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Mangrove of Walakiri, Sumba Island, Indonesia photo by Yanti Nainggolan

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Abstract:
Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta*. 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:
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Thesis, Dissertation:
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Short Communication: Willingness to participate in planting and protecting mangrove forest: community response related to mangrove fruit product utilization in Pariti, Timor Island, Indonesia

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Abstract. *Kurniadi R, Koeslulati EE. 2019. Short Communication: Willingness to participate in planting and protecting mangrove forest: community response related to mangrove fruit product utilization in Pariti, Timor Island, Indonesia. Trop Drylands 4: 1-4.* Mangrove forests provide a wide range of goods and services so that protecting them is of great importance. In some areas in Indonesia, there is some utilization of mangrove fruit as cookies or any kind of food, however, it was not the case in Pariti, Kupang Regency, Nusa Tenggara Timur (NTT) Province. This form of utilization might serve as stimulus for mangrove restoration and protection by local community. This research aimed to investigate the attitude of local communities in mangrove conservation which is reflected by their willingness to restore and protect the forest stimulated by fruit utilization for cookies. A total of 27 respondents were interviewed using a questionnaire, purposively selected. The result showed that the willingness of communities to protect the mangrove forest was low (3.7%) as well as the willingness to plant mangrove trees (3.7%). Despite the acceptance to develop cookies from mangrove fruit was high (100%), but they need to see its market. They will be motivated to plant mangroves if the market for fruit products exists or when there is a program. Unless the market of mangrove fruit cookies is developed, it could not serve as the stimulus for planting and protecting mangroves.

Keywords: Community, mangrove forest, willingness to plant, willingness to protect, cookie from fruit of mangrove

INTRODUCTION

Mangroves forests provide a range of essential ecosystem functions, such as protection from abrasion, storm and tsunami, carbon sequestration, habitat and breeding ground for various marine biota, and provision of various goods in the form of wood and non-wood products. Communities utilize mangroves as source of firewood, charcoal, tannin, dyes, food and beverages, medicine, pole, and timber (Ramadhan and Savitri 2007). Various organisms are found in mangrove forests (Rusydi, Ihwan, and Suaedin 2015) including mangroves crabs, and other invertebrates, such as mollusk and crustaceans, i.e., shrimp, clams, and crabs. They are fishery commodities exploited by local people to generate income (Ramadhan and Savitri 2017).

The province of Nusa Tenggara Timur (NTT), Indonesia has mangrove forest area with an extent of 40,695.54 ha, including those located in the coastal zone of Timor Island. Mangrove forests are about 2.25% of total forest area in NTT Province and they play essential role in local community, especially as a source of food (Lio and Stanis 2018). Despite the small portion of mangroves in NTT, it consists of high biodiversity. For example, in Timor Island, NTT Province, there are 11 species of mangroves trees in, i.e., *Rhizophora apiculata, Rhizophora mucronata, Rhizophora stylosa, Burguiera gymnorrhiza, Osbornia octodonta, Avicennia officinalis, Avicennia marina, Scyphiphora hydrophyllacea, Lumnitzera racemosa, Sonneratia alba* and *Aegiceras corniculatum* (Rusydi et al. 2015), and there were seven species of mollusk i.e *Littorina scabra, Littorina undulata, Terebralia sulcata, Nerita planospira, Nassarius distortus, Morula margariticola,* and *Saccostrea cucullata* and one species of Crustacea group i.e *Semibalanus* sp (Imakulata and Tokan 2018).

Of the mangrove forests in NTT, around 8285.10 ha or 20.40% are heavily damaged, 19,552.44 ha or 48.14% are lightly damaged, and 12,776.57 ha or 31.46% are in good condition (BPHM 2011). The deforestation and degradation of mangrove forests are caused by human activities, such as logging, reclamation for infrastructure development along the coastline, mangrove forest conversion for intensive agriculture and fisheries, and waste disposal (Jayanthi et al. 2018; Poedjirahajoe and Matatula 2019).

Communities might play essential roles in protecting mangrove forests, however, their participation in sustaining mangroves is low in some locations (Roy 2014). There are some factors that prompted their participation in mangrove conservation. Amzu et al. (2007) stated there is component that related to community attitudes, namely stimulus which can be classified into 3, namely (i) natural stimulus, (ii) useful stimulus, and (iii) religious stimulus. This research aimed to investigate the attitude of local communities in mangrove conservation which is reflected by their willingness to restore and protect the forest. In doing so, we focused on natural stimulus and useful stimulus (i.e. mangrove fruit utilization), since information about religious stimulus is limited in the community.

MATERIALS AND METHODS

Study area and period

This research was conducted on mangrove forest of Pariti Village, Sulamu Sub District, Kupang Regency, NTT Province (Figure 1). It is part of the 33,94 ha Kupang Bay's mangrove forest (Ramadhan and Savitri 2007) and has thickness of 50-200 meters (Hidayatullah and Ndolu 2015). The rationale for selecting this location is due to its potential source of fruit as alternative source of food (Koeslulat 2018). The research was conducted for three months, from April to June 2019.

Data collection procedure

Data were collected using interview method. Respondents were households selected purposely. The total respondents were 27 households, consisting of fish farmers, village leaders, gender representatives, small shop owners and pastry cookers. Information about the potential use of fruit was conveyed before the interview and they were invited to taste food products originated from mangrove fruits. After that, they were interviewed to answer questions related to current conditions of mangrove forests and its management. The interview was continued by asking their willingness to plant mangrove trees and the willingness to protect the mangrove forest in relation to mangrove fruit utilization.

Data analysis

Data were tabulated and processed using the frequency for each category. The results were descriptively analyzed and explained by existing theory to assist government to improve mangrove management and conservation. Some literature related to the studied site was also reviewed to add nuance to the analysis.

RESULTS AND DISCUSSION

Description of research location

Pariti village is one of the villages in the district of Sulamu, Timor Island, Indonesia with a total area of 1,305.5 ha. The area is mostly paddy fields (600 ha), settlements (300 ha), plantations (300 ha), and other public facilities such as graves, yards, parks, offices, and others. Pariti has 1,170 m coastline length and 100-480 m thickness. It was estimated 33,94 ha of mangrove area in the village (Ramadhan and Savitri 2007).

Pariti Village is one of the coastal areas where the majority of local people make a living as farmers and fishermen. Majority of the agricultural land is rain-fed rice fields, and in some lands people cultivate vegetables and other crops. Due to the large area of rice fields, production sharing system is commonly practiced. Access to the village is relatively good with paved road with distance of 17 km from the district capital and 60 km from the provincial capital. Good road access causes the marketing of agriculture, livestock, and marine products to go quite well.

In Pariti, mangrove thickness ranges between 100-200 m and there were 14 species (12 true mangrove and 2 associates mangrove) in which Rhizophoraceae family was found the most, i.e *Bruguiera cylindrica* (L). BI., *Ceriops tagal* (Perr), *Rhizophora mucronata* Lmk and *Rhizophora stylosa* Griff (Hidayatullah and Ndolu 2015). The density of mangrove forests in Pariti is classified as low to dense with 733-1.760 tree/ha (Hidayatullah et al. 2014).

The utilization of mangrove fruit in Pariti

The utilization of mangroves in Pariti is shown in Table 1. Table 1 shows that most of respondents utilized mangrove forests as source of shrimps, fishes, shells, and crabs (92.6%) and only a few respondents utilized mangrove forests as source of firewood (7.4%). This is in line with Ramadhan and Savitri (2017) that stated utilization value from captured fisheries in mangroves was Rp 19.204.934.508,-, higher than wood utilization (Rp. 229.605.000).

There was no utilization of fruit of mangrove (0%). Most of the respondents stated that they never know about the information of the utilization of mangrove fruit and questioned its safety. In 2017, Koeslulat (2018) has investigated sensory acceptance of *Sonneratia* sp cakes held in Pariti. The result suggested that the cookie needs to be improved especially in regards to taste. Because the respondents were limited in number, so the majority still did not yet know the feasibility of mangroves as a food source. In general, the community was excited by this new information although some suggestions arose during this survey related to its taste. Several questions arose regarding its possibility as a functional food (medicine), the fruit sustainability and its market.

Willingness of communities to plant trees

The willingness of communities to plant trees in mangrove is stated in Table 2. Table 2 shows that only one respondent was willing to plant trees in mangrove forests (3.7%). The fruit utilization was not enough to stimulate the community to plant trees since there was no clear information about the market, process, safety, and fruit sustainability. This finding is similar to Amzu et al. (2007) that conservation is failed because it is not in accordance with stimulus and attitude of conservation. The utilization of fruit of mangrove (useful stimulus) did not become stimulus for community since it was not clear about the information, especially about the market.

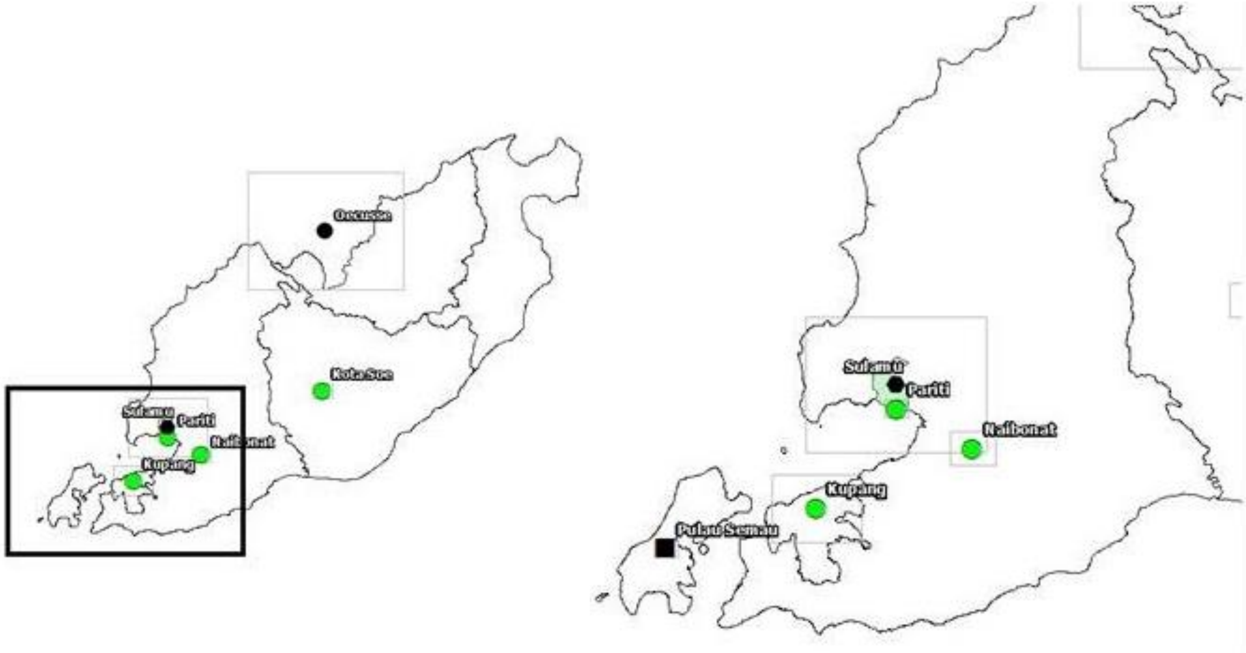

Figure 1. Map of study location in mangrove forest in Pariti Village, Timor Island, Nusa Tenggara Timur Province, Indonesia

It was presumed that the natural stimulus (decreased numbers of the plants) could be an effective stimulus more than the useful stimulus (economic value of the fruit of mangrove). However, along with the success of past planting projects supported by NGOs, there had been a change in attitude towards conservation since the degree of stimulus had weakened. Some of the reasons were: (i) the condition of the mangrove forest started to improve, (ii) there were village regulations (PERDES) that indicated the task of forest management was the duty of the government, (iii) there was no fund to support planting program. According to 7 levels of participation proposed by Hobley (1996), this condition was classified in the fourth level, namely Participation for Incentives. At this level, people participate through support in the form of resources, for example, labor, food support, income, or other material incentives. The weakness of this participation model is if the incentives run out then the program also stopped (Jariyah 2014).

Willingness of community to protect forest

The willingness of community to protect mangrove forests is shown in Table 3. The result indicated that most of the respondents were not willing to protect the forest (96.3%). It contradicts with Hidayatullah and Ndolu (2015) that the community's participation was good. It is likely caused by a change in attitude after the local regulation (PERDES) was published that due to the improvement of the forest. Besides, there was a perception that the government should play a role in protecting the forest instead of the community. The actions to protect the forest by the community were limited only to monitor the forest when they entered the forest.

Related to fruit utilization, the potential of the economy (useful stimulus) did not attract the community to protect the forest. In the perspective of the natural stimulus in the damaged area, it used enough to drive the community to plant the forest, but along with the success of past planting projects that were supported by NGOs, there had been a change in attitude towards conservation since the degree of stimulus had weakened.

Tabel 1. Utilization of mangrove forest by the respondents

Utilization of mangrove	Number of respondents	Percentage (%)
Wood	2	7.4
Source of shrimp, fish, shell and crab	25	92.6
Fruit as source of food	0	0.0
Total	27	100.0

Table 2. Willingness of the respondents to plant trees to improve the productivity of mangrove fruit

Willingness to plant trees	Number of respondents	Percentage (%)
Not willing	26	96.3
Willing	1	3.7
Total	27	100.0

Table 3. Willingness of the respondents to protect the forest

Willingness to protect forest	Number of respondents	Percentage (%)
Not willing	26	96.3
Willing	1	3.7
Total	27	100.0

According to Bloom's cognitive theory (Notoadmodjo 2011), there were 6 levels of cognitive knowledge i.e know, comprehension, application, analysis, synthesis, evaluation. The knowledge related to fruit utilization was at the lowest level. The information was only about the fruit potential utilization which was learned from other locations and was not adequate to stimulate the willingness to participate. The information has to be escalated by the information of the market and technical planting. Most of the community did not know about the technical planting of *Sonneratia* sp, while that of the *Rhizophora* sp was already known.

In conclusion, the information about fruit of mangrove utilization was not able to stimulate the community to participate in planting and protecting the mangrove forest. The information about the utilization of the fruit product, has to be completed by market and technical planting information.

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The efficacy of seed extract of *Tephrosia vogelii* and *Annona squmosa* on larvae of *Helicoverpa armigera*

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Abstract. *Nenotek PS, Ludji R. 2019. The efficacy of seed extract of* Tephrosia vogelii *and* Annona squmosa *on larvae of* Helicoverpa armigera. *Trop Drylands 4: 5-9.* Corncob borer (*Helicoverpa armigera*) is important pest of corn, urging the use of insecticide for its eradication. While using chemical insecticides is not sustainable, the use of plant-based insecticides is thus recommended. This study aimed to determine the efficacy of *Annona squamosa* and *Tephrosia vogelii* seed extract mixture on the mortality of 3rd instar larvae of *Helicoverpa armigera*. A range of concentration, as treatments, were evaluated, i.e., 0.05%, 0.11%, 0.28%, 0.65%, 1.5% and a control (water only) applied with three replicates in each treatment. Ten larvae of *H. armigera* at each treatment were infested in baby corn, using the residue method. Mortality was observed at 24, 48, 72, 96, and 120 hours after treatment (HAT). Percent mortality of the 3rd instar of *H. armigera* larvae was analyzed using Probit Polo PC, then proceed with mixed activity analysis. The results showed that the mixture of *A.squamosa* + *T. vogelii* seeds extracts killed *H. amigera* larvae with the value of LC_{50} and LC_{95} of 0.07% and 2.07%, respectively. A mixture of *A. squamosa* seeds + *T. vogelii* seeds extract was synergistic to *H. armigera* larvae with combined index values at LC_{50} and LC_{95} were 0.53 and 0.58, respectively. Thus, the use of a mixture of *A. squamosa* seed extract and *T. vogelii* seed is more efficient because the raw materials used were less at low concentrations to control *H. armigera* larvae than the extract applied separately.

Keywords: *Helicoverpa armigera, Annona squamosa, Tephrosia vogelii*, mortality

INTRODUCTION

Corncob borer (*Helicoverpa armigera*) is one of the main pests of some crops in Indonesia, attacking corn, soybeans, tomatoes, and cotton (Setiawati et al. 2002; Tenriwawe 2011; Indrayani 2013; Bedjo 2015). In corn, yield losses caused by this pest can reach 60% (Luther et al. 2007). The larvae bor the cob and eat the kernels, decreasing the quality and quantity of corn yields. In some corn plantations around the City of Kupang and Kupang Regency, East Nusa Tenggara Province, symptoms are often found due to corn cob borer. To suppress its development and damage, farmers often mix up three types of synthetic pesticides (i.e. carbofuran, BMPC, and diazinon) which are applied on a weekly basis.

The extensive uses of synthetic pesticides in controlling pests can cause various negative impacts such as pest resistance, environmental pollution, residues, and various types of diseases in humans (Gill and Grag 2004). For example, there are 260 species that are resistant to pesticides from the organophosphate group, 48 species are resistant to pyrethroids, and 85 species are resistant to carbamates (Dhaliwal et al. 2006). *H. armigera* is one of the pests that has been resistant to these three groups of pesticides (Ahmad 1997; Ahmad 2001; Ahmad 2007; Torres-Villa et al. 2002; Chaturverdi 2007). Corncob borer in India has been resistant to insecticides from the organophosphate, pyrethroid, and carbamate groups (Armes et al. 1996).

One of the pest control technologies that can minimize the negative effects of synthetic pesticides is plant-based pesticides. Each type of plant produces a variety of secondary metabolites that are sometime toxic to pests and diseases, act as repellent or attractant, can reduce appetite, and fertility (Vickery and Vickery1981; Schmutter 1990). In Indonesia, there are many plants that are potential as plant-based pesticides. It is estimated that 2400 species are potential as plant-based pesticides including *Annona squamosa* and *Tephrosia vogelii* (Kardinan 1999; Hasyim et al. 2015).

Botanical insecticide has several advantages, one of which is two or more species of plants can be mixed as a single pesticide. Through this mixture, insects are not easily resistant to the extracted plant compounds, and it can also increase synergism and reduce the use of raw materials. The compatibility of the mixture can be inferred from the synergistic nature of the mixture with higher toxicity rate compared to non-mixing plant extract. For example, the mixture of extracts of *Piper retrofractum*, *A. squamosa*, and *Aglaila odorata* was effective in controlling major pests in the cabbage, *Crocidolomia pavonana* and *Plutella xylostella* (Dadang et al. (2011). The mixture of *T. vogelii* seed extract and *Quassia amara* leaf extract had insecticidal properties against *C. pavonana* larvae, which was stronger than separately extract treatment (Nenotek 2010). In a previous study, separate testing of *A. squamosa* and *T. vogelii* seeds effectively killed the larval instar III *H. armigera*, with LC_{50} values of 0.89 and 0.15 (Nenotek and Ludji 2016). Information about the synergy of a mixture of *A. squamosa* and *T. vogelii* seed extracts has not been reported. Therefore, this study aims to determine the insecticidal nature of the mixture of *A. squamosa* and *T. vogelii* seeds extract against mortality of 3rd instar *H. armigera* larvae, and to obtain LC_{50} and LC_{95} values smaller than separately testing.

MATERIALS AND METHODS

Research design

This research used a Completely Randomized Design. A mixture of *A. squamosa* seeds and *T. vogelii* seeds at a ratio of 1: 1 (w/w) was tested at a concentration of 0.05%; 0.11%; 0.28%; 0.65%; 1.5%; and control. Each treatment of concentration had three replicates and each replicate consisted of 10 larvae instar 3rd *H. armigera*.

Test insects rearing

Helicoverpa armigera larvae were obtained from farmers corn crops around Baumata Village, Tarus, and University Nusa Cendana Dryland Laboratory, Kupang, Indonesia. Larvae *H. armigera* instar 1st and 2nd were kept in 30 cm x 10 cm plastic boxes (the lid was made of rectangular holes and fixed with gauze as air circulation) and fed with baby corn. Up to 3rd instar larvae to pupae were kept in a pudding cup, each cup contained one larva. Sawdust was given as a media for the end instar larvae to pupae, then the pupae were transferred into plastic cages until they became imago. Imago was kept in a 30 x 30 x 30 cm^3 wooden frame, fed with 10% liquid honey, which was absorbed on a lump of cotton. Cotton was replaced every day because imago lay their eggs on it. Cotton containing *H. armigera* eggs was put in a plastic box. Before the eggs hatch, baby corn or corn was given to the container as food for newly hatched larvae.

Extraction of plant material as a botanical insecticide

The extraction process was carried out at BioScience Laboratory Universitas Nusa Cendana. *A. squamosa* and *T. vogelii* seeds were dried at room temperature that was not exposed to direct sunlight. *A. squamosa* seeds were separated from the seed coat, whereas *T. vogelii* seeds were not separated from the seed coat. Each seed of the plant was blended with a blender and then sieved using a 0.5 mm edged sieve until it became powder. Soursop seed powder was soaked with methanol at a ratio 1: 10 for at least 24 hours, filtered using a glass funnel (9 cm in diameter) lined on no.12 Waltman paper. The extract was collected in a vaporizer flask, then evaporated with a rotary evaporator at 45°C and 337 mbar pressure. The remaining methanol obtained from evaporation was used to soak the pulp of extract and then evaporated. This activity was carried out until it was colorless. The extract obtained was stored in the refrigerator at ± 40°C until the time of testing. Whereas *T. vogelii* seed flour was soaked with ethyl acetate at the same ratio.

Toxicity assay of mixed extracts on *H. armigera* larvae

Mixed form of *A. squamosa* seed extract and *T. vogelii* seeds were tested at a ratio of 1: 1 (w/w) at a concentration of 0.05%, 0.11%, 0.28%, 0.65%, 1.5%, and control. Each active component was mixed with methanol solvent and Agristick adhesive (final concentrations of methanol and agristick in the test preparation were 1% and 0.2%, respectively) and then diluted with aquadest to the specified concentration.

Pesticide-free baby corn was dipped into the mixed extract at each concentration until it was evenly wet, then dried for a few months into a 5 cm diameter custard cup with hole in the cover and covered with gauze for air circulation. In each pudding cup containing one 3rd instar, *H. armigera* larvae were given feed treatment for 48 hours, after which it was replaced with feed without treatment. The dead larvae were counted and removed from the pudding cup while the living ones were reared with baby corn without treatment until the larvae became pupae. Mortality was observed at 24, 48, 72, 96, and 120 hours after treatment (HAT). The percentage of *H. armigera* larvae mortality was analyzed using Probit Polo PC analysis (LeOra Software 1987).

Analysis of the mixture activity nature

The mixed *A. squamosa* and *T. vogelii* seeds extracts were analyzed with different working models to calculate the combination index (IK) at the LC_{50} and LC_{95} levels (Chou and Talalay 1984):

$$IK = \frac{LCx^{1(cm)}}{LCx1} + \frac{LCx^{2(cm)}}{LCx2} + \frac{LCx^{1(cm)}}{LCx1} x \frac{LCx^{2(cm)}}{LCx2}$$

The two active component extracts LCx in separate tests, $LCx^{1\ (cm)}$ and $LCx^{2\ (cm)}$ respectively are extract components in the mixture resulting x mortality (50% and 95% of sample concentration), LCx values in the mixture are the result of LCx multiplication with a proportion of the component concentration in the additives mixture. The nature of the interaction of the mixture was divided into four categories namely (i). IK <0.5, the mixed composition is strongly synergistic; (ii). IK = 0.5-0.77, the mixed component is weakly synergistic; (iii). IK = 0.77-1.43, the mixture component is additive; (iv). IK> 1.43, the mixture component is antagonistic (Kosman and Cohen 1996).

RESULTS AND DISCUSSION

The results of the study showed that *A. squamosa* seed extract, *T. vogelii* seed and a mixture of *A. squamosa* + *T. vogelii* seed extract had the ability to kill larvae 3rd instar *H. armigera*. However, the toxicity of the mixture (*T. vogelii* + *A. squamosa* seed extract) killed the test insect more strongly than the separate method (Table 1). At a concentration of 0.11%, a mixture of *A. squamosa* + *T. vogelii* extract killed the test insects up to 70%, while mortality of *H. armigera* larvae that were given separate extracts of *A. squamosa* and *T. vogelii* was 26.26% and 50%, respectively. At a concentration of 1.5%, *A. squamosa* seed extract can only kill 56.67% of test insects, while the toxicity of mixed *T. vogelii* extract and *A. squamosa* + *T. vogelii* against test insects were 86.67% and 96.67%, respectively.

Table 1. Percent mortality of *H. armigera* larvae treated with *A. squamosa*, *T. vogelii* seed extract, and mixture of *A. squamosa* + *T. vogelii*

Conc. (%)	Cumulative mortality (%)		
	A. squamosa	*T. vogelii*	Mix *A. squamosa* & *T. vogelii*
Control (0)	0.00	0.00	0.00
0.05	20.00	26.67	36.67
0.11	26.67	50.00	70.00
0.28	40.00	56.67	80.00
0.65	43.33	80.00	80.00
1.50	56.67	86.67	96.67

The number of killed test insects at concentration of 0.05% for all treatments was categorized as low (Table 1). This shows that the toxin contained in each treatment is still low so it can be tolerated or neutralized by 3rd instar *H. armigera* larvae.

The mortality of 3rd instar *H. armigera* larvae treated with mixed extracts is presented in Table 2. At a concentration of 0.05% the mortality of test insects has not reached 25%, whereas at other concentrations the mortality percentage has reached 45-60%. Mortality rates continued to increase at 48 HAT and 72 HAT (hours after treatment) for all concentrations except controls. At the concentrations of 0.05% and 0.11% still found another test insects died at 96 HAT and 120 HAT.

In the mixed extract, mortality had begun to appear at 24 HAT at all concentrations. This shows that during 24 HAT there was a reaction of secondary metabolite compounds from the extracts of *T. vogelii* and *A. squamosa* seeds that poisoned the body of *H. armigera* larvae that worked as antifeedants, stomach poisons, and contact poisons. As an antifeedant, larvae recognized that the feed given was foreign object and not for consuming so that its body did not get energy, getting weak, and eventually dies. As a stomach poison, larvae consume food that already contains toxins and was carried into the digestive system thereby damaging cells in the digestive system that cause the death of test insects. When larvae activity directly contacts the feed, poison enters the insect's body through the pores of the cuticle. Furthermore, the poison was carried to the target site by the blood of the insect, thus damaging the cells and causing the death of the test insect. Poisoned larvae showed dislike to eat, lack of activity or movement, body-color changed to light brown and black when it died which began to appear on the first day after treatment.

The results of probit analysis (Table 3) show that a mixture of *A. squamosa* + *T. vogelii* seeds was more toxic to *H. armigera* larvae compared to separately extracts. LC_{50} value of *A. squamosa* seed extract + *T. vogelii* seeds was more toxic 2.14 times to *T. vogelii* seed extract and 12.71 times more toxic to *A. squamosa*. At LC_{95}, mixed extracts were more toxic 1.91 times than extracts of *T. vogelii* alone and 132.18 times more toxic than *A. squamosa* seeds alone. Thus a mixture of *A. squamosa* seeds + *T. vogelii* seeds was more effective against 3rd instar *H. armigera* larvae compared to extracts separately.

The combination index value (CI) of *A. squamosa* seed extract + *T. vogelii* extract has synergistic activity properties and stronger efficacy on the mortality of *H. armigera* larvae than the two extracts applied separately. The LC_{50} and LC_{95} combination index values are 0.53 and 0.58, respectively. The synergistic nature is probably caused by the activity of the active compound on different targets and at the same time resulting in a greater effect than the activity of the active compound separately. Another possibility is the presence of compounds from *A. squamosa* seeds and *T. vogelii* seeds can increase the workability of other compounds. Interaction of compounds in a synergistic mixture is a result of the activity of active compounds at different targets simultaneously providing a stronger effect than those compounds alone (Nenotek 2012). Mixture of several active compounds is synergistic if these compounds can increase the effectiveness of control of a species that is tested and the characteristics are called compatible (Clody 2010). Conversely, mixing two or more types of incompatible compounds is called an antagonist. Metclaf (1967) states that the mechanism of synergism occurs in the body of insects because toxic compounds can inhibit enzymes that function to decompose poisonous compounds in the insect's body.

Table 2. Percentage of mortality of *H. armigera* larvae treated with a mixture of *T. vogelii* + *A. squamosa* seed extracts

Concentration (%)	Percentage of mortality				
	Observational time (JSP)				
	24	48	72	96	120
Control (0)	0.00	0.00	0.00	0.00	0.00
0.05	13.33	20.00	26.67	30.00	36.67
0.11	50.00	60.00	63.33	66.67	70.00
0.28	46.67	70.00	80.00	80.00	80.00
0.65	53.33	76.67	80.00	80.00	80.00
1.50	66.67	83.33	96.67	96.67	96.67

Table 3. Estimating the toxicity parameters of *A. squamosa* seeds + *T. vogelii* seed extracts against *H. armigera* larvae

Type extract	a ± GBb	b ± GBb	LC_{50} (CI 95%) (%)	LC_{95} (CI 95%) (%)
Seeds of *A. squamosa* + *T. vogelii*	0.72 ± 0.11	0.51 ± 0.15	0.07 (0.02-0.13)	2.06 (0.08-32.07)
Seeds of *A.** *squamosa*	0.31 ± 0.15	0.66 ± 0.20	0.89 (0.42-6.92)	272.31 (19.42-2124600.5)
Seeds of *T. vogelii**	0.95 ± 0.17	0.17±0.22	0.15 (0.08-0.23)	3.95 (1.67-23.37)

Note: CI: Confidence Interval (Nenotek and Ludji 2016)

Anonna squamosa seeds contain acetogenin (Pomper et al. 2009). Some of the acetogenin compounds in *A. squamosa* are annonin I, squamosin, and asimine (Isman 2006). In general, acetogenin works to cut the energy supply by inhibiting the production of ATP energy in the mitochondria so that the test insects infested by these compounds will become weak and eventually die (Alali et al. 1999). These compounds are thought could kill various types of pest insects, including the *Sitophilus zeamais* (Nenotek et al. 2018), *Croccidolomia pavonana* larvae (Nenotek and Ludji 2014), and *Thrips* sp. (Nahak et al. 2018).

The active compounds in *T. vogelii* seeds are rotenone, rotenolene, and rotenoids (containing tephrosin and deugelin) and all are water-soluble (Enyiukwu et al. 2016; Chukwu 2018; Cabizza et al. 2004). Rotenon works as a contact, systemic, and selective poison to slowly kill test insects (Perry et al. 1988; Wirawan 2006). Tefrosin and deugelin in rotenone not only directly kill insects but also work to inhibit their feeding activity and growth development (Morris 1999).

Rotenone works in the body of insects by interfering with the function of respiration enzymes that work between NAD and coenzyme Q which causes failure in respiratory function. Rotenone also works in the mitochondria which inhibits the transfer of electrons in the NADH-coenzyme ubiquinone reductase so it can inhibit cellular respiration and decrease the energy source of ATP. This causes the test insects to become weak, paralyzed, and eventually die (Lu et al. 2006; Hollingwort 2001; Matsamura 1985; Wirawan 2006). A mixture of *A. squamosa* seed extracts + *T. vogelii* seeds is recommended to control *H. armigera* larvae because they are compatible, synergistic, require fewer raw materials, and increase application efficiency in the field at lower concentrations. Using a mixture of plant-based insecticides in different ways can delay the possibility of pest resistance to the components of the mixture (Georghiou 1983), reduce the negative impact on the environment, phytotoxicity, and non-target organisms.

In conclusion, a mixture of *A. squamosa* seed extracts + *T. vogelii* seeds has synergistic activity properties against *H. armigera* larvae. The LC_{50} and LC_{95} values of a mixture of *A. squamosa* seeds + *T. vogelii* seeds were 0.07% and 2.07%, respectively. Thus, the use of a mixture of *A. squamosa* seed extract and *T. vogelii* seed is more efficient because the raw materials used were less at low concentrations to control *H. armigera* larvae than two extracts applied separately.

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Inventory and identification of banana cultivars and diseases caused by bacterial and fungal pathogens in West Timor, East Nusa Tenggara Province, Indonesia

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Abstract. *Henuk JBD, Kadja DH, Mau YS. 2019. Inventory and identification of banana cultivars and diseases caused by bacterial and fungal pathogens in West Timor, East Nusa Tenggara Province, Indonesia. Trop Drylands 4: 10-16.* Banana is one of the most important horticulture crops in West Timor, East Nusa Tenggara Province, Indonesia. But the productivity of this crop is still low due to many factors, one of which is diseases caused by bacterial and fungal pathogens. There are many banana cultivars in West Timor but information on their cultivar identity and the diseases they suffer are absent. The present study aimed at: (i) identifying the banana cultivars in West Timor, (ii) assessing the symptoms of the diseases on the banana cultivars, and (iii) identifying the pathogens causing the diseases. The sampling of research location was done purposively while sampling of banana plantation was using a snowball method. Banana cultivar showing bacterial blood and fungal disease symptoms were further examined to isolate and to identify the pathogens based on the pathogen morphological characteristics. Twenty-one banana cultivars were found in West Timor, and were included in three genomic groups, i.e., ABB, AAB, and AA. Symptoms and signs of bacterial infection were only found on Pisang Kepok. Two bacteria isolates and soil samples were further cultured on specific and general bacterial media and also subjected to gram staining, all of which revealed that the bacterial isolates were not the causal bacterial pathogens of Blood disease or banana *Xanthomonas* wilt. Thus, no blood disease or banana *Xanthomonas* wilt is present in West Timor at the moment. Various and abundant fungal disease symptoms were exhibited by most of the cultivars. Banana diseases caused by fungal pathogens included Cordana Spot disease (*Cordana musae*), Anthracnose disease (*Colletotrichum musae*), Sigatoka disease (*Mychosphaerella* sp.), Leaf spot disease (*Phyllachora musicola*), *Curvularia* spot disease (*Curvularia* sp.) and Freckle disease (*Phyllosticta musarum*).

Keywords: Inventory, identification, bacterial and fungal pathogens, banana cultivar, West Timor

INTRODUCTION

A number of bacterial diseases of banana had been reported to occur in Indonesia. The diseases included blood disease (blood disease bacterium/BDB) caused by *Pseudomonas celebensis*, moko disease caused by *Ralstonia solanacearum* race 2, and bacterial wilt caused by *Xanthomonas vasicola* pv. *musacearum* (Semangun 2007). Banana diseases caused by bacteria have also been reported to occur explosively during the last few years in Sumba Island, East Nusa Tenggara (ENT) Province, Indonesia. The local government of Southwest Sumba District, ENT Province reported that banana plantations in the region had been infected by *Xanthomonas* wilt disease with very high intensity, especially on the local cultivars called Pisang Kapok/Pisang Marmia and Pisang Ambon, which caused total loss of the crop. Our preliminary study (Mau and Henuk 2016) also revealed disease symptoms typical to those caused by *X. vasicola* pv. *musacearum*, indicated by rotten flowers and premature ripened fruits, and yellow bacterial ooze inside the premature fruits. *Xanthomonas* wilt pathogen attacks the banana plant very quickly and even can cause plant death in just one month (Mackie et al. 2007). Therefore, it is recommended that the infected plants have to be eradicated as soon as possible to reduce losses caused by the disease. In addition to bacterial diseases, fungal diseases of banana have been endemic in this region. The information on the kind of diseases in banana and their symptoms is lacking despite the highly abundant banana cultivars that exist in ENT Province (Mudita 2012).

The banana disease pathogens are easily transmitted through water, wind, soil, vectors such as insects and birds, contaminated harvesting equipment, infected planting materials, etc. These may have facilitated the dangerous bacterial diseases such as banana blood disease to be spread from Sumba Island to the neighboring Islands in ENT Province such as Timor Island, Flores Island, etc. The uncontrolled transportation of banana products and its planting materials among islands in ENT Province may have caused the banana disease to spread along with the islands.

Timor Island is a major Island in ENT Province as well as a banana producing center in the province. To prevent the banana diseases epidemic in this island, especially the bacteria-causing diseases such as that happened in Sumba

Island, it is necessary to do an inventory and identification of the diseases caused by bacterial pathogens, especially those of vascular bacterial pathogens attacking banana plantations in Timor Island. In addition to bacterial diseases, banana diseases caused by fungal pathogens may cause considerable losses as well, depending on the banana cultivars. There are many banana cultivars that exist in West Timor but information on their cultivar identity and the diseases they suffer are not available at present. The objectives of this study were to carry out an inventory of banana diseases caused by bacterial and fungal pathogens and to identify the causal pathogens. The study results will be used as a basis for formulating the development strategy of bananas in ENT Province, and West Timor Island in particular, as well as the development of disease management strategy through, among others, the use of banana cultivars resistant to important diseases of bananas in the region.

MATERIALS AND METHODS

Study area and period

This study was conducted in banana plantations growing districts in West Timor, Indonesia, i.e., Kupang District, Timor Tengah Selatan (TTS) District, and Malaka District from May to October 2016. A survey method was used in this study focusing on the villages of banana production centers. The villages were purposively selected based on information on the number of farmers having banana plantations. A multi-stage snowball sampling method was used to determine the villages (study location) and farmer households having banana plantations. In the selected village, the first farmer household owning banana plantation was selected, and the next farmer household was determined based on information obtained from the first farmer household, and so forth until a total of three farmer households were met in each selected village. In each district, a total of 15 farmer households having banana plantations were interviewed and their banana plants were observed for the various diseases.

Identification of banana cultivars

Selected farmers were interviewed for the name (local name) and type of banana cultivars they grow in their fields, followed by direct observation of the banana cultivars for identification of morphological characters. Identification of banana cultivars in the field was based on banana genome notation proposed by Simmonds and Shepherd (1955). Differentiation of banana cultivars for genomic notation was based on 15 morphological characters of the banana (Mudita 2012). Pictures of the morphological characters were taken and then used to determine the banana genome. Each morphological character was given a score of unity (1) if it showed the character of *Musa acuminata* and a score of five (5) if it showed the character of *M. balbisiana*. Banana cultivars that showed morphological characters in between the two species were given scores of 2, 3, or 4, depending on the level of their similarities with the two species. Those with morphological characters more closely resembling *M. acuminata* were scored 2, and those in between the two were scored 3, and those more resembling *M. balbisiana* were scored 4. The *M. acuminata* banana genome was denoted by the letter A and the *M. balbisiana* banana genome with the letter B. Scores obtained from the 15 characters were then summed and used to determine the banana cultivar genome as shown in Table 1.

Sampling of banana plants for disease symptoms assessment

Disease symptom assessment was done separately for each banana cultivar. A total of three healthy and three diseased plants were observed for each banana cultivar. The sampled plants were determined using a stratified systematic sampling method. Assessment of disease signs and symptoms were carried out with the assistance of pictorial field key/guide of various banana diseases.

Identification of the diseases and pathogens

Infected parts of diseased banana plants were then taken to laboratory for further identification of the causal pathogens by using a conventional technique. Laboratory preparations included the sterilization of equipment by using an autoclave at 121˚C for 15-20 minutes; and preparation of the growing media to isolate pathogens that are thought to be pathogenic bacteria in vascular tissue and the fungal pathogens in the infected leaf tissue.

The Nutrient Agar (NA) medium was used to isolate the pathogenic bacteria. The prepared selective medium for *Xanthomonas* pathogenic bacteria was a Yeast Dextrose Carbonate Agar (YDCA) medium, for *Ralstonia* was a Tetrazolium Chloride (TZC) medium and for *Pseudomonas* was a King's B medium.

Table 1. Examples of banana genomic groups based on 15 morphological characters (Mudita 2012)

Genomic group	Score	Examples of local banana cultivar
AA/AAA	15-25	*Musa* AA 'Pisang Mas', *Musa* AAA 'Pisang Ambon Hijau', *Musa* AAA 'Pisang Susu'
AAB	26-46	*Musa* AAB 'Pisang Raja', *Musa* AAB 'Pisang Raja Sereh', *Musa* AAB 'Pisang Tanduk'
AB/AABB	47-49	-
ABB	59-63	*Musa* ABB 'Pisang Awak'
ABBB	67-69	-
BB/BBB	70-75	*Musa* BBB 'Pisang Kepok'

Infected parts of pseudostem were cut into small pieces and immediately inserted into a test tube containing 5 ml of sterile distilled water. Ooze of the bacteria from the stem pieces in the distilled water was allowed to stand for a few minutes to obtain sufficient amount of suspension for culturing the bacteria in the media. The bacteria were cultured by scraping a loop of bacterial suspension onto the media in a petri dish using a quadrant method. Each growing bacterium was then further sub-cultured to obtain a pure culture, which then further subjected to gram staining or KOH assay.

Each type of pathogenic bacterium that causes disease in banana plant samples was identified by using a conventional technique. Conventional identification of bacteria was done using guidelines of Pests and Disease Image Library (PaDIL, http://www.padil.gov.au) and Plant Pathology Guidelines for Master Gardeners (http://erec.ifas.ufl.edu/plant_pathology_guidelines/module_05.shtml). Fungal pathogens were identified using guidelines of Pests and Disease Image Library (PaDIL, http://www.padil.gov.au), MycoBank (http://www.mycobank.org/Biolomics.aspx?Table=Mycobank&Page=200&ViewMode=Basic), and APSNet (http://www.apsnet.org/edcenter/Pages/phi.aspx#illustrated glossary). Disease symptoms and signs were observed in the infected banana plants, and their diseases symptoms, were presented in forms of photographs.

Isolation and identification of fungal pathogens are described as the following. Sample of each disease symptom was surface sterilized by dipping it into sodium hypochlorite (2%) solution for 30 seconds followed by dipping in 70% ethanol for one minute, then was rinsed twice using sterile distilled water. Infected tissue of approximately 2 mm x 2 mm size was cut from the edge of the symptom or lesion, then was planted in a petri dish containing half-strength medium of Potato Dextrose Agar (1/2 PDA) [19 g PDA + 10 g Agar in 1 L distilled water) provided with antibiotics (0.2 g L^{-1} novobiocin) to inhibit bacterial growth. The petri dish was then incubated for 3-7 days at room temperature (25 °C). A pure culture was then made from each growing colony.

Microscopic characters of the fungal pathogen were observed with a light microscope. Macroscopic observations were made on the color of the colony, the shape of the colony, and the time or duration of growth of the pathogen.

RESULTS AND DISCUSSION

Banana cultivars found in West Timor

Study results revealed that 11 banana cultivars (local name) were grown by farmers in Kupang District i.e., Pisang Kepok, Pisang Rote, Pisang Ambon, Pisang Beranga, Pisang Susu, Pisang Raja, Pisang Tembaga Merah, Pisang Tembaga Putih, Pisang Meja, Pisang Kulit Mentah, and Pisang Amerika. Meanwhile, 15 banana cultivars were found to be grown by farmers in Timor Tengah Selatan (TTS) District; nine of which were similar to those grown by farmers in Kupang District (Pisang Kepok, Pisang Rote, Pisang Ambon, Pisang Susu, Pisang Cavendish, Pisang Meja, Pisang Tembaga Merah, Pisang Kulit Mentah, Pisang Amerika), and the rest were Pisang Mas, Pisang Luan, Pisang Aceh, Pisang Singapura, Pisang Dilli, and Pisang Pinang. In Malaka District, 11 banana cultivars were found, i.e., Pisang Kepok, Pisang Ambon, Pisang Meja, Pisang Susu, Pisang Raja, Pisang Luan, Pisang Batu, Pisang Kulit Mentah, Pisang Kafendis, Pisang Asam, and Pisang Mas.

Interview results revealed that each farmer usually cultivates 3-5 cultivars of banana around their home yard and gardens. Banana cultivars commonly found in the fields were Pisang Kepok, Pisang Rote, Pisang Susu, Pisang Tembaga, Pisang Meja, Pisang Ambon, and Pisang Kulit Mentah. These types of bananas are scattered throughout the observation area in the districts of Kupang, TTS, and Malaka, both in the highlands and the lowlands, as these banana cultivars are very easy to grow on various soil conditions and are drought resistant. These banana cultivars have been well-known by the community in the research areas.

Almost all parts of banana were utilized by the respondents. Pseudo stems and leaves of banana are usually used as fodder (for cattle and pigs). Besides, the leaves are also commonly used for packaging various types of food and cakes. The banana flowers commonly called the male buds are used for public consumption as vegetables, while the ripened fruits are consumed directly, or used as materials for a wide variety of cakes and snacks and even as an alternative food.

Bananas have an important role in food security for local communities. FAO (2009) reported that the banana is a staple food in many developing countries, including Uganda, Burundi, and Rwanda, because people in these countries consume 3-11 bananas per day or 250-400 kg per year (Biodiversity 2012). In West Timor, unripe fruit of Pisang Luan cultivar is boiled or steamed and consumed as an alternative food (Mudita 2012).

Banana cultivar identification

Based on the 15 morphological characters descriptors used to identify and distinguish the cultivars of banana by genome notation proposed by Simmonds and Shepherd (1955), the banana cultivars in the three districts in West Timor are presented in Table 2. Table 2 shows that there are three banana genome groups in West Timor, namely genomic groups ABB, AAB, and AA. The cultivars included in the ABB genomic group were Pisang Kepok, Pisang Rote, Pisang Singapura, Pisang Amerika, Pisang Pinang, Pisang Aceh, and those in the AAB genomic group are Pisang Ambon, Pisang, Pisang Cavendish, Pisang Raja, Pisang Asam, and Pisang Dilli. The AA genomic group consisted of Pisang Susu, Pisang Tembaga, Pisang Tembaga Merah, Pisang Tembaga Putih, Pisang Meja, Pisang Kulit Mentah, Pisang Baranga, Pisang Mas, Pisang Luan, and Pisang Batu.

Table 2. List of Banana Cultivar's Genome found in West Timor, Indonesia

Local name of banana	Score*	Genomic group**
Pisang Kepok	65	ABB
Pisang Rote	67	ABB
Pisang Ambon	34	AAB
Pisang Susu	20	AA
Pisang Kafendis	26	AAB
Pisang Tembaga	24	AA
Pisang Tembaga merah	24	AA
Pisang Tembaga putih	19	AA
Pisang Meja	16	AA
Pisang Kulit mentah	20	AA
Pisang Amerika	67	ABB
Pisang Baranga	19	AA
Pisang Raja	26	AAB
Pisang Mas	19	AA
Pisang Luan	19	AA
Pisang Asam	26	AAB
Pisang Singapura	65	ABB
Pisang Dilli	28	AAB
Pisang Pinang	59	ABB
Pisang Aceh	65	ABB
Pisang Batu	20	AA

Note: *Score was based on 15 morphological characters. **Genomic group was based on value ranges score of the 15 morphological characters

Symptoms of banana diseases

The results showed that the signs and symptoms of banana diseases caused by bacterial pathogens were very rarely found. There were only a few plants of Pisang Kepok that were found to exhibit symptoms and signs of diseases caused by bacterial pathogens, i.e., in Merbaun Village of Kupang District (Figure 1.A), in the villages of Oebobo, Mio, and Batu Putih of TTS District (Figures 1.B and 1.C).

Signs and symptoms of diseases allegedly caused by pathogenic bacteria were used to perform visual identification as well as macroscopic and microscopic examinations. Visually, disease symptoms found on Pisang Kepok cultivar in three villages were thought to be caused by bacterial pathogens, indicated by all the leaves that turned yellow, necrotic, wilted, and hanging down due to broken and even the tree was fallen. The ooze is the main characteristic of pathogenic bacteria infection, however, there was no bacterial ooze produced/found when the pseudostem was cut horizontally, and instead, the middle part of the pseudostem was destroyed and produced a very foul smelling. The fruits of the infected plant turned to mummy but again, no bacterial ooze was observed when the fruits were cut into pieces. The pseudostem of banana plant from Mio Village, TTS District also shared the same symptoms of that from Kupang District, however, when the pseudostem was cut transversely, there was a hole along the middle section of the pseudostem without rotten smell, but there were larvae of insect at the end of the hole. In a normal condition, the pseudostem, including the middle section, is in a compact form that contains fiber that comprises polymers such as cellulose, hemicellulose, pectin, and lignin (Manilal and Sony 2011).

External symptoms that appeared on the leaves were almost the same as the description of the symptoms of blood diseases by CABI (2013), i.e., if the pathogenic bacteria of blood disease infect a tissue vessel and the fruit, it will cause yellowing of all the leaves with gradual necrosis, then withered, broken and hanging down. However, internal symptoms of pseudostem and fruit of diseased banana plants in this study produced no signs or symptoms of pathogenic bacteria infection as there was no bacterial ooze found. According to Promusa (2013), internal symptoms and signs in pseudostem are yellow mucus that comes out of the vessel when the stem is cut. The same symptoms and signs can also be seen in other parts of the infected tree. Based on descriptions of symptoms and signs of CABI (2013) and Promusa (2013), external and internal symptoms found on Pisang Kepok cultivars was not caused by blood disease and *Xanthomonas* wilt bacteria, but to ensure these allegations, the plant tissue and soil samples were isolated and grown in NA medium, and then was purified in YDCA as a specific medium for *Xanthomonas*, and in TZC as a specific medium for *Ralstonia*. If the bacteria could grow on the TZC and YDCA media, their morphological characteristics were identified macroscopically and microscopically by conventional techniques.

Plant and soil samples that were isolated and grown in NA medium produced two different isolates (Figures 2 and 3). Isolates 1 had a cloudy white colony color, shiny, round shape, slightly convex, shiny, and translucent, while isolates 2 had a round form flat-edged colonies, bright yellow color or striking, somewhat translucent, convex and shiny. Gram staining was carried out to determine the gram characteristic of both bacterial isolates. Gram staining revealed that both bacterial isolates could not grow on YDCA and TZC media, but they grew normally in an NA media. Thus, these two bacterial isolates were not identified further because it is certain that both bacterial isolates are not the pathogens of blood disease or banana *Xanthomonas* wilt; and they are most likely secondary bacterial present in the infected banana plant.

In contrast to the limited number of bacteria causing banana disease signs and symptoms, there were abundant signs and symptoms of banana diseases caused by fungal pathogens in the research area. Various banana cultivars, included Pisang Kepok, were found to exhibit fungal disease signs and symptoms as presented in Table 1. Signs and symptoms of each of these diseases are typical and easily characterized by visual inspection. Visual identification of the disease was assisted by various pictorial images of each of the diseases, and the causal pathogen was identified through microscopic characters of each pathogen (Table 1).

Table 1 shows that various cultivars of banana in the research areas, including Pisang Kepok, suffered various diseases caused by fungal pathogens; the diseases included Cordana Spot disease, Anthracnose disease, Sigatoka disease, Leaf spot disease, *Curvularia* spot disease, and Freckle disease.

Figure 1. Symptoms and signs of bacterial pathogens on Pisang Kepok cultivar in Kupang and TTS Districts. A. in Merbaun Village of Merbaun, Kupang District, B. in Oebobo Village, TTS District, C. in Mio Village, TTS District

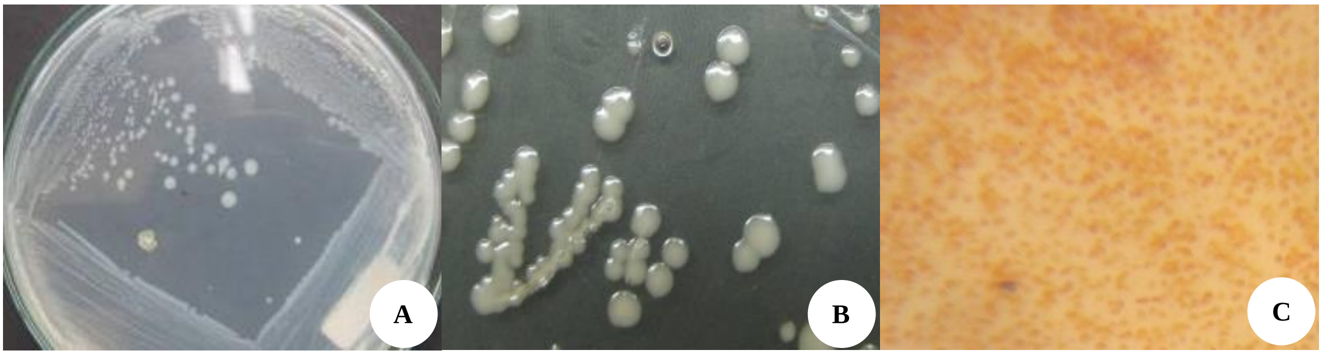


Figure 2. Growth characteristics of bacteria isolated from soil samples on NA Medium: A. Bacterial growth on the petridish, B. Bacterial colony, C, Gram staining

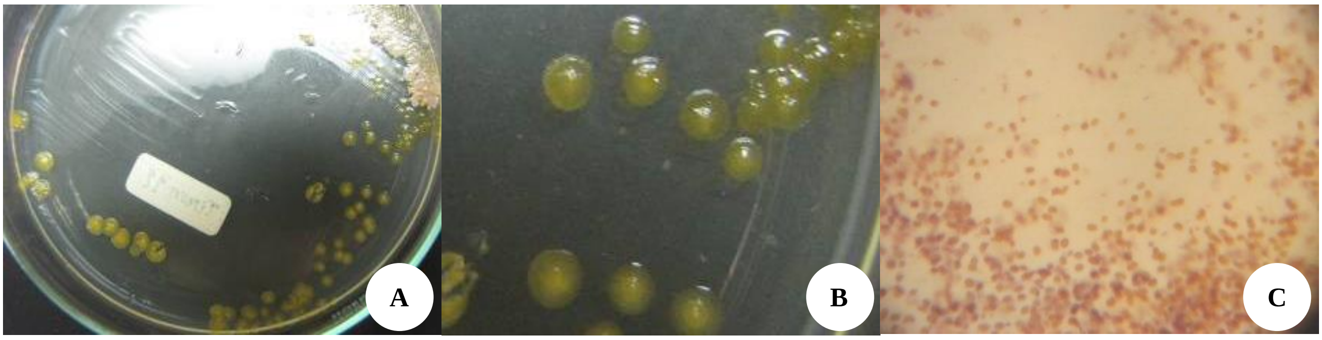
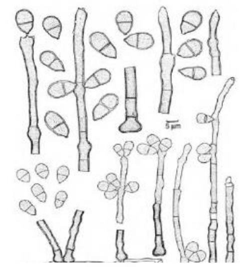
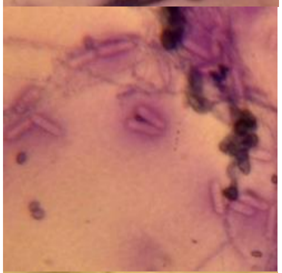
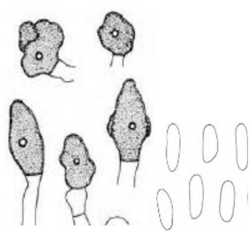
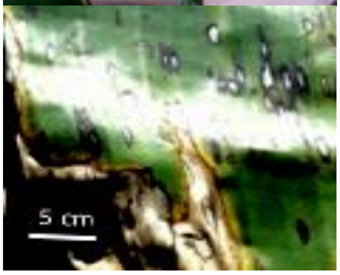
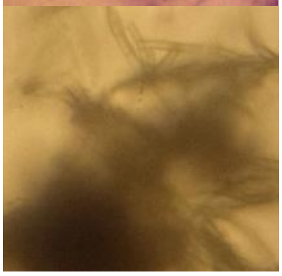
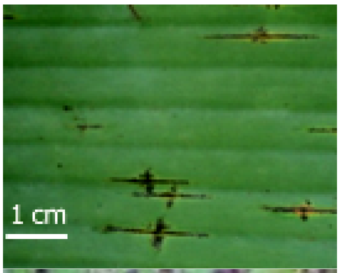
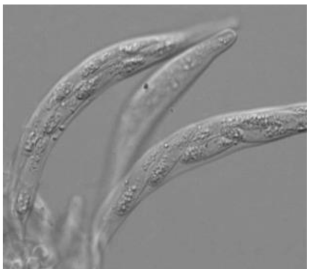
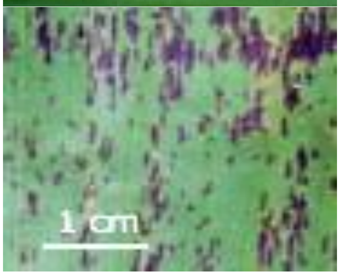
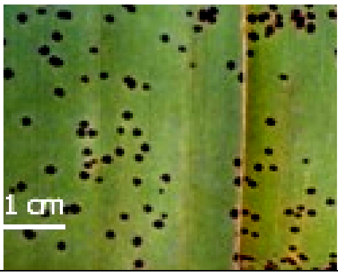


Figure 3. Growth characteristics of bacterial isolates from infected plant samples on NA Medium: A. Bacterial growth on the Petri dish, B. Bacterial colony, C. Gram staining

Table 1. Various symptoms and signs of observed banana diseases, observed and reference microscopic characters of pathogens causing the diseases, and description of microscopic characters of the pathogens. A: Cordana Spot disease (*Cordana musae*), B: Anthracnose disease (*Colletotrichum musae*), C: Sigatoka disease (*Mychosphaerella* sp.), D: Leaf spot-cross bar disease (*Phyllachora musicola*), E: *Curvularia* spot disease (*Curvularia* sp.), F: Freckle disease (*Phyllosticta musarum*)

	Disease symptom	Observed microscopic character of the pathogen	Reference picture for the microscopic character of the pathogen	Description of the microscopic character of the pathogen
A				Cordana Spot disease is caused by *Cordana musae*. *C. musae* has a stick-shaped conidiophore and pyriform conidia. In the middle of the conidia, there is a black septum that divides the conidia into two cells (Ploetz 2003).
B				Anthracnose disease is caused *by Colletotrichum musae*, which has brown appressoria. The appressoria are formed from hyphae, single conidia, hyaline, and elliptical shape (Ploetz 2003).
C				The causal pathogen of Sigatoka disease is *Mychosphaerella* sp., which has a stroma; pale brown, insulated and branched conidiophores; the conidia are sub-hyaline, cylindrical and generally consist of 5 septa (Liberato et al. 2011).
D				Leaf spot-cross bar disease, is caused by *Phyllachora musicola*. *P. musicola* has a clavate-shaped, sharp edge, hyaline and non-insulated ascospores (Liberato 2006).
E				The causal pathogen of *Curvularia* spot disease is *Curvularia* sp. *Curvullaria* sp. has an insulated, oval, and curved or one-sided like curve conidia. The conidia are formed in groups at the end of the conidiophores. One group of conidia usually consists of at least 3 cells (Watanabe 2002).
F				Freckle disease is caused by *Phyllosticta musarum*, which has a group of round to oval conidia shapes (Liberato et al. 2011).

To conclude, there are 21 banana cultivars that have been cultivated by farmers in West Timor, ENT Province, Indonesia. The banana cultivars can be classified into three genomic groups, i.e., ABB, AAB, and AA. Banana cultivars included in ABB group were Pisang Kepok, Pisang Rote, Pisang Singapura, Pisang Amerika, Pisang Pinang, and Pisang Aceh, and those in the AAB genomic group are Pisang Ambon, Pisang Kafendis, Pisang Raja, Pisang Asam, and Pisang Dilli. The AA genomic group consisted of Pisang Susu, Pisang Tembaga, Pisang Tembaga Merah, Pisang Tembaga Putih, Pisang Meja, Pisang Kulit Mentah, Pisang Baranga, Pisang Mas, Pisang Luan, and Pisang Batu. Signs and symptoms of diseases caused by pathogenic bacteria were only found on Pisang Kepok cultivar in Kupang and TTS Districts but the bacteria were not the causal pathogens of Blood Disease or banana *Xanthomonas* wilt; they are most likely secondary bacterial present in the infected banana plant. Banana diseases caused by fungal pathogens included Cordana Spot disease (*Cordana musae*), Anthracnose disease (*Colletotrichum musae*), Sigatoka disease (*Mychosphaerella* sp.), Leaf spot disease (*Phyllachora musicola*), *Curvularia* spot disease (*Curvularia* sp.) and Freckle disease (*Phyllosticta musarum*).

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Water balance analysis of Talau-Loes Watershed, a cross border watershed of Indonesia and East Timor

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Abstract. *Riwu-Kaho M, Mella WII, Mau YS, Riwu-Kaho NPLB, Nur MSM. 2020. Water balance analysis of Talau-Loes Watershed, a cross border watershed of Indonesia and East Timor. Trop Drylands 21: 17-24.* The Talau-Loes watershed is a cross-border watershed in Indonesia and Timor Leste (East Timor) which has traditionally been a natural resource for living, cultivation and conservation areas for communities in several districts of Belu Regency, Indonesia, and several areas in the Timor Leste territory. Water shortages in the land system are thought to play a significant role in the low productivity of agricultural crops. This study aimed to predict water balance in the Talau watershed, and to estimate river discharge in Malibaka Sub-watershed of Talau-Loes watershed. The study results showed that the amount of annual precipitation of 1679 mm was smaller than the total amount of water lost, amounting to 1914.79 mm per year, originating from evapotranspiration (ET) of 1650.91 mm and runoff water of 263.85 mm. Thus, theoretically, there would be an annual deficit of 235.79 mm in the Talau watershed. However, at the peak of the groundwater deficit, it turned out that the Malibaka River in the Malibaka sub-watershed and the Talau watershed had a discharge of 18 mm^3/sec. This gives a clue about the ability of the groundwater level to gradually release its water reservoir as a source of base flow. Soil and water conservation actions that combine integrated systems such as agroforestry systems with mechanical conservation actions are proposed as solutions that need to be studied and developed in the future.

Keywords: Agricultural productivity, river discharge, soil and water conservation, spatial water balance, Talau-Loes watershed

INTRODUCTION

From an Indonesian legal perspective, a watershed is defined as a land area that is an integral part of the river and its tributaries, which functions to accommodate, store and flow water that comes from rainfall into lakes or into the sea naturally, where the boundary in the inland is a topographic divider and the boundary in the sea is the waters that are still affected by land activities (Article 1 of Government Regulation No. 37 concerning Watershed Management). This definition implies that the watershed is a unitary area of the ecosystem, where catchment water flows from the ridge (upstream) to its outlets river (middle and downstream) to the sea. Watershed function in capturing and holding the water integrates various landscape features that function to capture water (Kendall and McDonnel 1998).

Watershed ecosystem services can vary, but in the aspect of agriculture, the carrying capacity of water in a watershed becomes a determinant factor. The balance between water intake and output will determine the amount of water available. This can be drawn through the estimation of watershed water balance which gives an illustration of the balance between the amount of stored water in the soil and the amount of water loss from the ground due to the evapotranspiration process and runoff. Water balance is simply the amount of rainwater that falls into the ground minus evaporation and surface runoff. In other words, the water balance depicts the relationship between the flows of water into the ground in the form of inputs with water output (output) within a certain time period. Output water can be in the form of actual evapotranspiration and surface runoff. Here, the most important variables for calculating water balance are the availability of rainfall data (precipitation) in addition to air temperature, land cover and soil type and condition (soil) in the study area. Therefore, discussing the water balance is inseparable from the components of rainfall, solar radiation, humidity, land cover, soil and rock conditions. Land water balance in watersheds is dynamic and differences can occur between time (dt/ds) depending on the determinants explained by Kendall and McDonnel (1998) such as rainfall, edaphic and biotic factors, especially land cover.

Talau-Loes River Basin is a watershed located on the border of the Republic of Indonesia and East Timor, covering an area of 260,457 ha in which around 28% is located in the Indonesian part (Talau). The upstream part of Talau-Loes watershed is a water conservation area and the downstream part is the mainland and coastal ecotone area, while the middle part is the only transportation and utilization area. The average rainfall of around 1600 mm/year is limited by the high evaporation which reaches 1800 mm/year. The type of Quartz geological formation that rapidly converts surface water to fast flow causes base flow and available water to become very scarce during the dry season, which lasts for 5-6 months in a year.

Traditionally, farming communities in the Talau watershed use water not only for domestic consumption but also for farming. Research by the Undana team (2018) shows that almost 95% of community that lives in Talau watershed are farmers who rely on water supplies from the watershed. Human nature and behavior also determine the success of the watershed farming community. Deforestation is triggered by destructive farming patterns such as slash and burn farming, illegal logging and off-farm, causing small amount of water to be retained on the water table matrix.

Based on the above-mentioned background, the condition of the water balance in the Talau-Loes watershed system, especially in the Talau (Indonesia) section (with Malibaka Sub-watershed) can be as assessed, which is useful to predict the spatial distribution of water, i.e., the area of additions or output from the catchment area. The size of the catchment area is a very important parameter for managing recharge areas as a water supply area for farmers' needs. Through the water balance approach, the area of the Talau watershed can be determined based on surface and subsurface conditions.

The objectives of this study were (i) to predict the Talau watershed water balance, and (ii) to estimate the Malibaka river discharge, Malibaka Sub-watershed of Talau-Loes watershed, as verification of the Talau-Loes watershed situation. The most important aspect of this research is that in Indonesia there are only 3 locations that have cross-border watersheds, namely Kalimantan, Papua and East Nusa Tenggara (ENT). Of these 3 locations, watershed on the border of ENT (Indonesia) and East Timor is the first watershed to be managed together by both countries with an emphasis on aspects of livelihood and food security.

As agriculture and food security are the main sectors in the Talau-Loes watershed, there is a crucial need for information about water carrying/holding capacity (DTA) and water balance in the watershed, which are presently unavailable. Thus, this research was intended to provide such information. Furthermore, this research is actually a synthesis of several scientific disciplines, namely animal nutrition, agriculture, forestry, socio-economic and cultural as well as engineering. Thus, the main contribution of this research to science and technology is an interdisciplinary integration as a precondition for watershed management that is cross-regional, system and discipline.

MATERIALS AND METHODS

Study area and period

This research was carried out in the Talau-Loes watershed with the location of the study focused on the Indonesian territory, in the Malibaka sub-watershed, Maumutin District, Belu Regency (Figure 1). The research was carried out from August to October 2019. The Talau-Loes area (Figure 1) is divided into 3 ecosystem zones, namely upstream, middle and downstream. (i) Upstream watershed is zone limited to the upstream part where > 70% of the land surface generally has a slope of > 8%. (ii) Middle watershed is zone where water flow and limited to the middle section, where approximately 50% of the land surface has a slope <8%. (iii) Downstream watershed is zone in the downstream part, where approximately 70% of the land surface has a slope <8%.

The analysis of the Talau-Loes watershed area shows that 102,029 ha (39.2%) of the Talau-Loes watershed is in the upstream area, 100,162 ha (38.5%) in the middle area and 58,266 ha (22.4%) are in the downstream area. By referring to the proportion of watershed zoning between the two countries, 88% of the upstream area and 93% of the downstream area of Talau-Loes watershed are in the East Timor territory, whereas 56% of the middle region is in the Indonesian territory.

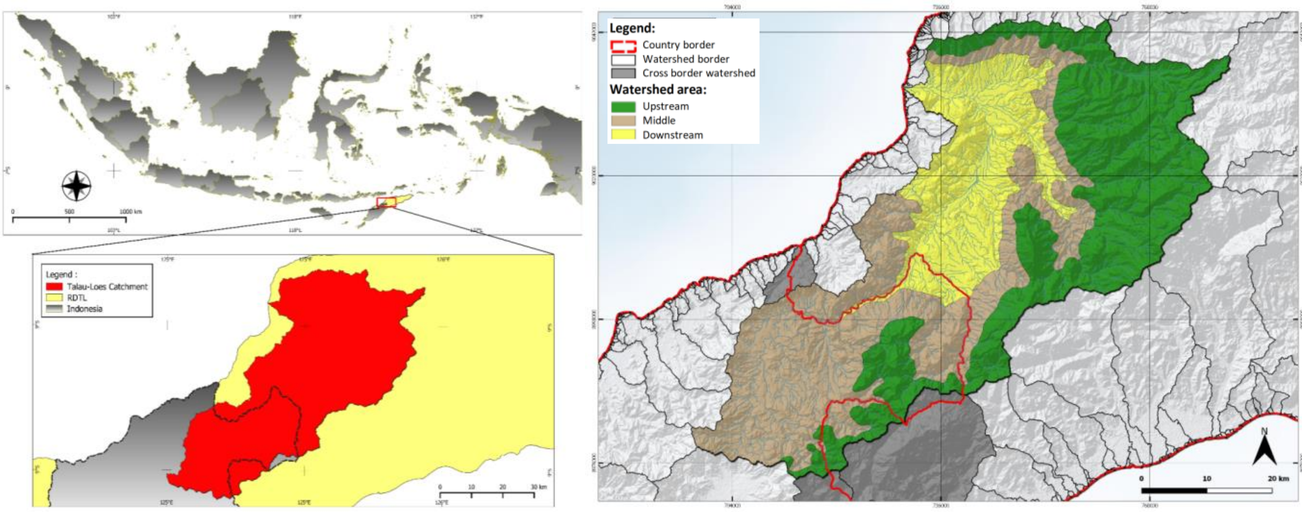

Figure 1. Research site in Talau-Loes Watershed, Timor Island (border between Indonesia and East Timor)

Geological properties in the Talau area consist of rocks such as silt, coral, filit, quartize, skiz, alluvium sand, and sandy beaches with foreign chunks (bobonaro). The previous survey in Atambua revealed that the groundwater level was around 11.2-11.25 m, with percolation of soil ranging from 1.15 x 10-6 to 2.8.10-7 $m^2.day^{-1}$, while water discharge through the aquifer surface was around 5 x 10-6-1 x 10-7 $m^2.day^{-1}$ (Arismunandar and Ruchijat 1995). The soils formed on these rocks are alkaline. This alkaline soil needs to be anticipated in the development of the agricultural sector, because the calcareous layer and clay are dominated by soil types of Entisol, Inceptisol, Vertisol with parent material of sandstone, clay and limestone. The Talau-Loes watershed is generally dominated by areas with elevation of 0-500 meters above sea level with an area of 12,476 ha (48.6%). The analysis shows that the slope class in the Talau-Loes watershed tends to be spread evenly. However, cumulatively, the slope class is rather steep to very steep of 143,850 ha (55%) of the entire Talau-Loes watershed.

Morphologically, the physiographic condition of the upper region of the Loes River are mountains and hills, and the terrain is choppy to bumpy. These physiographic conditions trigger erosion and landslides, causing the release of sediment materials from various places, which are then deposited downstream. There are about 6 types of soil in the Talau watershed with an average depth of up to 90 cm and a topsoil depth of around 20 cm. The soil is dominated by Inceptisol with shallow and moderate topsoils, solum and silt depth. Based on this data and that of Suprayogo (2003), relevant soil types in each sub-watershed with their depth can be estimated.

Referring to the river flow pattern, the Talau-Loes watershed is more inclined to form a dendritic pattern that forms a pattern like tree branches. The shape of the Talau-Loes watershed tends to be elongated, but the outlets in the middle and downstream tend to narrow so that the accumulation of flow tends to be high in the upstream and then slows down in the middle and downstream. At the peak discharge, buttresses are easy to occur, especially if the amount of sediment that causes siltation of the river downstream is taken into account. When the peak discharge occurs, flooding is easy to occur because the water overflows beyond the capacity of the river. Floods start from the meeting point of the river in the downstream area to the extent of flooding areas.

Based on data from Sukabitek climate station, monthly rainfall data from 1973 to 2013 (gap of data is found in 1982) (Figure 2) and East Tasifeto station data from 1989 to 2002, annual rainfall in the Talau watershed (part of Indonesia) varied between 625-1838 mm per year with an average rainfall of 1634 mm per year. Talau has a difference in the conditions of the rainy season and extreme dry season, where about 95% of the rain falls from November to April. Whereas, in the dry season the total monthly rainfall is very low with less than 50 mm per month. The average air temperature ranged between 23-27°C, with an evapotranspiration potential of 1430 mm per year.

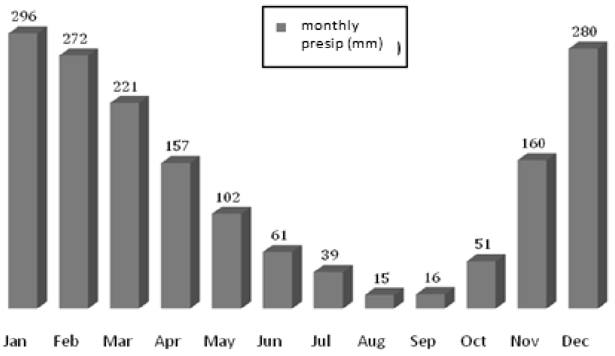

Figure 2. Average monthly rainfall of Talau-Loes watershed (Source: Climatology Station of Sukabitetek 1973-2013)

Methods

The estimated water balance in this study used the Thornthwaite-Mather model. This model was chosen to have several advantages including not requiring a lot of input data, relatively simple calculations and able to provide a complete picture of hydrological potential (Dianitasari and Purnama 2017).

Input data needed are: rainfall, potential evapotranspiration (ETP), soil moisture at the field capacity level (KL) of each soil type, and soil moisture content at the level of permanent withering point (TLP) of each type of soil. The sequence of how to calculate the land water balance in the Talau-Loes watershed is as follows: (i) Temperature is the data of average monthly air temperature in one year, which is calculated from the data of the last 10 years. (ii) Heat Index (I) is the sum of the monthly heat index value (i) calculated using the formula: i = (T / 5) 1.514. (iii) Potential evapotranspiration (ETP) before correction based on the temperature value monthly and heat index values (Mather Table). (iv) Corrected evapotranspiration, i.e., ETP x latitude position (Table Mather). (v) Rainfall, average monthly rainfall count over the past 10 years from stations around the Talau-Loes watershed (Indonesia part) (mm). (vi) Precipitation-ET corrected. (vii) Accumulated Potential Water Loss (APWL), to determine the potential for water loss in the dry month. Method of calculation: Starting from the P-EP value that has a negative value, then was sequentially summed with the next P-EP value up to the last negative P-EP value. (viii) Groundwater Content (ΔS), calculated from the ability of the soil to hold water. The ability of the soil to retain water is obtained based on the results of multiplication between percentages of land use, available water and root zone depth (using Thornwaite-Mather Table 1957). (ix) Δ KAT, calculated as the change in Soil Water Capacity (KAT) from month to month, i.e., reduce this month to the previous month. (x) Actual ET, ETA in the months where CH> ETP was corroded. (xi) Deficits (D), the conditions of the month in which ETP is corrected, ETA is different on deficit months. (xii) The surplus value (S) is obtained based on the formula S = (P-EP)-Δ KAT. (xiii) Surface flow Runoff (RO) is obtained from a surplus of water which is assumed to be 50% and the rest will come out to be runoff the following month.

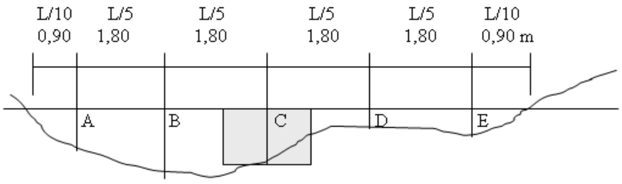

Figure 3. Method for calculating the momentary discharge

This analysis was done by calculating the momentary discharge at the outlet. The simplest method was used in this study. i.e., the calculated discharge was a spring and a river cross-section discharge (Figure 3).

RESULTS AND DISCUSSION

Total annual rainfall

Total annual rainfall in the Talau watershed was 1679 mm with 7 rainy months in a bimodal pattern. Monthly rainfall with intensity of more than 100 mm (Schmidt-Ferguson category) occurred between November and May. Meanwhile, there were five dry months (rainfall <60 mm month^{-1}), which is between May-October.

Total annual potential evaporation

Total annual potential evapotranspiration was 1650.91 mm/year. The largest potential evapotranspiration (ETP) occurred in May at 151.41 mm while the most recent actual evapotranspiration (ETA) occurred in December, at 280 mm when the average temperature reached 27.1°C.

In January-May, the value of rainfall is higher than the potential evapotranspiration and at that time, there was a surplus of water (groundwater supply). The same condition also occurred in November-December. The total annual groundwater supply is 527 mm. Meanwhile, during May-October, there was a deficit of 150 mm of groundwater. Water loss from the cycle also occurs because the flow of water (Q), in this case, runoff, is 263.85 mm/year mm year^{-1}.

Focusing on the description of the water balance in the Talau-Loes watershed in the Indonesian part (Talau), it can be said that in general the hydrological conditions in the Talau watershed are marked by water balance imbalances. Total annual precipitation is 1679 mm while the water depletion component includes 1914.79 mm which includes 1650.91 mm of potential evapotranspiration and runaway water of 263.85 mm.

The water surplus that occurs in the rainy season which increases soil moisture levels will quickly decrease during the 5 consecutive dry months. There are indeed two rainy months at the end of the year but the magnitude of evapotranspiration, both potential and actual, will cause a constrained field capacity that makes it easy for plants to use water.

It should also be noted that the soil in the Talau watershed is dominated by quarts, inceptisol, bobonaro clay, which can easily convert water into gravitational water but on the other hand will hold the water too strong and make it difficult for the roots to absorb water. Affirmed by Lascano (1991, cited by Shebat 2014) that the factors affecting land water balance are mainly climate conditions and soil type conditions. The difference in the value of field capacity and the value of permanent withering points influence the availability of water in the soil (Shebat 2014).

Calculated water balance of Talau-Loes watershed is presented in Table 1 and Figure 4.

Table 1. Calculated water balance of Talau-Loes watershed, Timor Island

No.	Climate elements	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nop	Dec
1	Temp (T) °C	27.3	27.4	27.4	27.8	27.9	27.4	27.2	27.1	27.4	27.4	27.0	27.2
2	Heat Index (I)	13.07	13.14	13.14	13.43	13.5	13.14	12.99	12.29	13.14	13.14	12.85	12.99
3	ETP. non-adjust	4.7	4.8	4.7	4.9	4.9	4.7	4.7	4.7	4.7	4.7	4.6	4.7
4a	correction to ETP	31.5	28.2	31.2	30.3	30.9	30.0	31.2	31.2	30.3	31.2	30.6	31.5
4b	ETP adjust (ETPotential)	148.05	135.36	1466	148.47	151.41	141	146.64	146.64	142.41	146.64	140.76	148.05
5	Rainfall (P)	296	272	221	157	102	61	39	15	16	51	169	280
6	R – ETP adjust	147.95	136.64	7436	8.53	-49.41	-80	-107.64	-131.64	-126.41	-95.64	28.24	131.95
7	APWL (average potential water loss)					-49.41	-129.41	-237.95	-368.69	-495.1	-590.5		
8	Soil moisture storage (ST)	107.7	107.7	107.7	107.7	65	33	12	1	1	1	107.7	107.7
9	? ST	0	0	0	0	-42.7	-32	125.64	11	0	0	106.7	0
10	ETA	148.05	135.36	146.6'	148.47	144.7	93	86.64	120.64	126.41	52	169	280
11	Deficit (D)	0	0	0	0	22.71	48	60	26	16	0	0	0
12	Surplus (S)	1479.5	136.64	7436	8.53	0	0	0	0	0	0	28.24	131.95
13	Run-Off (Ro)	73.98	68.32	3718	4.27	0	0	0	0	0	0	14.12	65.98

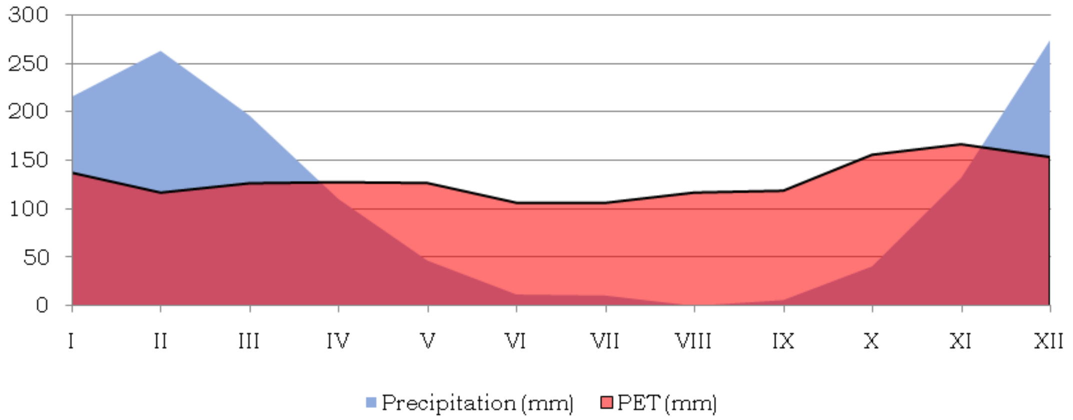

Figure 4. Average water balance of Talau-Loes watershed, Timor Island

River discharge

Measurements are made, firstly, by making a cross-section profile of the river open channel to get the length of the measurement trajectory. The total length of the cross-section of the river is 9 meters and, thus, according to the provisions, the estimated channel length is 27 meters rounded to 30 m. The observations showed that the Malibaka river discharge at the peak of the dry season (October 2019) was 18 mm^3/second (30 mm). Following the formulation of Thornwaite-Mather (1957) that run off when the deficit is 50%, it is estimated that in the rainy season, the discharge will reach 36 mm^3/second. This fact provides confirmation of the water balance data previously calculated in the May-October (dry) period that there was a water deficit of 150 mm/year. The fact that the Malibaka river still has a discharge of 18 mm^3/second gives a hint that even though groundwater depletion occurred during the dry season, the water in the "water table" zone in the Talau watershed is not completely depleted. This may be a theoretical description (Shebat 2014) that the river flow patterns in the Talau watershed can be broken down into three stages, namely (i) the initial phase is the phase of groundwater storage at the beginning of the rainy season, (ii) the second half of the rainy season where some large rainfall flowed into rivers, and (iii) the dry season in which rivers and springs obtain water through a gradual release of water reserves (gradual water release).

In general, groundwater level (water table zone) is water near the surface of the soil or in the vadose zone or soil zone (generally) where the roots uptake and get water (Shebat 2014). Soil area is mostly used for agriculture. Water will be lost due to transpiration, evaporation and percolation which causes water to be released gradually in the dry season. The contribution of water supply originating from the phreatic zone located below the water level zone needs to be observed in subsequent studies. Nevertheless, the facts resulting from the estimation of the water balance and discharge of the Talau watershed provide an indication that there is an opportunity to conserve water and soil in the Talau watershed to increase the carrying capacity of the water table for agricultural productivity. In other words, an agricultural system to be sought is not only water-saving but also at the same time increasing the carrying capacity of water resources.

Forest cover

At present, forest cover in the Talau-Loes watershed reaches 55.406 ha, equal to 21.3% of the total area of the watershed (260.457 ha). According to Indonesian Law No. 41/1999 on Forestry, the minimum requirement of forest cover is 30%, implying that the proportion of forest cover in Talau-Lowes watershed is still far below the minimum requirement. However, if observed carefully for each segment of the watershed area, the forest area in the upstream zone in the East Timor region is still adequate (62.7%). Unfortunately, the forest area in the middle zone of the watershed, mostly in the Republic of Indonesia territory, the forest area is only around 17.2%. When only accounting for Indonesian part, the forest area in the Talau watershed is only around 6-7%. This needs attention as it shows a high vulnerability of the environmental system. Allegedly, the slash-burn agriculture practices became an important part of the deforestation process that occurred.

Hydrological modeling for the Talau watershed has been carried out by the CIFOR team (2007) to support the development of an environmental service system. The study showed that although it can be useful for controlling surface runoff, reforestation in the Talau watershed is thought to have no significant effect on land discharge. Even though the results of this modeling are more likely to be true but there is still a chance that by controlling runoff, hypothetically, infiltration water can be increased. This is a way to increase the water level in the water surface zone which will be transformed for the groundwater level that is beneficial for the agricultural system. This situation is likely to come true considering the present study results on water balance and land discharge which shows a theoretical construction that supports the improvement of water reserves in the Talau watershed.

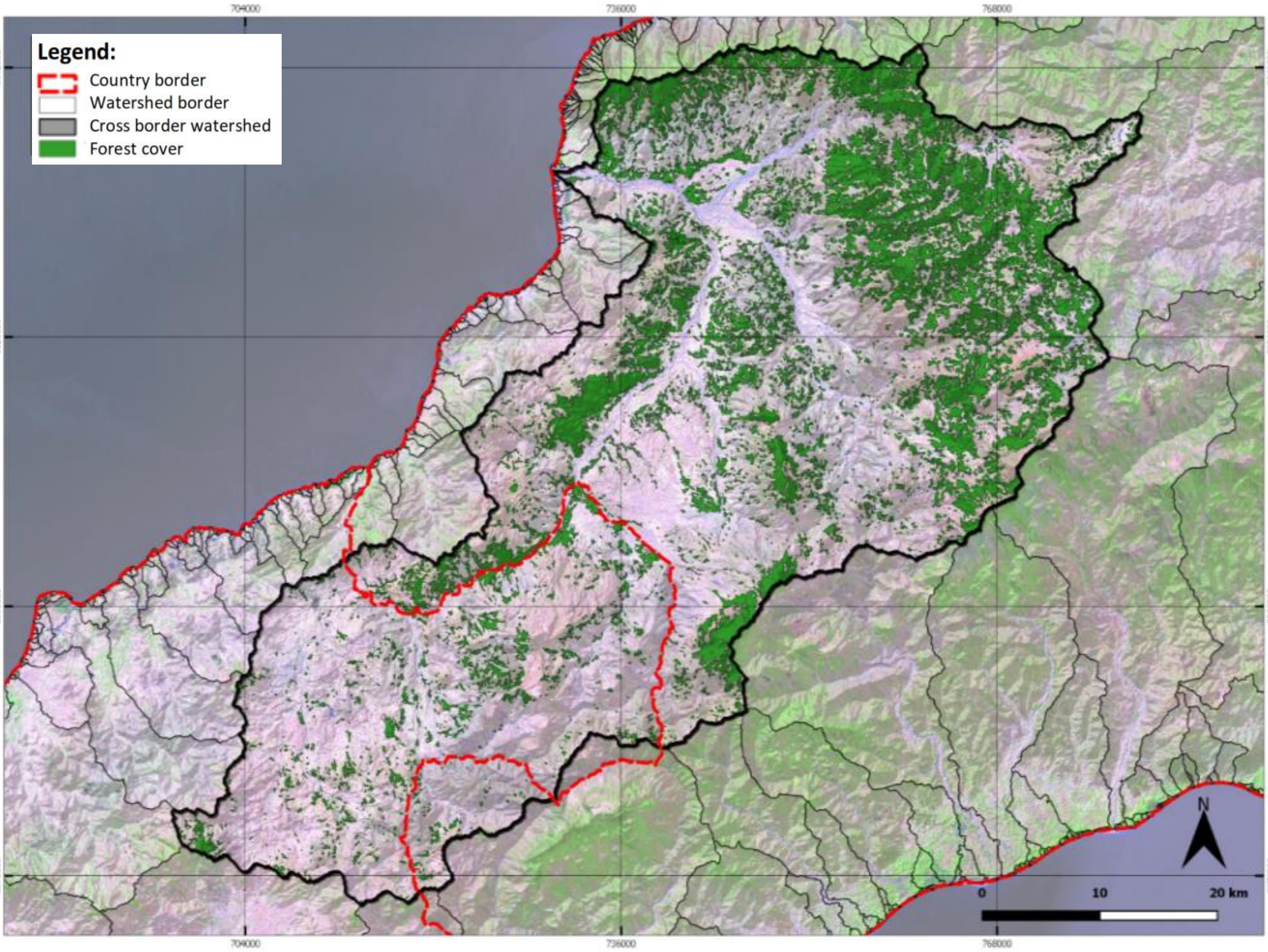

Figure 5. Forest cover of Talau-Loes Watershed, Timor Island (Source: Landsat Imagery 8-OLI, 2017)

There is a need to retain infiltrated water as long as possible in the Talau watershed with challenges to soil types, water zone profiles in the soil, and other ways to improve "water holding capacity". Combining reforestation and other soil and water conservation technologies will be the key answer to the problem of water imbalance in the Talau-Loes watershed. If reforestation is proposed, three things to consider: (i) conversion of unproductive land (grasslands and shrubs) into forests; (ii) conversion of unproductive land (grasslands and shrubs) into agroforestry; and (iii) conversion of unproductive land into agricultural systems with good land management under the rules of soil and water conservation.

The present study concludes the following: (i) The hydrological system in the Talau-Loes watershed is not balanced, where the water entering is smaller than the water coming out of the hydrological system. (ii) Annual rainfall as input is recorded at 1679 mmm but the total water lost is 1914.79 mm per year, originating from evapotranspiration (ET) 1650.91 mm and runoff water of 263.85 mm. Thus, theoretically, there would be an annual deficit of 235.79 mm in the Talau watershed. (iii). Malibaka river discharge, Malibaka sub-watershed, Talau-Loes watershed during the peak of the rainy season (October) was18 mm^3/second which is thought to originate from gradual release of water from the ground table (water table) in the Talau watershed. (iv) The proportion of land covered by tree or forests in the Talau-Loes watershed is only 21.3% which is below the standard value of tree cover area (30%) especially in the middle of the watershed, namely Talau watershed in Indonesia which is only 6-7%. Deforestation due to slash-burning agriculture practices is thought to be a determinant factor.

To be more comprehensively explain the groundwater balance in the Talau-Loes watershed and find solutions to the hydrological imbalance in the watershed, then the following recommendations need to be considered: (i) The groundwater in the Talau-Loes watershed needs to be balanced by combining reforestation to conserve soil and water in the water table. (ii) The relationship between the movement of water between water in the vadose zone and the phreatic zone needs to be further studied.

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Optimization production model and financial feasibility analysis on planning of integrated lontar sugar industry in Rote Ndao, East Nusa Tenggara, Indonesia

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Abstract. *Fahrizal, Jasman, Nggadung Y, Kartiwan. 2020. Optimization production model and financial feasibility analysis on planning of integrated lontar sugar industry in Rote Ndao, East Nusa Tenggara, Indonesia. Trop Drylands 21: 25-30.* In general, lontar (*Borassus flabellifer*) sugar consists of molded sugar and crystal sugar produced from lontar sap. Both types of sugar can be produced together in one business unit, but in fact, most home industries produce them partially. This research aimed to obtain an optimization of production model and financial feasibility of integrated lontar sugar industry. The linear programming optimization method was used to determine the optimal amount of molded and crystal lontar sugar production with the objective function of profit maximization. The model was validated on lontar sugar home industry in Rote Ndao District, East Nusa Tenggara Province, Indonesia. Scenario of price change and interest rates were used to measure the level of sensitivity of financial feasibility. The results showed that a maximum profit of IDR 186,741 was obtained by producing 47.25 kgs of molded sugar and 57.93 kgs of crystal sugar every day. The financial feasibility analysis of IRR, NPV, and BC indicators showed that the project was still feasible when the sugar price fall down by 10%, the price of lontar sap increased by 20%, and interest rates rose to the level of 24%.

Keywords: Financial feasibility, lontar sugar industry, optimization production model

INTRODUCTION

The main objective of industrial activity or business is to obtain the maximum profit by maximizing revenue and minimizing cost (Budiasa et al. 2012; Priyanto 2008; Sukanteri et al. 2013; and Soedjana 2007). The maximum profit can be achieved through product diversification in one integrated business unit. Diversification can be performed in the form of diversifying the types of products produced (horizontal integration) or further processing to produce other products (vertical integration).

In the production process, the final product can be obtained from a number of inputs of raw materials. Jonnson (2008) divides the production process into various groups, including the final product that can be produced from the same source of raw materials. For example, molded sugar and crystal sugar can be produced from the same source of raw material, i.e. lontar sap (*Borassus flabellifer* L.). Molded sugar is brown sugar that is produced from the process of evaporation of lontar sap and then molded in a certain shape using any tools made of lontar leaf while the crystal sugar is produced in the form of small granules like flour. Besides the shapes, the main difference between the two products is production/ processing time, economic value, shelf life, and taste.

Lontar sugar is an agro-industrial product that is produced through the activity of processing the lontar sap through mechanical and chemical processes. Stages of processing carried out depends on the type of sugar produced. The initial stage in the production of both molded sugar and crystal sugar is collecting the sap and then filtering it. This process aims to separate the impurities for example twigs, leaves, and insects from the sap. Further, the evaporation process is carried out by cooking the sap on the stove using firewood until it thickens. After stirring, thick sap is immediately put into a circular mold, and is called molded sugar or *gula lempeng*.

The steps of making crystal sugar are longer than those of molded sugar. When the sap has been thickened, it is then cooled while stirred so that the crystallization occurs. Next, scouring is done to avoid clumping which may reduce the size of the crystal granules. Sieving, a mechanical size separation process (Toledo 2007), is done to produce the desired size of crystal granules. Crystal sugar produced at this stage still has high water content, so it needs to be dried. Drying process may be done naturally in the sun or using an oven. The moisture of crystal sugar is very influential on shelf life. In the drying process, clumping may occur, so it needs to be sieved again. At this stage, crystal sugar produced is separated into two, the first are those pass the sieve that matches the desired size, and the second are those not pass the sieve.

The production of lontar sugar at the level of home industry is carried out partially; meaning that the making of molded sugar and crystal sugar is performed separately. The facts show that business units managed in this way are susceptible to risk of failure, inefficient use of resources, and ultimately reduce the benefits obtained.

Integrated business system is one of the strategies to maximize revenue. Integrated system in lontar sugar production is defined as an effort to produce molded sugar and crystal sugar in one business unit, home industry for example. Limited resources factor is an important reason for the need for an integrated business system. A number of studies have shown that an integrated business system can maximize revenue (Budiasa et al. 2012; Priyanto 2008; Sukanteri et al. 2013; and Gradiz et al. 2007) and minimize risk (Soedjana 2007), also provided added value (Kusumastuti et al. 2015).

The maximum profit in a business can be known by using optimization methods, for example, linear programming optimization. This method is a formal mathematical technique that selects the combination and level of activities of all plausible activities without ignoring the availability of resources and other specified constraints. A number of studies have been using linear programming, for example, Gradiz et al. (2007), in calculating economically integrated production between sugarcane cultivation and livestock. Budiasa et al. (2012); Sukanteri et al. (2013) used a linear programming approach for optimization of integrated farming systems. Abbas and Indriani (2010) used linear programming to optimize the production process of food products.

Mathematically, the problem of linear programming is generally stated as follows (Cohen and Cyert 1976):

Maximize:

$$Z = \sum_{j=1}^{n} c_j x_j \quad (1)$$

Constraints to:

$$\sum_{j=1}^{n} a_{ij} x_j \{\leq = \geq\} b_i ; i = 1, 2, \ldots , \quad (2)$$

$$x_j \geq 0 ; j = 1, 2, \ldots , \quad (3)$$

Where Z in equation (1) is the objective function; x*j* is the activity or decision variable; c*j* is the contribution of activity *j* to the value of the objective function; a*j* is the i-th resource unit used or i-th output unit produced per activity unit of *j*; and *bi* is the level of available resources or minimum requirements for each obstacle. Equations (2) and (3) respectively are a collection of constraints and non-negative conditions that must be met in the optimization process.

Essentially, planning is a process of preparing a set of decisions that are carried out in such a directed and systematic manner that goals can be achieved effectively and efficiently (Fahrizal 2015). In an effort to maximize the economic potential of lontar trees and the revenue of lontar sugar business, it is necessary to set planning of the integrated of molded and crystal lontar sugar home industry, especially in the aspects of production and assessment of financial feasibility of investment, as well as strategies for maximizing benefits.

MATERIALS AND METHODS

Research design

This research refers to problem-solving methods using a system approach. The system approach is an organizational analysis approach using system characteristics as a starting point for analysis. The study was designed to consist of two stages. Stage 1 was the preparation of an optimization model of molded sugar and crystal sugar production. The output data of the optimization model of molded sugar and crystal sugar production were used to perform stage 2, i.e. financial feasibility analysis for the integrated molded and crystal lontar sugar industry.

The flow diagram of developing the sugar production optimization model and financial feasibility is presented in Figure 1.

Data collection

The research was carried out in the lontar sugar home industry, Duadolu Village and Oetutulu Village, Rote Barat Daya District, Rote Ndao District, East Nusa Tenggara Province. Both of these villages are production centers of molded sugar and crystal sugar in Rote Ndao District. Data collection used literature study methods, field observations, interviews, filling out questionnaires and depth interviews with a number of experts who are considered to have knowledge of molded and crystal sugar. The collected data was then analyzed qualitatively and quantitatively.

Data processing and analysis

The stages of compiling the optimization model of integrated molded and crystal sugar production are as follows: developing the objective function, namely revenue maximization, then formulating the constraint function, consisting of constraints of production capacity, number of requests, number of workers, number of fuelwood and integer number constraints. The next step is calculating the amount of molded and crystal sugar production using linear programming method.

The formulation of the optimization model of molded sugar and crystal sugar production is stated as follows:

Maximize:

$$Z = H_{GC}X_1 + H_G \quad (4)$$

Constrains :

$$aX_1 + bX_2 \leq \quad (5)$$

$$cX_1 \leq GC ; dX_2 \leq \quad (6)$$

$$eX_1 \leq GC ; fX_2 \leq \quad (7)$$

$$gX_1 + hX_2 \leq \quad (8)$$

$$X_j \geq 0 ; j = 1,2 \quad (9)$$

Where:

Z = Maximum amount of revenue
HGC = price of molded sugar (IDR kg^{-1})
HGS = price of crystal sugar (IDR kg^{-1})
X1 = molded sugar production (kg day^{-1})
X2 = crystal sugar production (kg day^{-1})
GC = molded sugar could be partially produced (kg)
GS = crystal sugar could be partially produced (kg)

a = yield of molded sugar (%)
b = yield of crystal sugar (%)
NL = amount of lontar sap available (kg)
c = molded sugar demand (%)
d = crystal sugar demand (%)
e = molded sugar workforces
f = crystal sugar workforces
g = firewoods for molded sugar (kg day^{-1})
h = firewoods for crystal sugar (kg day^{-1})
KB = the amount of firewoods available (kg)

Equation (4) is an objective function; equation (5) is a constraint function of production capacity; equation (6) constraint of requests number; equation (7) labor constraints equation (8) firewood constraint; and equation (9) is a constraint of integer numbers or non-negative conditions that must be met in the optimization process.

Data input for optimization model is processed using the application program LINGO 12.0 *Lindo System Inc*. Data analysis was carried out by linear programming. Input data of investment feasibility models were analyzed using indicators of NPV, IRR, and BC ratio eligibility.

RESULTS AND DISCUSSION

Lontar sugar production

Lontar sugar production consists of two main activities, namely tapping and processing the sap (cooking sap into sugar). Marketing sugar is the next activity after production. These three activities are carried out by the home industry producing lontar sugar. Thus the lontar sugar business consisted of on-farm and off-farm activities. Sugar production is driven by the amount of sap collected.

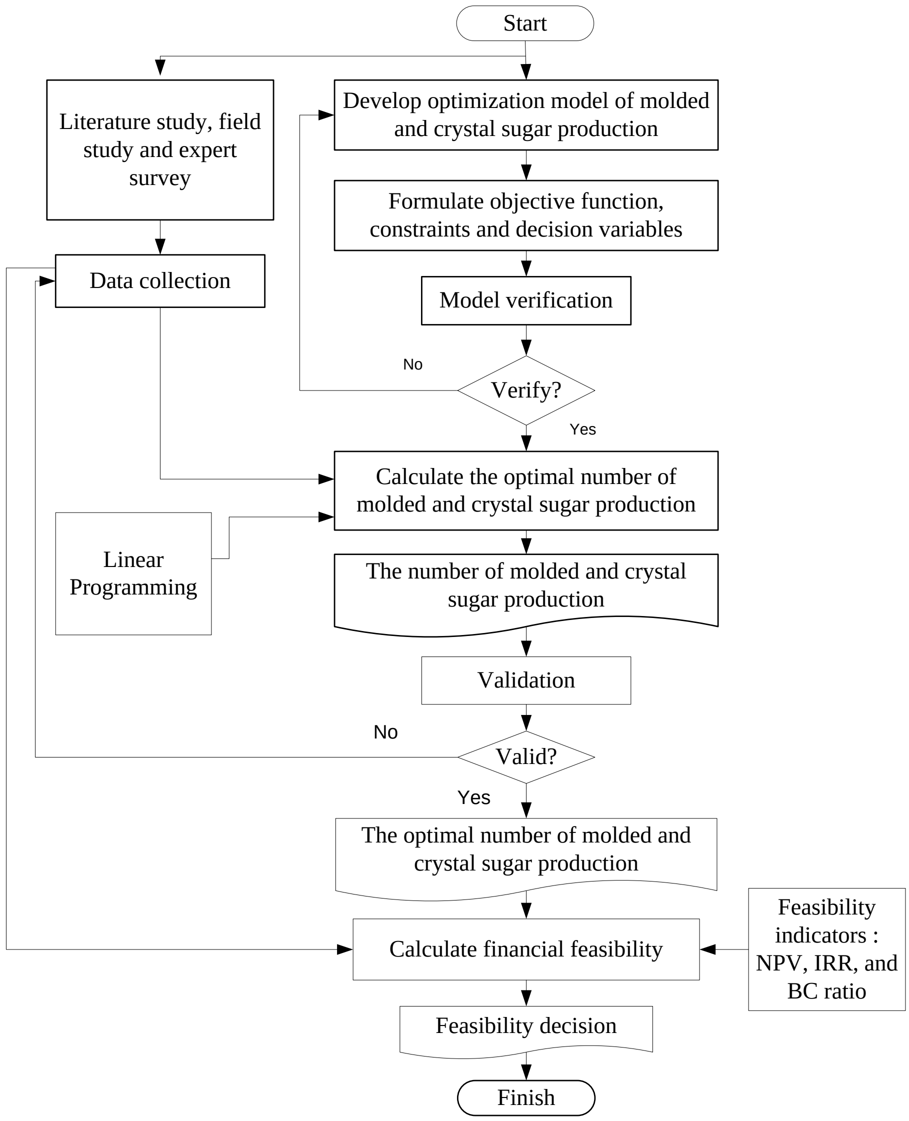

Figure 1. Stages of the research

The amount of sap collected is determined by the number of productive lontar trees, the number of flowers of each lontar tree, and the productivity of the flower. The study showed that the average number of tree ownership was 20, the average number of inflorescence (*mayang*) flowers per tree was 5, and the average productivity of flower was 2.5 liters of sap per day. Thus, the average of sap production was 12.5 liters per day per tree, or 250 liters for 20 trees. The amount of this sap is assumed to be constant during the sugar production season, from April to end of November every year.

Sugar yield is calculated from the ratio of the total sugar weight obtained to the total sap weight cooked. The result of calculation showed that the molded sugar yield was 15% with moisture content of 8.6%, while the crystal sugar yield was 13.8% with a moisture content of 2.68%. The water content of the two sugars are still suitable for the required limits of a maximum of 10% for molded sugar) and 3% for crystal sugar (National Standardization Agency of Indonesia 1995). The sugar production capacity then can be calculated or predicted based on the yield and the total sap obtained (Fahrizal 2015).

The activity of making sugar starts at 04 am. It starts with collecting sap from lontar tree, filtering the sap, and then cooking it into sugar on a stove heated using firewood, usually *kosambi* (*Schleichera oleosa*) wood. Firewood was bought as much as 4 cubic meters every 14 days (assuming 1 cubic is equivalent to 1000 kg). The firewood consumption for the production of molded sugar and crystal sugar is not the same. Based on the interview of farmers, the consumption of firewood is approximately 0.7 cubic for molded sugar and 0.8 cubic for crystal sugar per 3 days. This value then was used to estimate the amount of firewood consumption per day.

There are 3 workforces involved in making molded sugar, i.e. 1 tapper and 2 cookers as well as molding and packaging the sugar. Production of crystal sugar needs 4 workforces, i.e., 1 tapper, 2 cookers and at stage of refinement, it requires 1 workforce. On average each home industry has 5 workforces.

Lontar sugar products are sold at traditional markets every Wednesday and Friday. The sale is made after the activity of making lontar sugar is finished. Molded sugar is sold in units of pieces, while crystal sugar is in units of volume. No sales in weight units. When the units are converted, the price of molded sugar is IDR 15,000 per kg, while the crystal one is IDR 20,000 per kg. The sugar offered is not always sold out. The amount sold out fluctuated, depending on the demands. In general, the demand for molded sugar is higher than that of crystal one. Historical data on the exact number of requests is not available, therefore, a judgment approach is used by the home industry namely 90% for molded sugar and 80% for crystal sugar.

Production optimization of molded sugar and crystal sugar

Determination of the optimal amount of molded sugar and crystal sugar production was carried out in an integrated manner using the single objective optimization approach with the objective function of maximizing profits. There are two decision variables used, namely the amount of molded sugar and crystal sugar production. The formulation of constraint functions in the optimization model was developed based on the results of interviews with lontar sugar industry players and supported by direct observations in the field.

Linear programming optimization method was used to determine the optimal amount of molded and crystal sugar production. According to Taha (2003), linear programming is a mathematical method in allocating limited resources to achieve a goal such as maximizing profits and minimizing costs. The results of optimization showed that maximum profit possibly obtained was IDR 186,741,- per day. This value can be achieved by producing 47.25 kg of molded sugar and 57.93 kg of crystal sugar per day.

Analysis of financial feasibility

The financial feasibility analysis was carried out on the planning of the integrated molded sugar and crystal sugar industry of home industry scale in Rote Ndao District, ENT Province. The establishment or exploitation of the lontar sugar industry can be done by Village-Owned Enterprises (BUMDES), Regional-Owned Enterprises (BUMD), or private companies. The management model of the lontar sugar industry is a partnership system, which includes buying sap from farmers or tappers, then processing it into molded sugar and crystal sugar. The estimated investment cost is IDR 350,000,000. This fee is intended for the purchase of land, buildings, machinery and equipment, vehicles, and supporting facilities. Capital is obtained from bank loans as much as 60% of the total capital with a 10-year payback period with an interest rate of 12% per year. The remaining 40% is their own capital. Prices and costs of calculating financial feasibility are those that are applied at the time of calculation. In this analysis, product demand was stable, products were sold out at the end of each year, and throughout the life of the project. The assumptions used in the calculation of the financial feasibility analysis are presented in Table 1.

Table 1. Assumptions used in the calculation of the financial feasibility analysis

Description	Value
Investment (IDR)	350,000,000
Operational cost (IDR year^{-1})	362,135,000
Fixed cost (IDR year^{-1})	332,135,000
Variable cost (IDR year^{-1})	30,000,000
Revenue (IDR for 10-years)	5,773,462,500
Interest rate (% pa)	12
Length of investment (years)	10
Number of production days	8 months (± 245 days)
Molded sugar yield (%)	15
Crystal sugar yield (%)	13,8
Price of molded sugar (IDR kg^{-1})	15.000
Price of crystal sugar (IDR kg^{-1})	20.000
Price of lontar sap (IDR liter^{-1})	1.050

Table 2. Results of financial feasibility sensitivity analysis using scenarios

Scenario criteria	NPV	BC ratio	IRR (%)	PBP (years)	Conclusion
The price of molded sugar and crystal sugar fall as much as 10%	244,625,986	1.10	13.60	2.11	Feasible
Increase of interest rate as much as 24%	181,793,784	1.09	12.01	1.63	Feasible
Increase of price of lontar sap as much as 20%	190,925,898	1.06	10.43	2.46	Feasible
Increase of price of lontar sap as much as 30%	-15.005.407	1.00	0.89	-	Not feasible

The results of financial analysis found that at a discount rate of 12% the NPV value was IDR 561,265,811. A positive NPV means that the integrated lontar sugar industry is feasible. IRR value of 28.46% means that the project is feasible because it is greater than the specified bank interest rate which is 12%. BC ratio value was 1.21. This value is greater than 1, meaning that the integrated lontar sugar industry is feasible. The sensitivity analysis was then performed using a scenario by reducing sugar prices by 10%, raising interest rates by 24%, and raising lontar sap prices by up to 30%. The results of the sensitivity analysis are presented in Table 2. The results of the sensitivity analysis of the three components indicated that the business is no longer feasible if the price of lontar sap rises to 30% from the stipulated base price of IDR 1,050 per liter.

Discussion

Production of molded sugar and crystal sugar can be done together because the raw material is the same and the production process is not much different. The stages of crystal sugar production process are more numerous, because, after the evaporation process, it is continued with the process of cooling, crystallization, size reduction, sieving, and drying. Meanwhile, molded sugar was shaped immediately after the evaporation process. Production equipment was also not much different. The making of crystal sugar used more equipment because the production process stages are also more numerous. A number of production equipment can be used together, such as kitchens, filtering, and evaporation equipment. Thus, it can reduce investment costs. The skills to make molded sugar and crystal sugar are almost the same, so that home industry can make them. This is the main reason for these two products can be made together in one business unit.

Production of lontar sugar takes place twice a day, i.e. morning and afternoon. Based on optimization of production model, to get maximum profit, the manufacture of molded sugar and crystal sugar can be done together at one time or partially. The number of productions was 47.25% for molded sugar and 57.93% for crystal sugar respectively. The percentage of production will be obtained by separating thick sap into two parts after evaporation process. One part is for crystal sugar and another for molded sugar. Production of lontar sugar can also be carried out alternately, such as crystal sugar in the morning and molded sugar in the afternoon. The second alternative is more difficult to implement because the amount of sap is relatively the same.

Optimization of sugar production used a linear programming approach. The model was validated in the planning of lontar sugar home scale industry in Rote Ndao District, East Nusa Tenggara Province. Based on the optimization result, maximum profit of IDR 186,741 per day was obtained. This value is highly dependent on the variable productivity of sap, sap price, yield of lontar sugar, price of sugar, availability of firewood, and demand.

The maximum profit value was obtained from the optimization result, becomes a reference for analyzing financial feasibility, using indicators of Net present value (NPV), Internal rate of return (IRR), and Benefit-cost and ratio (BC Ratio). The results of the feasibility analysis found that the integrated lontar sugar industry is feasible to be implemented. In the feasibility analysis, the most influential factor is the price of sap. In this model, the price of sap is determined by the supplier farmer and value is constant. In reality, this value can change. Changes in sap price will have impact on the feasibility of establishing an integrated lontar sugar industry. Therefore, the recommendation of the research is to develop a model for determining the price of lontar sap. Fluctuation of lontar sap price will be inputted in determining the selling price of sugar, as well as an evaluation of the feasibility indicators.

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