considered was rice. Introduction of HYVs of rice in the mid-1960s and fostered during New Order government has pushed more and more people in ENT plants rice and slowly change their diets from diverse locally produced indigenous foodstuffs to becomes more dependent on rice. Indeed, in some parts of the region that have irrigated lowland rice, rice becomes the main staple food.

Despite innovation related rice have long been introduced, rice farmers in the State Boundary have little access to those innovation. Data from the Baseline survey conducted in 2013 showed that none of the single farmers in Raihat of Belu district implemented Good Agricultural Practices (GAP) of rice farming. Farmers were keeps planting local variety of rice and what they called as “Portu” variety. They received information regarding chemical fertiliser, but limited farmers do apply or applied only when they received government support.



Fig. 1. Traditional rice farming in Raihat – Belu District



Fig. 2. Improved rice farming in Raihat – Belu District

Existing rice farming in State Boundary of RI-RDTL has considered almost similar, however some aspects of Good Agricultural Practices (GAP) of rice in TTU and Kupang were considered little-bit improved compare within State boundary of Belu as figured-out above. Some important aspects of existing rice farming in State boundary of RI-RDTL showed in Table 2.

Table 2. Some dominant aspects of existing rice farming in state boundary of RI-RDTL

Aspect/s	Research site/district		
	Raihat/Belu	Mutis/TTU	East Amfoang/Kupang
Land preparation	By livestock	By hand tractor	By hand tractor
Variety	Local	Old HYV	Old HYV
Planting system	Sowing direct seed	Trans planting	Trans planting
Planting distance	None	Random/denced population	Random/denced population
Weeding	None	Yes	Yes
Chemical fertilizer use	None	Yes if there is government subsidy	Yes if there is government subsidy
Pesticide use	Yes	Yes	Yes
Production orientation	Subsistence	Subsistence	Subsistence - Semi-commercial

Source: FGD and Field observation.

IAARD has been developing and introducing rice innovation in recent years, and in the State Boundary have started in 2013 under the program so-called: Field Laboratory of Agricultural Innovation started in Belu District, and then continued/extended to TTU and Kupang Districts under the program so-called: “Agricultural Innovation Support (AIS) in the State Boundary.” After intensive assistance by AIAT-ENT technicians for almost five years, there have been significant improvements in rice productivity/production as direct impact of implementation of recommended rice innovations. Some improvement aspects in three different study sites showed in Table 3.

Table 3. Some changes in rice farming in state boundary of RI-RDTL

Aspect/s	Sub-District/District		
	Raihat/Belu	Mutis/TTU	East Amfoang/Kupang
Land preparation	Minimal - full tillage by hand tractor	Full tillage by hand tractor	Full tillage by hand tractor
Variety	HYVs	Old HYVs – HYVs	Old HYV - HYVs
Planting system	Trans planting	Trans planting	Trans planting
Planting distance	- Legowo: 20% Planting in line/row: 60% - Random: 20%	- Legowo (20%). Planting in line/row: 80%	- Legowo (10%). Planting in line/row: 50% - Random 40%
Weeding	Yes	Yes	Yes
Pest and diseases control	Yes	Yes	Yes
Rice productivity (ton/ha)	- Ciherang: 5.18 - Inpari 6: 6.6 - Inpari 10: 6.4	- Inpari 30: 8.1	- Inpari 41: 5.65
% Change of Rice productivity	326 – 380	100	185

Source: Primary data.

Note: HYVs: high yielding varieties

One of the important finding/innovations for rice in State Boundary of Belu is that there was improvement of rice production in the land or rice field that experienced regular failure or very low rice production before AIAT-ENT program started. It was realised based on soil analysis that in those rice field has deficiency in Zn and Cu. After the micro-nutrients fertiliser added to the soils/rice field, rice productivity increased significantly from 0.3 ton/ha

(without additional micro-nutrients fertiliser) to 3.53 ton/ha for spraying micro-nutrients only, 5,75 ton/ha for root dipped into micro-nutrients liquid fertiliser and 4.91 ton/ha if booth praying and root deepen applied [15].

Although, rice productivity among farmers varies, adoption of agricultural innovation on rice has boost rice productivity in State Boundary higher than conventional ones. Indeed, during 2016 El Niño - co-operator farmers still harvest considerable rice production when majority conventional system fails to harvest. Moreover, one farmer group in Tohe village was able to produce seed to supply neighbouring district of Belu and Malaka and even to some farmers in neighbouring district of Maliana – RDTL.

The stage of rice farming in the State boundary could be categorised from traditional subsistence in Belu district and semi-commercial in TTU and Kupang districts. Majority of rice farmers in Raihat and Maumutin villages stated that there was no excess production from their rice farming or even not enough for household consumption for a year. Farmers does compensate rice deficit by planting maize and mungbean in the upland farming.

After agricultural innovation of rice introduced in Tohe village introduced, rice productivity reached 6.60 ton/ha (Inpari 6), 6.44 ton/ha (Inpari 10) and Ciharang was 5.18 ton/ha from the existing rice productivity ≤ 2 ton/ha. This achievement in Tohe village keeps during the life period of the projects. It also important milestone of improvement rice productivity in Tohe village and in the State boundary in general. Adoption of rice innovations has clearly improved rice production/productivity in State boundary and it has recognised as important pathways for ensuring smallholder rice farming systems transformation [16,17].

3.3 Rice innovation preferences

ENT province was one of the provinces in Indonesia that experiencing deficit in rice production and therefore there have been growing concern to extend land area for rice production and in the same time to improve rice production systems by introducing some rice farming innovations (e.g., HYVs, cropping pattern, fertilisers, weeding, pest and diseases control). Those innovations have also introduced in the State Boundary of RI-RDTL that have vary and specific characteristics.

Through various programs, AIAT-ENT have been consistency introduced rice innovations since 2013/2014 in Raihat Sub-district of Belu and then followed with TTU and Kupang Districts. After around five years rice related innovations were introduced, it was revealed that farmers in State boundary showed vary response that make rice production performance vary among rice farmers even in the same area. Nevertheless, farmer’s preferences have mostly dictated by their specific farming circumstances. Farmers’ preferences to some rice innovations showed in Table 4.

Table 4. Farmer’s preferences to some rice innovations.

Innovation/s	Research site/district		
	Raihat/Belu	Mutis/TTU	East Amfoang/Kupang
Adaptability/drought tolerant	3	3	1
High productivity	1	1	2
Taste	2	2	4
Early mature	4	4	3
Pest and diseases resistance	5	5	5
Less/no external input use	6	6	6

Notes: Scale 1 – 6 (most – less important/preference)

When rice farmers asked to rank which innovations they prefer most, farmers from Belu and TTU prefer to rice variety that have high yield potency in their specific environment,

while farmer in East Amfoang/Kupang prefer most high adaptive rice crops or drought tolerant. Farmers in TTU and Belu districts were attempting to maximise rice production in small area of irrigated land. Most ricefield in East Amfoang is considered as rainfed lowland in coastal area and water availability is the main constraints for rice production and therefore they prefer most on drought tolerant rice crops. Early mature crops preference was also reflecting the climate environment in Amfoang region which is low and short rainfall period. These preferences conform those farmers willing to adopt and adapt new innovation that suitable with their farming environment as key element of adaptation and resilience [18,19] and reduce farmers' subjective uncertainties and risks [20].

To realise the potency of HYVs, it requires external input use, particularly chemical fertiliser. In the early years of the program, project supported farmers with chemical fertiliser. It was trigger farmers to adopt rice innovations after they got higher yield than conventional ones. As [21] stated that: "providing subsidized long-term facilities to low-income farmers' groups would also promote adoption".

Pest and diseases control seems less considered for all farmers in State Boundary. Easy access to pesticides and its direct affects when it applied becomes the major constrains for farmers to implement recommended Integrated Pest Management (IPM). As [22] showed that promoting IPM ideas in pest and diseases control requires extension beyond knowledge dissemination.

The way of the study conducted it reflected the variations of rice farmers and agro-ecosystem of rice field in State boundary. Variations of farmers preference reflects their specific rice fields circumstances; however, their ranks of preference were quite close regarding drought tolerant crops, high yield, taste and early mature rice crop. All farmers agreed that pest and diseases resistance and less or no external input use was in the least of their preference.

Despite HYVs of rice have been introduced, most farmers in State boundary prefer local varieties or Old HYVs like Cihorang. Based on the baseline survey indicated farmer prefers those varieties due to tolerant to drought, low or no external input use, and accessible to local market or exchange seed among farmers. This indicate that farmers' preference sometimes different with breeder preference which lead to low adoption rate [23] of agricultural innovations.

4 Conclusion

Adoption of introduced rice innovations in State Boundary of RI-RDRTL was able to increase rice production/productivity of co-operator farmers from existing practices of 2 ton/ha or less to become 5 – 7 ton/ha or more than double. This indicated that there is an opportunity to increase rice production in the State Boundary at least for self-sufficient.

Farmers' preferences have mostly dictated by their specific farming circumstances. The study showed that farmers that have more access to the rice innovation sources tend to adopt more rice innovations and willing to invest or purchase for external inputs, while farmers that have less access or in remote areas were less eager to purchase for external inputs and applied only when there was government supports. Numerous innovations related rice have been introduced, however, smallholder farmers were keen to adopt limited rice innovations that suitable with their specific environment and household circumstances.

The study concluded that rice innovations delivered to improve rice productivity in semi-arid areas should be focus on specific target groups that are addressed their environments and household' circumstances. Rice innovations should be delivered in the broader context not merely to increase rice productivity, rather to improve smallholder semi-arid farmers' resilience for food.

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