# TROPICAL Drylands

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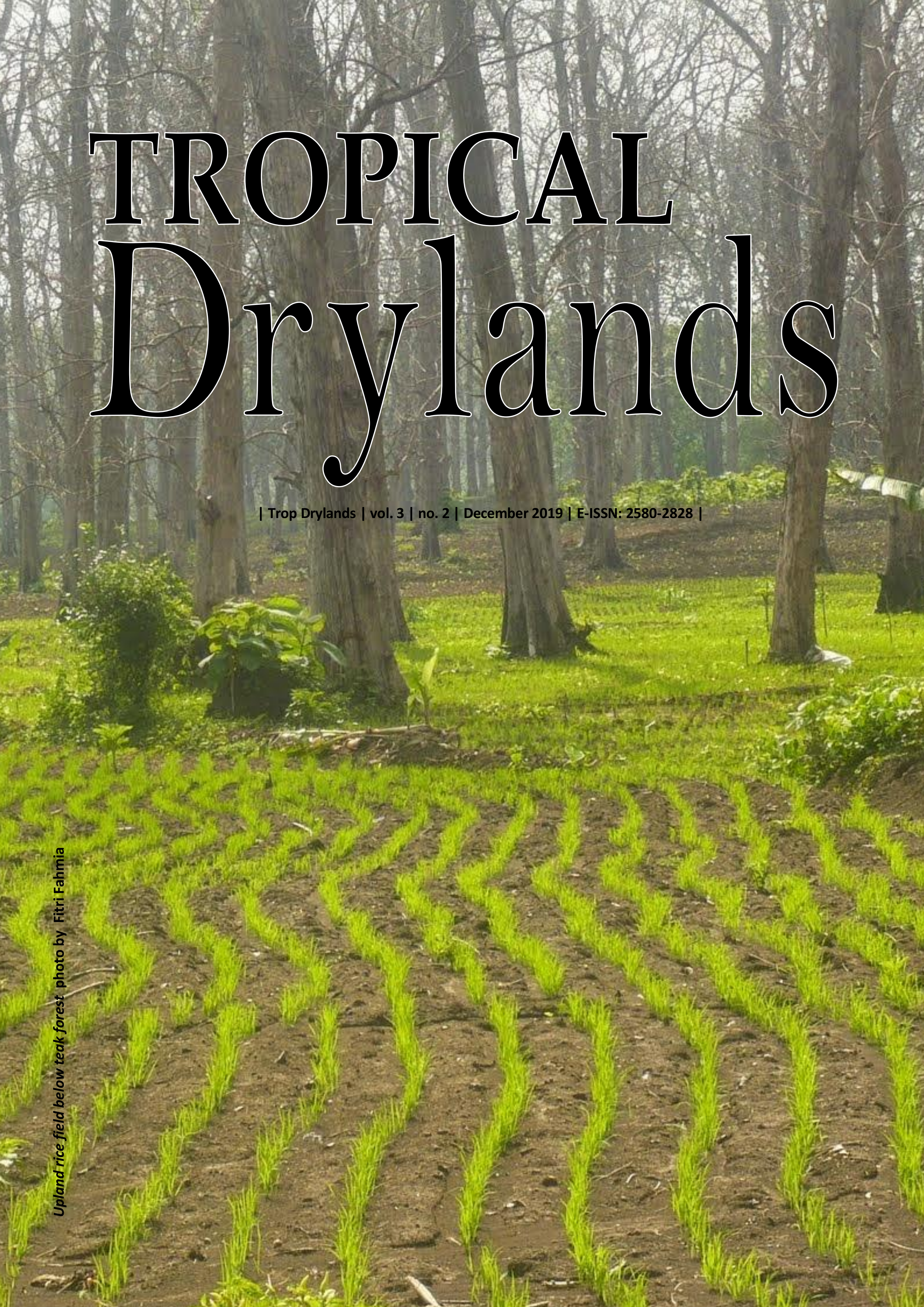

*Upland rice field below teak forest* photo by Fitri Fahmia

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**TROPICAL DRYLANDS**
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# Proximate composition and aroma quality of five aromatic upland-rice accessions from Sumba Barat Daya District, East Nusa Tenggara Province, Indonesia

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Manuscript received: 5 September 2019. Revision accepted: 16 October 2019.

**Abstract.** *Arsa IGBA, Lalel HJD, Pollo R. 2019. Proximate composition and aroma quality of five aromatic upland-rice accessions from Sumba Barat Daya District, East Nusa Tenggara Province, Indonesia. Trop Drylands 3: 35-40.* Dryland agriculture system has the potentials to produce aromatic rice despite the low productivity. Dryland regions, such as in Sumba Island, Indonesia have genetic resources of aromatic rice lines, although the information regarding such lines is less explored. This research aimed to know the proximate composition and aroma quality of five aromatic upland-rice accessions from Sumba Barat Daya District, East Nusa Tenggara Province, and their correlation with the physical and chemical properties of the soil taken from the planting area of each accession. The five accessions studied were ACC-04, ACC-05, ACC-06, ACC-08, and ACC-09. Proximate composition analysis of each aromatic upland-rice accession was carried out by method recommended by AOAC (1970) to determine the water content, ash, fat, protein, carbohydrate, starch, amylose, and amylopectin contents of the rice. The rice aroma score was determined by a sensory test. Analysis of physical and chemical characters of soil was done on a composited soil taken from planting area of each aromatic upland-rice accession at the time of harvest. The results showed that ACC-04 had the highest ash content, AC-09 had the highest fat content and protein contents, and ACC-06 showed the highest carbohydrate content. Furthermore, the best aroma quality of rice-based on aroma score and 2-AP content was shown by, respectively, ACC-06 and ACC-05. There was no significant correlation between proximate composition and aroma quality with any component of environmental factors, thus, they were more likely to be determined by genetic factors.

**Keywords:** 2-AP content, accessions, aromatic, proximate, upland rice

## INTRODUCTION

Development of food crops in East Nusa Tenggara (ENT) Province, Indonesia is mainly based on dryland farming system, which relies mainly on rainfall as the main water source. The potential dryland area in ENT is quite extensive but most of the areas have not been cultivated. Besides corn, rice is the second most cultivated crop in this dryland region. The total cultivated area of upland rice in ENT is less than 80,000 ha, or still far below the potential dryland area in the province. Sumba Barat Daya (SBD) District is one of the upland rice production centers in ENT Province. The harvested area of upland rice in the district during 2002-2006 period ranged from 8,955 - 13,464 ha with total production of 17,870 - 26,39 tons or average productivity of 1.855 - 1.996 t ha$^{-1}$ (Dinas Pertanian TPH NTT 2006).

The upland rice planting areas in SBD District are spread in several sub-districts, with the most extensive production centers are North Kodi and West Wewewa sub-districts. The interest of farmers to grow upland rice is driven by the availability of extensive dryland areas and high market demand for local upland rice from this district. The most popular local variety for the local people of SBD District and also the people of ENT, in general, is the aromatic rice variety, known as the Pare Wangi.

Efforts for extensive development of this rice variety are still facing many obstacles. One of them is unoptimal expression of the superiority of its fragrant aroma and fluffiness, and the quality of the rice when it is planted outside its specific location area. In an optimum growing location, the productivity of Pare Wangi variety can reach 3.0 t ha$^{-1}$ but its yield in North Kodi sub-district only reached less than 2.0 t ha$^{-1}$. Although the productivity in Kodi sub-district is just a moderate level, the aroma quality and taste of the rice from this sub-district is quite high. On the other hand, the aroma and taste of upland rice harvested outside North Kodi sub-district are not as good as upland rice harvested from Kodi sub-district (Arsa et al. 2016).

Aroma quality of aromatic upland rice may be related to genetic and environmental factors, and interactions of these two factors. Non-aromatic upland rice varieties planted near coastal areas produced no fragrant scent. Similarly, aromatic upland rice varieties also show changes in the quality and taste of rice when planted in other locations far from coastal areas. This indicated that edaphic factors are determinant factors for the expression of aroma quality of upland rice varieties. This is in line with Champagne (2008), which stated that fertilization or addition of nutrients to the soil is one of the environmental factors that determine the quality of rice aroma. Jin-xia et al. (2009) reported that the strongest fragrance was obtained in the treatment of $ZnCl_2$ at a dose of 80 - 120 mg kg$^{-1}$ of soil.

Jiang et al. (2007) reported that Zn content affected the protein content of rice, and the protein content of rice has a negative correlation with aroma (Champagne 2008). The main compound that has been widely reported contributing to the quality of fragrant scents is 2-acetyl-1-pyrroline (2-AP) (Buttery et al. 1982; Jezussek et al. 2002). In the case of the plant facing drought stress, and metabolic processes of the plant is disturbed, volatile flavor compounds will be formed, including 2-AP compounds (Champagne 2008). Thus, the drought factor can trigger an increase in aroma, but the yield of the plant may decrease. Differences in genetic factors are likely to differently affect the quality of rice aroma and rice nutrient content in a condition of drought stress or other stresses related to soil conditions, both physical and chemical properties of the soil.

The opportunity for obtaining fragrant upland rice varieties with good aroma quality and nutrient content is supported by the evaluation of several upland rice accessions collected from several regions in Sumba Barat Daya (SBD) District. Of the 10 upland rice accessions evaluated for the quality of their aroma, five local upland rice accessions showed quite a strong fragrance, namely ACC-04, ACC-05, ACC-06, ACC-08, and ACC-09 (Arsa et al. 2018). In addition to their aroma quality, the proximate composition of these rice accessions needs also to be determined. Since the five accessions were collected from various regions with different growing conditions in Sumba Barat Daya (SBD) District, it is also necessary to understand the relationships between the growing environmental factors and the aroma quality and proximate content of these rice accessions.

This study aimed to determine the proximate composition and aroma quality of five accessions of aromatic upland rice collected from several regions in Sumba Barat Daya (SBD) District, East Nusa Tenggara Province and their relationships with environmental factors.

## MATERIALS AND METHODS

### Research location and materials

The research materials used in this study, i.e. upland rice grains and soil samples, were collected in Sumba Barat Daya (SBD) District, East Nusa Tenggara Province. Analysis of soil properties was carried out in Soil Laboratory of Faculty of Agriculture, and analysis of grain proximate and aroma score of rice was carried out in Biosains Laboratory, Universitas Nusa Cendana. Grains of five accessions of aromatic upland rice were used in this study, i.e., ACC-04300518, ACC-05300518, ACC-06300518, ACC-08300518, and ACC-09310518. From here forward, these five rice accessions were coded as, respectively, ACC-04, ACC-05, ACC-06, ACC-08, and ACC-09. The first four accessions were collected in farmer's upland rice fields in Kodi Balaghar Sub-District (i.e. ACC-04 and ACC-05 were collected in Waiha Village, ACC-06 was from Panenggo Ede Village and ACC-08 was from Kahale Village), while the ACC-09 was collected from farmer's field in the Kendu Wela Village, North Kodi sub-district. The sampling of grains (whole, sun-dried grain) of all accessions was taken in May 2018.

A composite soil sampling was also carried out by digging and collecting soil from rice field of each aromatic upland rice accession. These soil samples were analyzed for its physical properties (soil moisture content and soil texture) and chemical properties (organic carbon content (C-org), nitrogen (N), phosphorus (P), potassium (K), sodium (Na), and zinc (Zn)).

### Proximate, starch, amylose and amylopectin analysis

The proximate content was determined based on the method recommended by AOAC (1970), including water content, ash/minerals, fat, protein, and carbohydrate contents. Water content (%) was measured by an oven method, ash/mineral content (%) was measured by a gravimetric method and ignition in the furnace, fat content was measured by Soxhlet Extraction method, crude protein content (%) was measured by Micro-Kjeldahl method, and total carbohydrate (%) was measured by the Difference Method. These methods were also used in previous studies by Arsa et al. (2016) and Murningsih et al. (2019). The nutrient content of rice measured was starch, amylose, and amylopectin levels.

Starch measurement was carried out by using the AOAC method (1970). The working principle used was extracting the perchloric acid and added with anthrone, then was heated at a temperature of 100 °C for 12 minutes, and cooled. After cooling down, the absorbance was measured at 607 nm and compared to the standard.

Amylose was measured using the IRRI method (Juliano 1971). The method used a 95% ethanol reagent and NaOH 1 N. 100 mg of flour was put into a test tube and then added with the two reagents, 1 mL and 9 mL, respectively. The mixture was heated in boiling water for about 10 minutes until a gel was formed, and the gel was transferred into a 100 mL measuring flask, then was shaken and added with water until the anchovy marks. 5 mL of the solution was pipetted and put into a 100 mL measuring flask. Then, the pipetted solution was added with 1 mL of 1 N acetic acid and 2 mL of iodine solution, and was added with water until the tarpaulin was shaken, and left for 20 minutes.

Furthermore, the intensity of the color formed was measured with a spectrophotometer at a wavelength of 625 nm. Amylose content in the sample was calculated using the standard amylose curve. After amylose content was measured, the amylopectin level could be determined by deducting the amylose content from the starch content.

### Quality of rice aroma (organoleptic test)

The sensory or olfactory organoleptic test was carried out by five trained panelists to assess the aroma and taste of the rice. Five grams of each rice sample was put in a test tube and then added with 15 ml of water and covered with aluminum foil. The test tube was shaken for 10 minutes and then cooked for another 15 minutes. The cooked rice samples were transferred to a petri dish and put in the refrigerator for 20 minutes. The cooled rice was then smelled and chewed by the trained panelist. The score used had an interval of 0 - 4 resembling the aroma criteria, i.e.,

<0.5 = not flavorful, 0.5 - <1.5 = weak flavorful, 1.5 - <2.5 = moderate flavorful, 2.5- <3.5 = flavorful, and a bit strong aroma, and ≥ 3.5 = strong flavorful.

**Data analysis**

Data from the measurement of grain samples in the laboratory were descriptively analyzed. A simple correlation analysis was carried out to know the relationship between the aroma quality and the other rice quality traits with physical and chemical properties of the soil taken from the areas where the rice accessions were grown. The correlation coefficient was calculated using the following formula:

$$r_{xy} = \frac{Cov_{x,y}}{\sqrt{(\sigma^2 x . \sigma^2 y)}}$$

Note:

| | | |
|---|---|---|
| $r_{xy}$ | = | Simple correlation of x and y |
| $Cov_{x,y}$ | = | Covariance of x dan y |
| $\sigma^2 x$ | = | Variety x |

## RESULTS AND DISCUSSIONS

**Soil physical and chemical properties**

Analysis results of soil physical and chemical properties are presented in Table 1. Textures of soil from aromatic upland rice fields of ACC-04, ACC-05, and ACC-08 were loam sandy while that of rice field of ACC-06 was sandy loam, and ACC-09 was sandy clay loam. Soil texture and rainfall conditions of the rice accession's planting locations were almost similar as they are located close to each other in the same sub-district, thus, the soil water content at harvest time was not much different among the planting locations of rice accessions ACC-04, ACC- 05, ACC-06, and ACC-08. Soil texture of the planting location of AAC-09 with a higher loam content contained higher soil moisture (28.40%) as compared to those of the other four accessions' planting locations.

Organic-C content of soil taken from the rice planting locations (Table 1) are in accordance with the finding of Rosmarkam and Yuwono (2002). The planting location of aromatic upland rice had high organic-C content (ACC-04, ACC-05, and ACC-09), and a very high C-organic content for ACC-06 (4.81%) and ACC-08 (6.48%) planting areas. Furthermore, the total N content of the soil was classified as low for ACC-04 (0.14%) and ACC-05 (0.14%) planting locations, and was moderate for ACC-06 (0.22%), ACC-08 (0.32%) and ACC-09 (0.29%) planting locations. Soil K and P contents of all planting locations were classified low, and Na and Zn contents in all planting locations were relatively moderate (Table 1).

Table 1 also shows a significant difference in the physical properties of soil, both in soil water content and soil texture indicated by the planting location of the aromatic upland rice accession ACC-09 as compared to those of other rice accessions. The difference in soil chemical properties was seen in total N content of the soil, where the total N content of soil of ACC-04 and ACC-05 planting locations was classified as low while that of ACC-06, ACC-08, and ACC-09 planting locations was of moderate level. Soil Na content at ACC-06 and ACC-08 planting locations tended to be higher than planting locations of other accessions, while other nutrient levels were relatively similar between planting locations of each aromatic upland rice accession.

**Proximate composition starch, amylose, and amylopectin contents**

The proximate composition analysis of five aromatic upland rice accessions from SBD is presented in Table 2. The highest moisture content was shown in ACC-09, and the lowest was in ACC-06. The differences in moisture content of rice were more likely occurred due to differences in the way farmers carried out the sun-drying of the grains. These differences may include the drying time or the intensity of sunlight during the grain drying. High water content is not good for grain storage because it triggers fungal growth (Murningsih et al. 2019). The highest ash content of aromatic upland rice accessions was shown by ACC-04 (3.66%), and the lowest was found in ACC-09 (0.34%). It can be said that ACC-04 is the best source of minerals among all observed rice accessions. This is in line with the opinion of Murningsih et al. (2019) that the level of ash content reflects the amount of total mineral content. Although ACC-09 has the lowest ash content, its fat and protein levels were the highest, 1.18% and 9.20%, respectively. This high fat and protein content indicates that ACC-09 rice is a nutrition-rich staple food. Fat is the highest energy source, while protein plays an important role in tissue growth, maintenance, and the replacement of dead cells (Murningsih et al. 2019). The highest nutritional value of rice is carbohydrates. Accession with the highest carbohydrate level was shown by ACC-06, followed by ACC-05, ACC-09, ACC-08, and ACC-04, respectively (Table 2).

Variations in ash, fat, protein and carbohydrate contents of rice accessions as described above are influenced by growing environmental factors. A study by Wang and Frei (2011) explained that drought stress (including salinity) generally could reduce seed mineral content. Drought stress was reported to reduce the content of Fe, Zn and Cu in corn yields but did increase Ca, Mg, Cu and Zn concentrations compared to control plants. The inconsistency of the relationship between soil water content (Table 1) and the ash content of rice (Table 2) was likely influenced by the interactions with soil nutrient status in the level of mineral absorption by plant roots. The same opinion was expressed by Wang and Frei (2011).

**Table 1.** Physical and chemical characteristics of soils taken from planting locations of all collected aromatic upland rice accessions

| Accession | Soil physical and chemical properties | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Texture | SWC (%)+ | Organic-C (%) | Total-N (%) | K (me/ 100 g | P (ppm) | Na (me/ 100 g) | Zn (ppm) |
| ACC-04 | Loam sandy | 8.0 | 3.2 | 0.1 | 0.8 | 50.8 | 0.7 | 52.4 |
| ACC-05 | Loam sandy | 7.6 | 3.2 | 0.1 | 0.8 | 51.,8 | 0.7 | 53.4 |
| ACC-06 | Sandy loam | 7.6 | 4.8 | 0.2 | 0.8 | 50.4 | 1.0 | 52.3 |
| ACC-08 | Loam sandy | 8.8 | 6.5 | 0.3 | 0.9 | 49.4 | 1.4 | 51.6 |
| ACC-09 | Sandy clay loam | 23.2 | 3.2 | 0.3 | 1.0 | 60.0 | 0.7 | 61.7 |

Note: +: Soil Water Content at harvesting stage of the rice

**Table 2.** Proximate composition of five aromatic upland rice accessions from Sumba Barat Daya, East Nusa Tenggara, Indonesia

| Rice accessions | Water content (%) | Ash (%) | Fat (%) | Protein (%) | Carbohydrate (%) |
|---|---|---|---|---|---|
| ACC-04 | 12.8±0.12 | 3.7±0.40 | 1.1±0.54 | 7.8±0.14 | 74.7±6.65 |
| ACC-05 | 12.7±0.28 | 0.4±0.08 | 0.4±0.12 | 5.8±0.42 | 80.6±1.98 |
| ACC-06 | 11.0±0.72 | 0.7±0.21 | 0.6±0.24 | 5.9±0.28 | 81.8±0.99 |
| ACC-08 | 12.7±0.38 | 1.1±0.07 | 1.2±0.17 | 5.6±0.28 | 79.4±0.99 |
| ACC-09 | 13.3±0.74 | 0.3±0.07 | 1.2±0.31 | 9.2±0.57 | 76.0±2.83 |

Note: Data were means±standard deviation of 2 replications

**Table 3.** Starch, amylose and amylopectin levels of local upland rice accession in Sumba Barat Daya, East Nusa Tenggara, Indonesia

| Accessions | Starch (%) | Amylose (%) | Amylopectin (%) |
|---|---|---|---|
| ACC-04 | 74.2±3.11 | 23.9±3.39 | 50.3±2.12 |
| ACC-05 | 72.9±6.22 | 24.4±2.40 | 48.5±1.98 |
| ACC-06 | 77.1±4.38 | 22.5±1.27 | 54.6±1.13 |
| ACC-08 | 74.3±3.25 | 27.2±2.83 | 47.1±0.85 |
| ACC-09 | 75.1±2.12 | 23.2±3.39 | 51.9±2.55 |

Note: Data were meant ± standard deviation of 2 replications

The soil water level as an indicator of the drought stress is also reported to affect the nutrient levels in seed yields, such as: fat, protein, and carbohydrates (Wang and Frei 2011). The drought is generally reported to induce an increase in total protein concentration in plant seed organs. The length of drought stress is explained as an important factor that determines the effect of drought stress on protein concentration in plant yields. The concentration of fat and starch produced by plants was reported to decrease due to drought stress, but inconsistencies were found in sugar concentration. In line with these results, Pandey et al. (2014) reported that amylose levels would also decrease due to drought stress. This was also found in a study by Arsa (2016), which showed that a decrease in soil water content caused a decrease in upland rice amylose content of Pare Wangi variety.

In this study, the relationship between soil water content did not show a consistent effect on fat and carbohydrate levels (Table 1), but there was a tendency of soil water content to influence the rice protein levels enhancement (Table 2). Soil moisture content also did not show a consistent effect on starch, amylose, and amylopectin levels (Table 3). The effect of soil water content on the nutritional value of rice, fat, carbohydrate, protein, starch, amylose, and amylopectin was shown by simple correlation coefficient values (Table 5). Environmental variations during the growth of aromatic upland rice as indicated by variations in soil chemical properties, such as: C-org, N, P, K, Na, and Zn (Table 1) likely affected the consistency of soil water content and nutrient content of rice. Another factor that might influence the rice nutrient levels to soil water content is the genetic factors difference of aromatic upland rice accession. In addition to soil water content, high soil nutrient levels, especially N, P, K and Zn, and low Na content caused ACC-09 to grow more optimal than others. This determines the factor influencing the high levels of rice fat and protein from ACC-09, although it did not look consistent for ACC-04 which had lower soil N levels compared to ACC-06. A consistent relationship pattern was not seen in the results of rice carbohydrates on growing environmental factors. Accessions that showed the highest carbohydrate content values are shown in ACC-06, followed by ACC-05, ACC-08, ACC-09, and ACC-04 (Table 3).

**Aroma quality**

Aromatic scores of five accessions of aromatic upland rice ranged from 1.8 to 3.4 (Table 4). The highest aromatic score was shown in ACC-06, while ACC-09 showed the lowest aromatic score. The aroma score was not always consistent with the level of 2AP of rice for each accession of evaluated aromatic upland rice. Accession with a high scent value of rice is reported to have high levels of 2AP and vice versa with a low aromatic score, because the levels of 2AP compounds were the main compounds that contributed to the aroma of rice (Buttery et al. 1982; Jezussek et al. 2002 ). Levels of 2AP compounds reported producing a fragrant aroma of rice were quite stable if the level of 2AP reaches at least 7.0 ppb.

**Table 5.** Correlation between soil physical and chemical properties with proximate content, starch, amylose, amylopectin, and aroma quality of rice

| r | Ka Rice | Ash | Fat | Pro. | Crb. | Starch | Amyl. | Amlp. | Arm |
|---|---|---|---|---|---|---|---|---|---|
| SWC | 0.54$^{ns}$ | -0.35$^{ns}$ | 0.47$^{ns}$ | 0.82$^{*}$ | -0.48$^{ns}$ | 0.13$^{ns}$ | -0.27$^{ns}$ | 0.23$^{ns}$ | -0.77$^{ns}$ |
| N | 0.14$^{ns}$ | -0.44$^{ns}$ | 0.58$^{ns}$ | 0.08$^{ns}$ | 0.04$^{ns}$ | 0.34$^{ns}$ | 0.40$^{ns}$ | -0.07$^{ns}$ | -0.68$^{ns}$ |
| K | 0.53$^{ns}$ | -0.37$^{ns}$ | 0.45$^{ns}$ | 0.81$^{*}$ | -0.46$^{ns}$ | 0.13$^{ns}$ | -0.28$^{ns}$ | 0.24$^{ns}$ | -0.77$^{ns}$ |
| P | 0.52$^{ns}$ | -0.37$^{ns}$ | 0.27$^{ns}$ | 0.84$^{*}$ | -0.45$^{ns}$ | 0.05$^{ns}$ | -0.43$^{ns}$ | 0.29$^{ns}$ | -0.66$^{ns}$ |
| Na | -0.31$^{ns}$ | -0.16$^{ns}$ | 0.24$^{ns}$ | -0.62$^{ns}$ | 0.45$^{ns}$ | 0.25$^{ns}$ | 0.68$^{ns}$ | -0.29$^{ns}$ | -0.07$^{ns}$ |
| Zn | 0.52$^{ns}$ | -0.39$^{ns}$ | 0.29$^{ns}$ | 0.83$^{*}$ | -0.43$^{ns}$ | 0.07$^{ns}$ | -0.39$^{ns}$ | 0.28$^{ns}$ | -0.69$^{ns}$ |

Note: KA Rice = moisture content of rice (%); Ash = ash content of rice (%); Fat = fat content of rice (%); Crb = level of rice carbohydrate (%); starch = rice starch content (%); Amyl = Amylose content of rice (%); Aml = rice amylopectin level; Arm = score of aroma of rice; ns= non significant, *= significant at p-value ≤ 0.05.

**Table 4.** Aroma scores and levels of 2AP local upland rice accession from Sumba Barat Daya, East Nusa Tenggara, Indonesia

| Accessions | Aroma score |
|---|---|
| ACC-04 | 3.0±0.17 |
| ACC-05 | 2.8±0.14 |
| ACC-06 | 3.4±0.14 |
| ACC-08 | 2.2±0.12 |
| ACC-09 | 1.8±0.16 |

Note: scent score <0.5 = not flavorful; 0.5 - <1.5 = weak flavorful; 1.5 - <2.5 = moderate flavorful; 2.5 - <3.5 = flavorful, and ≥ 3.5 = strong flavorful.

The mechanism to increase the levels of rice 2AP was generally associated with increased levels of proline amino acid in plant tissues triggered by drought and salinity stresses (Yoshihashi 2005). Several research reported that an increase in 2AP levels is associated with increasing uptake of soil nutrients such as N (Yang et al. 2012), P (Rohilla et al. 2000), and Zn (Jin-xia et al. 2009). In this study, there was no significant correlation between aroma score with soil water content (SWC) and soil chemical properties, especially N, P, K, Na and Zn levels (Table 5). Thus, the difference in the aroma quality among aromatic upland rice accessions was more likely determined by the differences in genetic factors. In the study of Arsa et al. (2016), correlation between 2AP level and soil moisture in upland rice of Pare Wangi variety showed a quadratic response, which means that an increase of 2AP levels of rice will reach a maximum at optimum soil moisture, and vice versa, the 2AP level will decrease along with the decrease of soil moisture (increase of drought stress). This is in line with the negative correlation value of the aroma score of rice with soil moisture content (Table 5). A negative correlation value was found between the aroma of rice with N, P, and K soil levels. This occurs through the mechanism of proline amino acid formation, which decreased at higher levels of soil N, P, and K contents. This can occur in soil moisture levels that have already passed the optimum soil moisture. The above findings explained that an increase in absorption of soil N, P, K elements would increase the level of rice 2AP rice if soil moisture is moderate enough to support the uptake of soil N, P, K elements and other soil nutrition elements by plant roots. Furthermore, the availability of plant tissue N, P, and K levels in a balanced amount, including micronutrients, will spur the proline amino acid biosynthesis process into a 2AP compound. Ram et al. (2013) stated that the macro and micronutrient balance significantly improved the quality of the rice aroma.

In conclusion, the study results revealed that the five aromatic upland rice accessions have a fairly variation in proximate content. ACC-04 rice produced the highest ash content, while ACC-09 rice had the highest fat and protein contents, and ACC-06 produced the highest carbohydrate content. The best rice aroma quality based on the aroma score was shown by, respectively, ACC-06 and ACC-05. There was no significant correlation between each of the proximate levels and aroma quality of the aromatic upland rice accessions with environmental factors; thus, the differences in proximate level and aroma quality among the rice accessions were more likely determined by the genetic factor.

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# Formulating strategies for development of lontar sugar industry in Rote Ndao District, East Nusa Tenggara Province, Indonesia

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**Abstract.** *Fahrizal, Jasman, Nggandung Y, Kartiwan. 2019. Formulating strategies for development of lontar sugar industry in Rote Ndao Regency, East Nusa Tenggara Province. Trop Drylands 3: 41-48.* Lontar (*Borassus flabellifer*) is a kind of palm tree utilized by home industries in Rote Ndao District, East Nusa Tenggara Province, for making sugar. Generally, the lontar sugar produced is molded sugar and crystal sugar. However, the home industries generally produce molded sugar more than the crystal one (which has better price), missing the opportunity to obtain higher benefits from lontar utilization. This research aimed to formulate and determine the priority of strategies for development of the crystal sugar industry in Rote Ndao District. Depth interview techniques, observation, and literature studies were used to identify the strategic factors, which were then presented in the form of EFE and IFE matrix. The value of each factor was obtained from pairwise comparison method. SWOT analysis resulted in 5 strategies to be applied with priority order of the strategies are: (i) development of crystal sugar industry by partnership system, (ii) application of technology for improving quality and quantity of the product, (iii) training of Good Manufacturing Practice and Good Agricultural Practice, (iv) institutional assistance from the related department, and (iv) increasing of marketing networks.

**Keywords:** Crystal sugar industry, IFE, EFE, SWOT

## INTRODUCTION

Lontar (*Borassus flabellifer*) is a kind of palm tree from *Arecaceae* family, known to well grow on dryland at altitude of 100-500 m above sea level with annual precipitation of 1000-2000 mm and 4-8 dry months (Tambunan 2010). In Indonesia, this plant can be found abundantly in East Nusa Tenggara (ENT) Province in the districts of Kupang, Sabu Raijua, West South Sumba, and Rote Ndao. Among them, the most potential growing area is Rote Ndao District with an estimated area of 10,409 ha (Forest Research and Development Center, Ministry of Forestry, Republic of Indonesia 2010).

The main product of the lontar utilized by the community is sap (a kind of liquid released from stem of the palm). The sap may be directly consumed as a sweet fresh drink, or being traditionally fermented to make alcoholic drink called *sopi*. The sap was also processed by farmers to make syrup, molded sugar, and crystal sugar. Among these products, molded sugar is the most frequently produced by the community, while crystal sugar is only produced in a limited amount. Besides the lontar tree, crystal sugar may also be produced from other palm trees, for example, coconut tree and *aren* (*Arenga pinnata* L.) tree. A large amount of crystal sugar, including from *aren*, is produced by home industry in the provinces of Central Java, East Java, West Java, West Sumatra, and South Sulawesi (Aliudin et al. 2011; Evalia 2015; Sugiyowati et al. 2015; Irmawati et al. 2015; Subekti et al. 2018).

Crystal sugar from lontar tree is one of derivated products with a high economic value and great potentials to be developed. This is because the product has some advantages over the other, for example, higher price, easier to be dissolved, easier to be mixed with other ingredients, easier to be packed and transported, and has a specific taste and aroma (Mustaufik and Dwiyanti 2007). Furthermore, crystal sugar may also be made from molded sugar by reprocessing technique (Mulyadi 2011). Considering the advantages, lontar crystal sugar appears to have high potential to be developed as prime product with high competitive value as high as crystal sugar from *aren* and coconut trees. Recently, coconut and *aren* crystal sugar are produced to meet both local and export markets (Evalia 2015).

Crystal sugar in ENT Province is produced by small home industry in District of Rote Ndao. Small scale production employs 3-4 employers, and every home industry owns about 12 to 30 lontar trees. Lontar sugar is usually made during the dry season, from April to the end of November every year. In this period, lontar trees produce flowers after the wet season. Along the period, sap productivity of lontar trees varies with the peak season occurring from September to October. Generally, the average sap productivity is 12.5 liters or about 10 kg per tree per day. Yield of crystal sugar from this sap is 13.8 % (Fahrizal et al. 2017), meaning that to produce 13.8 kg crystal sugar requires 100 kg of sap.

Production of crystal sugar is still performed using simple technologies passed down from old generation to younger generation. This technique still uses firewood as fuel, and then the product is sold at traditional markets. The crystal sugar is made just to meet the need of local community. There is no business unit organizing the product for broader marketing, for example, export to neighboring islands or other countries. The sugar is sold in batch in a volume base, not in weight base. There is no packaging of the product, thus, it could not be stored for a long time and the marketing range is limited. Sap productivity may be increased if good crop maintenance is applied for the lontar trees. Income of the industry may also be increased by exploiting the by-product obtained during the production period.

Not all of the sap produced is used to make crystal sugar; most of the sap produced is used to make molded sugar. Crystal sugar is usually produced at the end of the production season (October-November). This is based on the consideration that crystal sugar has a longer shelf life, so that it functions as the source of cash-saving and can be marketed after the production season. Conversely, molded sugar has a short shelf life, so the crystal sugar industry chooses to sell them directly rather than store them.

The lontar sugar industry has an important value in improving the welfare of all parties involved and its potential can be optimized. Nonetheless, the development of the crystal sugar industry faces many obstacles that must be addressed because of a number of inhibiting factors. However, it is undeniable that there are also a number of supporting factors. Therefore, there is a need for strategy formulation in its development.

The formulation of the strategy must be adjusted to the characteristics and problems of the industry concerned. The development strategy will have an effect on increasing competitiveness, increasing revenue and business sustainability, and improving regional economies. The purpose of this study was to formulate and determine the priority of alternative strategies in developing home industry of lontar palm sugar in Rote Ndao District, East Nusa Tenggara Province.

## MATERIALS AND METHODS

### Data collection

The research was carried out in the Home Industry of Crystal Sugar, Duadolu Village and Tualima 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 crystal sugar. The collected data was then analyzed qualitatively and quantitatively.

### Methods

*SWOT analysis*

SWOT Analysis (Strengths, Weaknesses, Opportunities, and Threats) is a tool commonly used for analyzing external and internal environments simultaneously in order to attain a systematic approach and support for a decision (Ozdemir and Demirel 2018; Goroner et al. 2012). In this study, SWOT analysis was used to analyze internal and external environmental factors that influence the development of the lontar sugar home industry in formulating strategies. To arrive at the goal of strategy formulation, identification of internal and external environmental factors that influence the development of the lontar sugar home industry was identified. Identification of internal strategic factors included aspects of strengths and weaknesses, as well as external strategic factors covering aspects of opportunities and threats. The results of identification of all factors were then summarized in the form of IFE (Internal Factor Evaluation) matrix, and EFE (External Factor Evaluation) matrix.

A pairwise comparison method was used to give weight to internal and external factors. The weighted strategic factors were obtained by determining the value of each strategy relative to the total values of all strategic factors (Arkeman et al. 2015; Triantaphyllou 1995). After that, the weight was normalized to get the total weight equals unity.

Rating of the IFE matrix shows the level of strategic factors strengths and weaknesses that influence the development of the crystal sugar home industry. While determining the rating on the EFE matrix was based on the ability of the crystal sugar home industry in reaching the opportunities and the magnitude of threats that can affect their existence. IFE and EFE matrix ratings were determined by giving values 1 to 4 for each factor with reference to the description in Table 1 and Table 2.

**Table 1.** Description of rating determination on the IFE matrix

| Value | Description |
|---|---|
| 4 | If the power factor is considered to have a very strong influence and if the weakness factor is considered to have a very weak effect (poor) |
| 3 | If the strength factor is considered to have a strong influence and if the weakness factor is considered to have a strong influence |
| 2 | If the strength factor is considered to have a moderate effect and if the weakness factor is considered to have a moderate effect |
| 1 | If the power factor is considered to have very little effect (poor) and if the weakness factor is considered to have a very strong influence |

**Table 2.** Description of rating determination on EFE matrix

| Value | Description |
|---|---|
| 4 | If the crystal sugar industry has a very good ability to reach opportunities and threat factors, it has a very weak influence on the crystal sugar industry |
| 3 | If the crystal sugar industry has the ability to achieve opportunities and threat factors, it has a weak influence on the crystal sugar industry |
| 2 | If the crystal sugar industry has a pretty good ability to reach opportunity factors and threat factors has a strong influence on the crystal sugar industry. |
| 1 | If the crystal sugar industry has a poor ability to reach opportunity factors and threat factors has a very strong influence on the crystal sugar industry. |

**Table 3.** Saaty's scale 1-9 used for pairwise comparison of decision making prioritization strategy

| Saaty's score | Definition | Description |
|---|---|---|
| 1 | Equal dominance | Two elements are of equal importance in regard to the higher-level objective |
| 3 | Weak dominance | Experience or judgment slightly favor one element over other |
| 5 | Strong dominance | Experience or judgment considerably favor one element over other |
| 7 | Very strong dominance | Very strong dominance of one element over the other |
| 9 | Absolute dominance | Dominance of the highest degree |
| 2,4,6,8 | Intermediate values | They are used to demonstrate compromise intermediate values of priorities between the above-listed score 1,3,5,7 and 9 |

Source: Dlbokic et al. (2017)

*Internal-external matrix analysis*

The strategy formulation in the development of the lontar crystal sugar industry in Rote Ndao District was used in SWOT analysis. Internal factors that describe strengths and weaknesses were summarized in the IFE matrix, while environmental factors that reflect opportunities and threats were summarized in the EFE matrix. The results of the assessment of internal and external factors in the IFE matrix and EFE matrix obtained the total score of each factor. The results of the assessment were used to determine the position of the lontar crystal sugar industry in the SWOT diagram (Rangkuti 2006; Sugiyowati et al. 2015).

*Alternative crystal sugar industry development strategy*

The strategic factors presented in the IFE and EFE matrix were then presented in the SWOT matrix to determine alternative strategies. Based on the SWOT matrix, four main strategies can be arranged, namely: SO strategies, WO, ST and WT strategies (Dlbokic et al. 2017; Rangkuti 2006). SO strategy is a strategy created by using the company's internal strength to take advantage of external opportunities. The WO strategy is created to correct internal weaknesses and use external opportunities. The ST strategy was made to anticipate external threats by using internal strengths, and the WT strategy was made to deal with weaknesses and threats that could not be dealt with using existing strengths and opportunities.

*Prioritization of strategies*

One of the major constraints in prioritization of strategies generated based on the SWOT matrix is the fact that the importance of each factor in the decision making cannot be quantitatively measured, which makes it difficult to assess which factor has the greatest impact on individual strategies. Strategy priorities were determined based on the assessment of a number of experts on the importance of each factor in the SWOT matrix using pairwise comparison method. One method used to determine priority order is Analytical Hierarchy Process (AHP). It has been used to determine the priority order of alternative strategies, for example, Setiyadi et al. (2011) and Luksmanto (2014). AHP and fuzzy approaches integrated have also been used for the same purpose, for example, Goroner et al. (2012), Hadavi and Mirabi (2017) and Karatop et al. (2018). According to Saaty (1983), for various problems, a scale of 1 to 9 is the best scale in expressing opinions. The values and definitions of qualitative opinions from the current comparison scale are presented in Table 3.

This study used a system approach (Wasson 2006), which is characterized by a number of stages that are systematic, logical and structured. The stages of the study consisted of identifying a number of internal and external factors, then proceed with a SWOT analysis. The final stage is weighing all alternatives to get priority orders. The research framework elaborated at the research stage is presented in Figure 1.

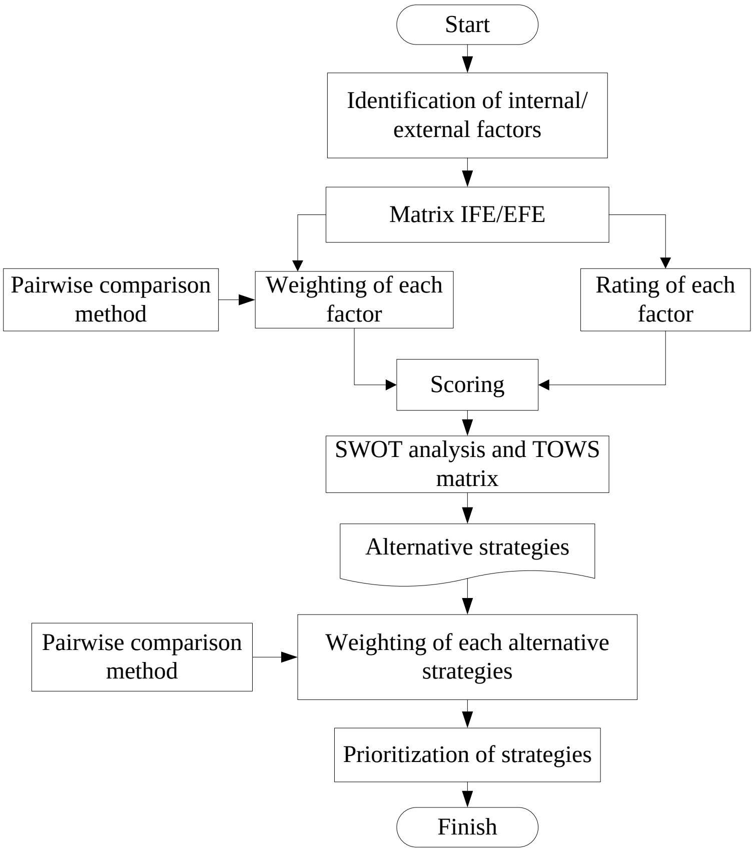


**Figure 1.** The research framework and stages applied in this study.

## RESULTS AND DISCUSSION

### Formulation of the lontar crystal sugar industry development strategy

In evaluating the factors that will affect the development of the lontar crystal sugar home industry in Rote Ndao District, we identified internal strategic factors including strengths and weaknesses, as well as external strategic factors including opportunities and threats. The strength factors are as follows: (i) Characteristics of lontar sugar. Lontar sugar has a distinctive taste, sweeter and browner color than the other sugar such as coconut sugar. These advantages cause lontar sugar more preferred by consumers. (ii) Naturally processed and environmentally friendly. No machines or chemicals are used in making lontar sugar as compared to that in the manufacture of cane sugar. As lontar sugar is processed naturally, it contains no harmful chemicals such as preservatives, dyes, thickeners, and other chemicals, and produces no waste that can damage the environment. (iii) Sugar levels are lower than cane sugar. Lontar sugar has lower levels of glymax compared to cane sugar. It is good for health, especially for people who suffer from diabetes mellitus. (iv) Local labor is sufficiently available. Processing of lontar sugar involves family workers. Processing locations are generally in rural areas so they are able to absorb a large potential of labor. (v) Availability of raw materials. Lontar sugar is made from the sap produced by lontar plants. These plants grow naturally in the yard or community field. Although not all communities work as sugar makers, almost all families maintain this plant. Thus, the availability of raw material in the form of sap is very high for the needs of crystal sugar industries.

Besides having internal factors that provide the strength of the lontar sugar industry in Rote Ndao District, there are also weaknesses factors, namely: (i) Traditionally produced. Lontar sugar is produced using simple technology, especially in the process of filtering the sap and cooking process. Filtering the sap has not yet used a filter that meets the standard method, which causes the sugar to still contain lots of impurities (Fahrizal et al. 2017). Cleanliness of production equipment has not been well done. The use of firewood causes high costs and the fire smoke pollutes the kitchen. (ii) Produced individually by households. Crystal sugar is made by families with a workforce of 2-3 people. There is no partnership, for example, between the sap producers and the craftsman. The sap producer is also a sugar crafter. (iii) Availability of raw materials depends on the season. Making of sugar depends on the availability of sap. Lontar trees produce sap for only about 7 to 8 months every year, i.e. April to November every year. (iv) There are no marketing networks. The crystal sugar produced is directly marketed in traditional markets that generally take place on Wednesdays and Saturdays at Busalanga Market. There are no collectors or wholesalers that accommodate their sugar production. (v)

Limited market. Crystal sugar has not been packaged, and is also not yet labeled and certified by Badan Pengawas Obat dan Makanan (BPOM), so its market is limited to traditional markets. BPOM is a non-ministerial government agency that conducts government affairs in the field of drug and food control. (vi) Product quality is still low. The product was dried not using by oven drying, so the water content was still high, ranging from 7 to 8 percent, causing a low shelf life of fewer than 4 months. Crystal sugar with 3% water content has a shelf-life of up to 8 months. (vii) Production quantity is not stable. The amount of sugar production is not fixed and is very dependent on the amount of sap. (viii) The quality of human resources is still low. Knowledge and skills in making the crystal sugar are not obtained from formal education or training, but just passed down from generation to generation. Therefore, the application of good processing technology such as drying and packaging technology has not been applied. (ix) Supporting institutions are lacked. There are no institutions such as Village-Owned Enterprises (BUMDES) or cooperatives that provide a platform for the development of crystal sugar production.

Identification of external factors obtained seven opportunity factors, as follows: (i) Culture of local residents. Making lontar sugar is the livelihood of the local population and has been going on for a long time from generation to generation. Lontar sugar is a very important source of food for the people in Rote Ndao. Therefore, making lontar sugar is not only a source of income but also for necessity of life. (ii) The increasing demand for organic sugar products. Demand for organic sugar including lontar sugar is increasing, especially for home consumption and food industry. (iii) Increased added value from processing lontar crystal sugar. Lontar sap can be consumed directly in the form of fresh drinks or flavor enhancers. However, the economic value is lower than that of crystal sugar. (iv) Local government support. The regional government provides the opportunity for the home industry of lontar sugar to sell its products not only in traditional markets, but also at ferry ports, and some also were sold in shops. (v) The waste of firewood after cooking sugar can be used for making charcoal. The remaining coal from combustion can be made of charcoal and sold as an additional source of income. (vi) The skill of making sugar products is inherited from generation to generation. Sugar making skills are not obtained through an internship or training process, but are obtained from the family environment. (vii) Development of science and technology. The technology of making sugar, including lontar sugar, continues to increase. This can encourage the use of more efficient technology in making lontar sugar.

Besides having external factors that provide opportunities for the lontar crystal sugar industry, there are also threat factors, namely: (i) Low and fluctuating production capacity. This causes the consumer demand cannot be fulfilled. (ii) Price competition with cane sugar products. The price of lontar sugar is relatively more expensive compared to cane sugar. This is a consideration of consumers, especially the food industry because it will cause an increase in production costs. (iii) Cultivation of lontar plant has not been done. Lontar plants grow naturally in the yard or in the community garden. Growing in groups and irregularly. This is because young plants that grow are derived from seeds that fall from trees. Although lontar cultivation techniques have been discovered (Bernhard 2017) and involved plant selection, planting, and maintenance, the community has not yet practiced them. (iv) Product demands according to standards. The lontar sugar must meet the crystal sugar quality requirements by referring to the quality standards set by the National Standardization Agency of Indonesia (1995). Not fulfilling the quality requirements causes the lontar crystal sugar fall short to meet the requirements to be marketed at a wider level. (v) The potential of lontar sap for alcoholic drinks and bioethanol. Lontar sap as a raw material for crystal sugar can also be made into alcoholic beverages. The higher price of alcoholic beverages causes some people to prefer to make this product instead of crystal sugar.

Internal factors that represent the strengths and weaknesses of developing the lontar crystal sugar home industry namely the weight of each factor, rating score, and total score, are summarized in the IFE matrix presented in Table 4. Whereas, environmental factors that reflect opportunities and threats are summarized in the matrix EFE and presented in Table 5.

**Determination of alternative and priority of the strategy for the development of lontar sugar industry**

There are four main approaches used to determine alternative strategies, namely: SO, WO, ST, and WT strategies. Based on the SO strategy, there were 3 alternatives, namely the development of the partnership of sugar industry, product and packaging diversification, and the utilization of combustion residual charcoal as a source of income. The WO strategy obtained 3 alternatives, namely the application of technology to improve the quality and quantity of production, institutional assistance from related agencies and improve marketing networking. ST strategy suggests 2 alternatives, namely training in Good Manufacturing Practice and Good Agricultural Practice and providing financial assistance to increase production. WT strategy recommends 2 alternatives, namely increasing commitment and cooperation between all stakeholders and marketing targets on traditional markets. Alternative strategies have different levels of importance or weight, so the order of priorities needs to be determined. The order of alternative priorities is based on the respective weights as shown in Table 6.

**Tabel 4**. Matrix of IFE (Internal Factor Evaluation)

| Internal factors | Weight | Rating | Score |
|---|---|---|---|
| **Strength** | | | |
| Characteristic of lontar sugar | 0.064 | 3 | 0.193 |
| Processed naturally and environmentally friendly | 0.060 | 3 | 0.180 |
| Sugar levels are lower than cane sugar | 0.098 | 3 | 0.296 |
| Local labor is available | 0.153 | 4 | 0.612 |
| Availability of raw materials | 0.123 | 4 | 0.494 |
| Total | | | 1.775 |
| **Weakness** | | | |
| Traditionally produced | 0.046 | 3 | 0.140 |
| Produced individually by households | 0.083 | 1 | 0.083 |
| Raw materials depend on the season | 0.053 | 2 | 0.107 |
| There is no marketing networks yet | 0.057 | 1 | 0.057 |
| Limited market share | 0.035 | 1 | 0.035 |
| Product quality is still low | 0.046 | 1 | 0.046 |
| Production quantity is not stable | 0.041 | 2 | 0.082 |
| The quality of human resources is still low | 0.085 | 1 | 0.085 |
| Supporting institutions are lacked | 0.050 | 2 | 0.101 |
| Total | | | 0.736 |

Source: Primary data processed (2019)

**Tabel 5.** Matrix of EFE (External Factor Evaluation)

| External factors | Weight | Rating | Score |
|---|---|---|---|
| **Opportunity** | | | |
| Local culture | 0.096 | 4 | 0.384 |
| The increasing demand for organic sugar products | 0.069 | 3 | 0.207 |
| Increased added value from the processing of lontar sap | 0.085 | 3 | 0.256 |
| Local government support | 0.092 | 4 | 0.370 |
| The waste produced by cooking can be used to make charcoal as a source of income | 0.045 | 2 | 0.091 |
| The skill of making crystal sugar is inherited from generation to generation | 0.068 | 3 | 0.204 |
| Development of science and technology | 0.042 | 3 | 0.127 |
| Total | | | 1.639 |
| **Threat** | | | |
| Low production capacity and volatility | 0.136 | 2 | 0.273 |
| Price competition with sugar cane products | 0.059 | 3 | 0.177 |
| Lontar cultivation has not been done well | 0.103 | 3 | 0.310 |
| Product demands according to standards | 0.124 | 2 | 0.248 |
| Conversion of lontar sap into bioethanol | 0.076 | 2 | 0.153 |
| Total | | | 1.161 |

Source: Primary data processed (2019)

**Table 6.** Results of alternative weight calculation strategies

| No. | Alternative strategies | Weight |
|---|---|---|
| 1 | Development of the crystal sugar industry partnership system | 0.154 |
| 2 | Application of technology to improve the quality and quantity of production | 0.147 |
| 3 | Good Manufacturing Practice training and Good Agricultural Practice | 0.136 |
| 4 | Institutional assistance from related agencies | 0.104 |
| 5 | Improve network marketing | 0.101 |
| 6 | Product and packaging diversification | 0.099 |
| 7 | Utilization of combustion residual charcoal as a source of income | 0.079 |
| 8 | Providing financial assistance to increase production | 0.065 |
| 9 | Increased commitment and cooperation between all stakeholders | 0.063 |
| 10 | Target marketing in traditional markets | 0.048 |

Source: Primary data processed (2019)

**Discussion**

Based on Table 4, the total score of the strength factor is 1.775 and the total score in the weakness factor is 0.736. This shows that the development of a lontar crystal sugar home industry has greater strength than its weakness with a difference of 1.039. Based on Table 5, the total score for the opportunity factor is 1.639 and the total score for the threat factor is 1.161, indicating that the opportunity for the lontar sugar industry is greater than the threat with a difference of 0.6. The difference value is then plotted in the SWOT diagram analysis.

According to Rangkuti (2006), SWOT diagrams consist of 4 quadrants that indicate the position of existing strategies, namely quadrant I: aggressive strategy, quadrant II: diversification strategy, quadrant III: improvement strategy, quadrant IV: survival strategy. Based on the analysis of the diagram, it is known that the development of the home industry of lontar crystal sugar is in quadrant I. This shows that the lontar sugar industry is in a very favorable situation because it has the strength and opportunity that can be utilized optimally. Thus, the strategy that should be used is a strategy that supports aggressive growth by utilizing existing opportunities (Rangkuti 2006; Sugiyowati et al. 2015).

Based on Table 5, it can be seen that the strategy for developing the lontar crystal sugar industry in the partnership system is the strategy with the highest weight value. The partnership system means that the crystal sugar industry can consist of beneficiaries as sapper suppliers, processing industries as processors, collectors or cooperatives and end consumers. In this partnership system, the small lontar sugar industry functions more as a processor that process raw material into finished product. The raw material for sap is obtained from suppliers. Product marketing is carried out by cooperatives, collectors, or retailers. Through this partnership system, the crystal sugar industry is easier to get capital assistance, training, mentoring, and supervision from related parties, so that the quality and quantity of products are guaranteed, as well as a wider marketing range. To carry out this strategy, clear rules, clear agreements, and strong commitment among all parties involved to achieve the goal are needed.

Another alternative strategy that gets priority is the application of technology to improve the quality and quantity of production. The technology is applied at the level of on-farm and off-farm. At the level on-farm, lontar sugar producers must apply good cultivation techniques (Good Agricultural Practice = GAP) to increase the yield such as planting, weeding and fertilizing. At the off-farm level, lontar sugar producers must implement good manufacturing techniques (Good Manufacturing Practices = GMP) such as room handlers, equipment cleanliness, and production sites. The critical point in making sugar generally lies in the treatment of sap before being processed into sugar (Marsigit 2005). A number of factors can cause the lontar sap to be damaged or fermented, which results in a decrease in the quantity and quality of sugar products. Therefore GAP and GMP training is an important strategy to improve the knowledge and skills of lontar sugar producers.

Support from the local government or related agencies is very important in the development of the crystal sugar industry. GAP and GMP training can be facilitated by the government or related agencies. Institutional assistance in the form of establishing cooperatives can be facilitated by the local government or related agencies. Cooperatives can function to accommodate production products at mutually agreed prices, as well as a forum for expanding market share and marketing networks, such as in the food industry, supermarkets, inter-island traders, and or exporters.

This research can be continued by using a combination method of SWOT and multiple criteria decision-making approach, for example, AHP (Analytical Hierarchy Process) or fuzzy logic framework with the AHP method to effectively analyze cases having uncertainty. Furthermore, any multiple criteria decision-making technique may be applied instead of the AHP in order for the results could be compared.

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# Yield and yield component performances of local pigmented upland rice cultivars from East Nusa Tenggara, Indonesia in three locations

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**Abstract.** *Ndiwa ASS, Mau YS. 2019. Yield and yield component performances of local pigmented upland rice cultivars from East Nusa Tenggara, Indonesia in three locations. Trop Drylands 3: 49-55.* There is increasing demand for pigmented rice due to nutritional benefits, yet the supply is limited. Dryland region in Indonesia, including East Nusa Tenggara Province, has local pigmented upland rice varieties which have been selected based on their agronomic performance, blast resistance, and drought tolerance traits. This study aimed to further elucidate the selected upland rice cultivars for their yield performance and stability in a multi-location trial in three locations. The results showed the significant effect of rice genotype, location, and interactions between rice genotype and location (GxE) on most observed variables, both in each location and across the three locations. Five genotypes produced average grain yield of ≥ 4.0 t/ha over three locations, i.e., NGR-22, PMK-01, ADN-05, Inpago 7 and Aek Sibundong. These five genotypes were found to produce high and stable grain yield under the three growing environments.

**Keywords:** Colored rice, local cultivar, multi-location, yield stability

## INTRODUCTION

Pigmented rice, such as red and black rice, has become increasingly popular in the last decades due to its considerable benefits as functional, healthy foods. Red and black rice contain high carbohydrates and also a substantial amount of protein, vitamin, mineral, and anthocyanin contents, all of which are regarded as health-promoting properties. The high anthocyanin content of red and black rice can serve as antioxidants (Satue-Gracia 1997; Abdel-Aal et al. 2006; Nam et al. 2006), anti-inflammatory (Tsuda et al. 2002) and anti-cancer (Hyun et al. 2004; Zhao et al. 2004). All these advantageous properties drive the increasing demand of pigmented rice while their availability in the market is still scarce (Badan Litbang Pertanian 2012).

The existing red and black rice superior varieties in Indonesia is lacking. Only a few superior varieties have been released until 2012, i.e., red rice varieties Bahbutong and Aek Sibundong (Santika and Rozakurniati 2010) and Mandel Handayani and Segreng Handayani (Departemen Pertanian 2009a, b), all of which are superior local varieties. The most recently released improved varieties included Inpari 24, Inpago 7, and Inpago Unram 1 (Badan Litbang Pertanian 2012); the former is a lowland variety while the last two are upland rice varieties. There is no released variety of black rice at the moment.

The limited number of red and black rice superior varieties (Badan Litbang Pertanian 2012) needs to be addressed to anticipate the increasing demand of this rice. Selection of local germplasm is an easier and faster way of handling this problem as local germplasm is abundantly available and easily accessed by the farmers (Mau et al. 2018). Besides, the selection of local germplasm promotes the use of these local resources and prevents them from extinction. Local superior germplasm can also be used as the parental source in hybridization programs to produce new superior varieties.

Pigmented upland rice germplasm from East Nusa Tenggara (Nusa Tenggara Timur/NTT) Province had been characterized for their genetic diversity (Mau et al. 2017) and also evaluated for their resistance to blast disease (Mau et al. 2018) and tolerance to drought (Mau et al. 2019) which resulted in several promising cultivars being selected. These selected cultivars have high grain yield potential, are resistant to blast disease, and are tolerant to drought, thus, they are highly promising to be further tested in multi-environment conditions to select for cultivars having high and stable yield. This study aimed to evaluate yield performance of red and black upland rice cultivars from NTT Province across multi-environment conditions, and to select cultivars that produce high and stable yields.

## MATERIALS AND METHODS

### Research location and materials

This research was conducted in three locations covering the low to medium altitude in East Nusa Tenggara (NTT) Province, Indonesia from April to October 2018. The general descriptions of the three research locations are presented in Table 1. Plant materials used in the study were local pigmented rice accessions from East Nusa Tenggara Province and check varieties.

**Table 1.** General descriptions of the research locations in East Nusa Tenggara Province

| Location | District | Altitude (m. asl) | Physical characteristic |
|---|---|---|---|
| Oerinbesi | Timur Tengah Utara | 360 | Dryland, Grumosol soil type |
| Penfui | Kupang | 100 | Dryland, Inceptisol soil type |
| Honihama | Flores Timur | 50 | Dryland, Alvisol soil type |

**Research design and procedures**

A Randomized Block Design was employed in each research site, consisting of 15 rice genotypes as treatment, which comprised of local cultivars, i.e. four red rice (ADN-04, ISN-02, SBD-04, HK-07) and eight black rice (ADN-03, ADN-05, HK-06, KMD-01, MGP-01, NGR-22, PMK-01, WTN-22), and two check red rice varieties (INPAGO 7, Aek Sibundong) and one advanced line of black rice (Aks-Htm-12). The check varieties were kindly provided by Indonesian Rice Research Institute, Sukamandi. The advanced line of black rice was provided by Dr. Buang Abdullah (personal communication) from Indonesian Rice Research Institute, Muara, Bogor.

Rice seeds were planted in trial plots, each measuring 1.5 m × 1.5 m at a planting distance of 25 cm × 20 cm. The planting was done directly into the planting hole. Each planting hole was planted with two seeds, and only one plant was retained until harvest. Fertilization was carried out with a compound NPK fertilizer (16:16:16) at a dosage of 56.25 g plot$^{-1}$ or equivalent to 500 kg ha$^{-1}$. Fertilization was done twice at the time of planting and at 45 days after planting. Weeds were discarded manually from the planting plots. Irrigation was provided daily to maintain field capacity levels. The main pests attacking the crops were birds and rice bugs. The former was controlled manually by driving them out from the rice fields while the latter was controlled by using chemical spray (Decis 25 EC).

**Observation and data analysis**

The observed variables included plant height at harvest, number of panicles per plant, harvesting date, and grain yield per plot, which was then converted to yield per hectare.

One-way ANOVA was performed on data obtained from each location. Bartlett test of homogeneity of variance was performed on data collected from the three sites. Data from the three sites with homogeneous variance were further subjected to the combined analysis of variance to see the effect of genotype by location interaction and yield stability.

## RESULTS AND DISCUSSION

**Results**

ANOVA results revealed a highly significant difference ($P<0.01$) amongst rice genotypes in each location. This indicated that the tested pigmented upland rice cultivars are highly diverse in the observed variables in each of the three locations. Bartlett test revealed that variances of productive tillers/panicle numbers across the three locations were non-homogeneous ($P> 0.05$). Error variances of harvesting date, plant height at harvest, panicle number per plant and grain yield per plot variables were homogeneous, thus, they were further subjected to combined analysis of variance. Means of panicle number per plant, plant height at harvest, harvesting date, and grain yield of tested rice genotypes are presented in Tables 2, 3, 4 and 5, respectively.

**Number of panicle per plant**

Error variances of panicle number per plant over three locations were heterogeneous, thus, combined analysis of variance was not performed on this variable. Instead, the mean panicle number per plant in each location was separately subjected to one-way ANOVA and presented in Table 2. Across the three research sites, the number of panicle or productive tillers averaged 4.25-19.9 panicles per plant; WTN-022 showed the highest panicle number followed by KMD-01. These two local cultivars consistently produced the highest number of panicles at three test sites and were not significantly different from Aek Sibundong in Flores Timur. The changes in the ranking of panicle number per plant across the three test locations indicate that each test location has different agro-climatic conditions such as soil fertility, temperature, humidity, etc., and each rice genotype has different responses to variations in the environmental conditions.

WTN-022, KMD-01, and Aek Sibundong could produce a large number of panicles per plant in the three locations. On average across the three locations, high panicle number per plant was observed in two local cultivars KMD-01 (18.05 panicles) and WTN-22 (19.90 panicles), and the check variety Aek Sibundong (14.85 panicles). The rest ten local cultivars produced low number of panicles per plant ranging from 4.43 – 10.70 panicles per plant. The average number of panicles per plant in the three locations was 10.2, 8.24 and 9.47 for Kupang, Flores Timur, and Timor Tengah Utara, respectively.

The local cultivars KMD-01 and WTN-02 consistently produced higher panicle number per plant in two locations, i.e. Kupang (23.5 and 25 panicles, respectively) and Timor Tengah Utara (18 and 19.9 panicles, respectively) but produced a lower panicle number in Flores Timur (12.6 and 14.8 panicles, respectively). Meanwhile, the check variety Aek Sibundong consistently produced almost similar panicle numbers per plant in the three locations, respectively, 15.50, 14.20, and 14.85 panicles.

**Table 2.** Mean panicle number per plant of pigmented rice cultivars from NTT Province in three locations

| Genotype code (G) | Location/district (E) | | | | | | Mean (G) |
|---|---|---|---|---|---|---|---|
| | Kupang | | Flores Timur | | Timor Tengah Utara | | |
| ADN-03 | 8.00 | abc | 5.40 | abc | 6.70 | abcd | 6.70 |
| ADN-04 | 3.50 | a | 5.00 | ab | 4.25 | a | 4.25 |
| ADN-05 | 5.00 | abc | 8.90 | cd | 6.95 | abcd | 6.95 |
| HK-06 | 4.00 | ab | 4.60 | a | 4.30 | a | 4.30 |
| HK-07 | 7.00 | abc | 2.50 | a | 4.75 | ab | 4.75 |
| KMD-01 | 23.50 | e | 12.60 | efg | 18.05 | ef | 18.05 |
| ISN-02 | 7.00 | abc | 9.60 | de | 8.30 | bcd | 8.30 |
| MGP-01 | 9.00 | abcd | 3.80 | a | 6.40 | abc | 6.40 |
| NGR-22 | 11.00 | bcd | 4.80 | a | 7.90 | abcd | 7.90 |
| PMK-01 | 11.50 | cd | 9.50 | de | 10.50 | d | 10.50 |
| SBD-04 | 10.50 | bcd | 10.90 | def | 10.70 | d | 10.70 |
| WTN-22 | 25.00 | e | 14.80 | g | 19.90 | f | 19.90 |
| INPAGO 7 | 10.50 | bcd | 8.30 | bcd | 9.40 | cd | 9.40 |
| Aks-Htm-12 | 9.50 | bcd | 8.70 | cd | 9.10 | cd | 9.10 |
| Aek Sibundong | 15.50 | d | 14.20 | fg | 14.85 | e | 14.85 |
| Mean (E) | 10.2 | | 8.24 | | 9.47 | | |

Note: Numbers followed by the same lowercase within the same column are not significantly different by post hoc DMRT (0.05).

**Table 3.** Mean plant height of pigmented rice cultivars from NTT Province in three locations (all values are in cm).

| Genotype code (G) | Location/district (E) | | | | | | Mean (G) | |
|---|---|---|---|---|---|---|---|---|
| | Kupang | | Flores Timur | | Timor Tengah Utara | | | |
| ADN-03 | 141.50 | e | 116.90 | ef | 129.20 | i | 129.20 | h |
| | C | | A | | B | | | |
| ADN-04 | 130.00 | d | 107.80 | de | 118.90 | fgh | 118.90 | efgh |
| | C | | A | | B | | | |
| ADN-05 | 125.50 | d | 124.80 | f | 125.15 | hi | 125.15 | gh |
| | A | | A | | A | | | |
| HK-06 | 120.00 | d | 117.30 | ef | 118.65 | fgh | 118.65 | efgh |
| | A | | A | | A | | | |
| HK-07 | 127.00 | d | 107.30 | de | 117.15 | fgh | 117.15 | efg |
| | C | | A | | B | | | |
| KMD-01 | 76.25 | ab | 69.20 | a | 72.73 | a | 72.73 | a |
| | A | | A | | A | | | |
| ISN-02 | 125.50 | d | 116.20 | ef | 120.85 | ghi | 120.85 | fgh |
| | A | | A | | A | | | |
| MGP-01 | 122.00 | d | 108.80 | de | 115.40 | fg | 115.40 | efg |
| | B | | A | | AB | | | |
| NGR-22 | 95.00 | c | 88.20 | b | 91.60 | bc | 91.60 | bc |
| | A | | A | | A | | | |
| PMK-01 | 97.50 | c | 105.40 | cd | 101.45 | de | 101.45 | cd |
| | A | | A | | A | | | |
| SBD-04 | 99.5 | c | 96.60 | bc | 97.98 | cd | 97.98 | cd |
| | A | | A | | A | | | |
| WTN-22 | 84.25 | b | 86.80 | b | 85.53 | b | 85.53 | b |
| | A | | A | | A | | | |
| INPAGO 7 | 105.60 | c | 111.20 | de | 108.40 | ef | 108.40 | de |
| | A | | A | | A | | | |
| Aks-Htm-12 | 102.50 | c | 123.20 | f | 112.85 | fg | 112.85 | ef |
| | A | | C | | B | | | |
| Aek Sibundong | 68.50 | a | 69.00 | a | 68.75 | a | 68.75 | a |
| | A | | A | | A | | | |
| Mean (E) | 108.03 | C | 103.25 | A | 105.64 | B | | |

Note: Numbers followed by the same letter (s) are not significantly different by post hoc DMRT (0.05). Uppercase indicates comparison within the same row while lowercase indicates comparison within the same column

**Plant height at harvest**

Combined analysis of variance showed that location, pigmented upland rice genotype, genotype by location/environmental interaction (GxE) had a significant (P <0.01) effect on plant height at harvest. This indicates that variation of plant height at harvest among the pigmented upland rice genotypes did not occur only within the same location but also between locations. There were changes in the ranking of harvesting date of the rice genotypes over the three sites as an indication of genotype by location interaction.

Over the three locations, plant height at harvest ranged from 68.75 cm to 129.15 cm. Aek Sibundong (68.75 cm) had the shortest plant height across the three locations, but was not significantly different from KMD-01 (72.73 cm), which indicates that shorter plant height of these two genotypes was genetically controlled. Meanwhile, the highest plant height was observed in ADN-03 (129.15 cm), which did not differ from ADN-04 (118.90 cm), ADN-05 (125.15 cm), HK-06 (118.65 cm), and ISN-02 (120.85 cm). These local cultivars were also the tallest plant when grown in at least two of the three test sites, indicating the effect of genetic control on the plant height.

**Harvesting date**

Combined analysis of variance showed that location caused no significant effect on harvesting date but rice genotype, genotype by location/environmental interaction (GxE) had a significant (P <0.01) effect on harvesting date. This indicates that variation of harvesting date did occur among rice genotypes and the magnitude of the changes is depending on the location. Changes in the ranking of harvesting date of the rice genotypes over the three sites indicate significant genotype by location interaction effect.

**Table 4.** Mean harvesting date (days after planting) of pigmented rice cultivars from NTT Province in three locations

| Genotype code (G) | Location/district (E) | | | Mean (G) |
|---|---|---|---|---|
| | Kupang | Flores Timur | Timor Tengah Utara | |
| ADN-03 | 135.50 b A | 141.00 c A | 138.50 def AB | 138.33 cd |
| ADN-04 | 128.50 a A | 142.00 cd C | 135.50 cd B | 135.33 bc |
| ADN-05 | 129.50 a A | 142.50 cd C | 136.00 cd B | 136.00 bc |
| HK-06 | 131.00 a A | 142.50 cd C | 137.00 cde B | 136.83 bc |
| HK-07 | 143.50 d A | 153.00 e C | 148.50 g B | 148.33 d |
| KMD-01 | 130.50 a A | 136.00 b B | 133.50 bc AB | 133.33 abc |
| ISN-02 | 129.00 a B | 122.50 a A | 126.00 a B | 125.83 ab |
| MGP-01 | 148.00 e A | 148.50 d A | 148.50 g A | 148.33 d |
| NGR-22 | 130,50 a A | 145,00 c C | 138,00 def B | 137.83 cd |
| PMK-01 | 128.50 a C | 120.00 a A | 124.50 a B | 124.33 a |
| SBD-04 | 146.50 de C | 134.50 b A | 141.00 f B | 140.67 cd |
| WTN-22 | 140.00 c C | 122.50 a A | 131.50 b B | 131.33 abc |
| INPAGO 7 | 144.50 de C | 135.00 b A | 140.00 ef B | 139.83 cd |
| Aks-Htm-12 | 138.50 bc C | 122.50 a A | 131.00 b B | 130.67 abc |
| Aek Sibundong | 129.00 a C | 119.50 a A | 124.50 a B | 124.33 a |
| Mean (E) | 135.53 A | 135.13 A | 135.60 A | |

Note: Numbers followed by the same letter (s) are not significantly different by post hoc DMRT (0.05). Uppercase indicates comparison within the same row while lowercase indicates comparison within the same column

**Table 5.** Mean grain yield plot$^{-1}$ (1 m$^2$) (g) of pigmented rice cultivars from NTT Province in three locations.

| Genotype code (G) | Location/district (E) | | | Mean (G) |
|---|---|---|---|---|
| | Kupang | Flores Timur | Timor Tengah Utara | |
| ADN-03 | 380.40 fg A | 419.35 e A | 391.88 d A | 397.21 e |
| ADN-04 | 319.75 de A | 425.60 e B | 407.68 d B | 384.34 e |
| ADN-05 | 367.15 f A | 415.40 e B | 417.03 d B | 399.86 e |
| HK-06 | 288.50 d A | 415.90 e B | 307.20 c A | 337.20 d |
| HK-07 | 284.70 d A | 355.70 d B | 320.20 c AB | 320.20 d |
| KMD-01 | 241.00 c A | 291.00 c B | 256.00 b AB | 262.67 c |
| ISN-02 | 175.50 b A | 226.00 b B | 250.75 b B | 217.42 b |
| MGP-01 | 114.25 a A | 163.60 a B | 138.93 a AB | 138.93 a |
| NGR-22 | 453.50 h A | 543.05 f B | 482.68 e A | 493.08 f |
| PMK-01 | 449.50 h A | 514.60 f A | 469.50 e A | 477.87 f |
| SBD-04 | 353.90 ef A | 413.90 e B | 403.90 d B | 390.57 e |
| WTN-22 | 346.90 ef A | 331.90 d A | 339.40 c A | 339.40 d |
| INPAGO 7 | 418.70 gh A | 513.85 f C | 465.28 e B | 465.94 f |
| Aks-Htm-12 | 314.10 de A | 340.90 d A | 320.00 c A | 325.00 d |
| Aek Sibundong | 412.20 gh A | 431.75 e A | 414.48 d A | 419.48 e |
| Mean (EL) | 328.00 A | 386.83 C | 358.99 B | |

Note: Numbers followed by the same letter (s) are not significantly different by post hoc DMRT (0.05). Uppercase indicates comparison within the same row while lowercase indicates comparison within the same column

The mean harvesting dates in Kupang, Flores Timur, and Timor Tengah Utara were insignificant, respectively, 135.53, 135.13, and 135.60 days after planting. Across the three locations, mean harvesting date of the tested rice genotypes ranged from 124 days after planting (DAP) (PMK-01 and Aek Sibundong) to 148 DAP (MGP-01 and HK-07). In Kupang location, the shortest harvesting date (128 DAP) was observed in PMK-01 and ADN-04, but was not significantly different from that of Aek Sibundong, ADN-05, ISN-02, KMD-01, NGR-22 (129-131 DAP). The longest harvesting time in Kupang was observed in HK-07 and MGP-01 (143-148 DAP). Aek Sibundong has harvested the fastest (119 DAP) in Flores Timur and was not significantly different from local accessions PMK-01, WTN-22, Aks-Htm-12 and ISN-02 (120-122 DAP). Local accessions PMK-01 and MAU-02 (124 DAP) were harvested earlier in TTU location. MGP-01 and HK-07 were harvested the last in the three locations with average 148 DAP. Thus, it can be said that genetic factors are very dominant in determining the harvesting date in three growing locations.

**Grain yield**

Combined analysis of variance showed that the location and pigmented upland rice genotype by location interaction had a significant effect (P <0.01) on grain weight plot$^{-1}$. This indicates a variation in grain weight plot$^{-1}$ among upland rice genotypes within each location and across the three locations. Variations in grain yield plot$^{-1}$ might have occurred due to differences in genetic factors and their responses to changes in agro-climate environment conditions in the three locations.

The average grain weight plot$^{-1}$ presented in Table 5 shows that, across the three test sites, mean grain weight per plot ranged between 139 g (MGP-01) and 493 g (NGR-22) or equals to 1.39-4.93 t ha$^{-1}$. NGR-022 produced the highest grain yield in each of the three locations (453-543 g plot$^{-1}$, equivalent to 4.53-5.43 t ha$^{-1}$), but not significantly different from PMK-01 (449 – 514 g equals to 4.49-5.14 t ha$^{-1}$) and the check variety Inpago 7 (418-513 g equals to 4.18-5.13 t ha$^{-1}$). This indicates that these cultivars have high yield potential in the dryland conditions of NTT Province during the dry season.

**Discussion**

The present study results (Table 2) revealed variation in panicle number per plant across the three test locations, indicating that each test location has different agro-climatic conditions, such as soil fertility, temperature, humidity, etc., and each rice genotype has different responses to variations in the environmental conditions. The number of panicles per plant, according to Sunihardi et al. (2004), can be classified into four groups, i.e., low (9-11 panicles), moderate (12-14 panicles), high (15-20 panicles) and very high (>20 panicles). Based on these criteria, the number of panicles of the tested red and black upland rice varieties from NTT Province ranged between low to high categories.

Plant height of the tested rice genotypes was significantly affected by genotype by locations, which means that the genotypes had variation in plant height when they were planted in different locations. The check variety Aek Sibundong had the shortest plant height (68.75 cm) across the three locations, but was not significantly different from local cultivar KMD-01 (72.73 cm), indicating that shorter plant height of these two genotypes was genetically controlled. According to Suparyono dan Setyono (1993), short plant height is one of preferable traits of rice since this trait can prevent the rice plant from lodging caused by extreme weather conditions such as heavy rain and wind. Siregar et al. (2003) explained that plant height is related to photosynthesis process. Shorter plants absorb more sunlight as compared to the taller ones, since the sunlight more easily penetrates their canopies. Such two advantages of short plant height are supposed to be responsible for higher yield of most superior varieties (Yoshida 1981).

Mean harvesting dates of tested rice genotypes across the three locations ranged from 124.22-148.33 days after planting, which are, in general, classified as medium to late maturity based on the harvesting date category for rice, i.e., a) short maturity: 100-115 days, b) medium maturity: 116-125 days, and c) late maturity: 126-150 days (Siregar et al. 2013). Only three genotypes were medium maturing genotypes, i.e. ISN-02, PMK-01, and Aek Sibundong while the rest were late maturing genotypes. Genotypes with low to medium maturity types are more suitable for dryland areas with short rainy seasons such as East Nusa Tenggara Province, which has only about 3-4 months of rain during a year.

Table 5 shows variation in grain yield and also a slight change in the ranking of the genotypes in different locations. This indicates the existence of the effect of upland rice genotype by environmental interaction. From plant breeding perspective, the presence of genotype by environment interaction indicates specific adaptation. However, data in Table 5 also show that several rice cultivars (NGR-022, PMK-01, INPAGO7, and Aek Sibundong) produce consistently high grain yield irrespective of the change of environment/location. This shows that these rice genotypes have wide adaptability and yield stability in diverse agro-climate conditions (Yan and Kang 2003; Baafi and Safo-Kantanka 2008). Rice genotype with stable yield under various environments shows wide adaptability. The two local cultivars NGR-022 and PMK-01 had also been found to be drought tolerant and high yielding in an earlier study by Mau et al. (2019). Thus, the local red and black upland rice cultivars from NTT; NGR-22 and PMK-01 can be used as the parental source for the generation of new superior varieties or can be directly proposed as local superior varieties with stable and high yield.

In conclusion, the present study results showed genotype by location interaction effect on all observed variables except for the number of panicles per plant. Five genotypes were found to produce an average grain yield of $\geq 4.0$ t $ha^{-1}$ in the three locations, i.e., NGR-022, PMK-01, ADN-05, Inpago 7 and Aek Sibundong. These rice genotypes produced high and stable yields, and thus, have wide adaptability to environmental conditions of East Nusa Tenggara Province. Thus, they can be used as parental sources for generation of new superior varieties and, the local cultivars can be directly proposed as superior varieties with specific adaptation for environmental conditions of East Nusa Tenggara Province.

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# The effect of cattle manure and mineral fertilizers on soil chemical properties and tuber yield of purple-fleshed sweet potato in the dryland region of East Nusa Tenggara, Indonesia

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Manuscript received: 27 August 2019. Revision accepted: 7 December 2019.

**Abstract.** *Nur MSM, Arsa IGBA, Malaipada Y. 2019. The effect of cattle manure and mineral fertilizers on soil chemical properties and tuber yield of purple-fleshed sweet potato in the dryland region of East Nusa Tenggara, Indonesia. Trop Drylands 3: 56-59.* Sweet potato is potential crop developed in dryland regions, yet the yield is deemed low due to poor soil conditions. Thus, fertilizers are often needed to improve soil quality, leading to increasing tuber yield. A field experiment was carried out to study the effect of combination of cattle manure and mineral fertilizer on the soil chemical properties and yield of purple sweet potato. The experiment was arranged in a Randomized Block Design, with six treatments and four replicates. The assigned treatments were P0 = without manure and without mineral fertilizer, $P_1$ = 100% recommended dosage of manure (20 tons ha$^{-1}$), $P_2$ = 75% recommended dosage of manure (15 tons ha$^{-1}$) + 25% recommended dosage of mineral fertilizer (25 kg urea ha$^{-1}$, 25 kg SP-36 ha$^{-1}$ and 37.5 kg KCl ha$^{-1}$), $P_3$ = 50% recommended dosage of manure (10 tons ha$^{-1}$) + 50% recommended dosage of mineral fertilizer (50 kg urea ha$^{-1}$, 50 kg SP-36 ha$^{-1}$ and 75 kg KCl ha$^{-1}$), $P_4$ = 25% recommended dosage of manure (5 tons ha$^{-1}$) + 75% recommended dosage of mineral fertilizer (75 kg urea ha$^{-1}$, 75 kg SP-36 ha$^{-1}$ and 112.5 kg KCl ha$^{-1}$), and $P^5$ = 100% recommended dosage of mineral fertilizer (100 kg urea ha$^{-1}$, 100 kg SP-36 ha$^{-1}$, 150 kg KCl ha$^{-1}$). The results showed that $P_1$ and $P_2$ treatments produced the highest contents of organic-C, total-N, available-P, exchangeable-K and soil Cation Exchange Capacity. However, the highest tuber weight was obtained in treatment $P_3$. These results indicated that the combination of 50% recommended manure dosage (10 tons ha$^{-1}$) + 50% recommended mineral fertilizer dosage (50 kg urea ha$^{-1}$, 50 kg SP-36 ha$^{-1}$ and 75 kg KCl ha$^{-1}$) could provide a balanced nutrient content in sufficient quantities that meet the sweet potato requirements from the early growth stage to the tuber formation stage, and create soil physical conditions that support the sweet potato tuber development.

**Keywords:** Purple fleshed sweet potato, soil chemistry

## INTRODUCTION

Sweet potato (*Ipomoea batatas* L. (Lam) is one of the potential food crops that can be used as the main staple food – other than rice and corn – since the sweet potato tuber contains high carbohydrates (± 28%). In Indonesia, the average national sweet potato productivity is about 16 t ha$^{-1}$, which is still far below the potential yield of superior varieties of sweet potatoes which can reach 25-40 t ha$^{-1}$ (BP 2015). The low productivity of sweet potato in Indonesia, particularly in the dryland region such as East Nusa Tenggara (NTT) Province, is caused by many factors, including poor soils and crop management, especially fertilizer application. In general, farmers do not apply fertilizers for sweet potato crop, although there are many sources of fertilizer, such as cattle manure that is abundantly available in the vicinity of agricultural areas and settlements.

The nutrient requirement in sweet potato cultivation can be met through a combination of organic and inorganic/chemical fertilizers. The use of organic fertilizer can improve soil structure, and eventually provide better root growth. Furthermore, inorganic fertilization can fulfill the high nutritional needs of sweet potatoes. This high nutrient requirement can not be met only by providing organic fertilization, except if it is provided in a high dosage which often cannot be afforded by the farmers. The combination of inorganic/chemical fertilizers and organic fertilizers is an ideal alternative as these fertilizers combinations are able to meet the needs of the crop and also can maintain sustainable production and soil fertility.

The effect of a combination of inorganic and organic fertilizers on sweet potatoes has been reported by many studies. Salawu and Muktar (2008) recommended the use of 5 to 10 t ha$^{-1}$ cattle manure combined with NPK inorganic fertilizer. Meanwhile, the combination of NPK (15:15:15) at rates of 300 kg ha$^{-1}$ with 3.2 t ha$^{-1}$ of chicken manure produced the highest sweet potato yield in Ultisols (Omenka et al. 2012). This study also recommended the application of a combination of moderate rates of inorganic fertilizers (150-300 kg NPK ha$^{-1}$) with 2-3 t ha$^{-1}$ of manure for sweet potato cultivation in Ultisols with low to moderate soil fertility.

In Indonesia, in general, the recommended inorganic fertilizer rate for sweet potato fertilization is 100-150 kg of

Urea + 100 kg SP-36 + 150 kg KCl – $ha^{-1}$ (Saleh et al. 2008). However, the application of such fertilizers is also recommended to be applied in combination with organic fertilizers, such as manure, with rates of 3-5 t $ha^{-1}$. Many studies have also been carried out under proportional combination of organic and inorganic fertilizers on sweet potatoes. However, study on the effect of these fertilizers combination on a specific variety of purple sweet potato particularly in the dryland region with alkaline soils such as in East Nusa Tenggara Province, Indonesia is limited. The present study was aimed to (i) evaluate the effect of a combination of organic (cattle manure) and inorganic fertilization on the soil physical and chemical properties and the yield of purple sweet potato, and (ii) identify the best fertilizer combination for purple sweet potato grown on alkaline soils.

## MATERIALS AND METHODS

### Research location and materials

The experiment was conducted in the Integrated Field Laboratory of Archipelagic Dryland Center of Excellence, Universitas Nusa Cendana, Kupang, East Nusa Tenggara, Indonesia (10º09"15.34" S and 123º4012.47" E), commencing from November 2017 to March 2018. The average annual rainfall was 1,539 mm with the wet season occurring for three months from December to March/April. Average daily air temperature was 31ºC and relative humidity was 82%. The soil type is classified as a Typic Ustropept (Soil Survey Staff 1998) containing 34% clay. Materials used in this study were a purple sweet potato variety, cattle manure, and inorganic/mineral (NPK) fertilizer.

### Experimental design

The experiment was arranged in a Randomized Block Design with six treatments and four replicates. The assigned treatments were $P_0$ = without manure and without mineral fertilizer (Control), $P_1$ = 100% recommended dosage of manure (20 tons $ha^{-1}$), $P_2$ = 75% recommended dosage of manure (15 tons $ha^{-1}$) + 25% recommended dosage of mineral fertilizer (25 kg urea $ha^{-1}$, 25 kg SP-36 $ha^{-1}$ and 37.5 kg KCl $ha^{-1}$), $P_3$ = 50% recommended dosage of manure (10 tons $ha^{-1}$) + 50% recommended dosage of mineral fertilizer (50 kg urea $ha^{-1}$, 50 kg SP-36 $ha^{-1}$ and 75 kg KCl $ha^{-1}$), $P_4$ = 25% recommended dosage of manure (5 tons $ha^{-1}$) + 75% recommended dosage of mineral fertilizer (75 kg urea $ha^{-1}$, 75 kg SP-36 $ha^{-1}$ and 112.5 kg KCl $ha^{-1}$), and $P_5$ = 100% recommended dosage of mineral fertilizer (100 kg urea $ha^{-1}$, 100 kg SP-36 $ha^{-1}$, 150 kg KCl $ha^{-1}$). Each treatment had four replicates, thus, 24 experimental units were evaluated.

### Research procedures

*Field preparation and plant cultivation*

The planting field was cleared from weeds, plowed as deep as 30 - 40 cm, and then grazed. Twenty-four single row planting plots, each measuring 3 m x 1 m with a 30 cm deep, were made. Space between blocks was 100 cm while between plot spacing was 70 cm. At two weeks before planting, cattle manure was applied to each planting plot according to the treatment. The NPK fertilizers (16:16:16) were applied at early planting time with rates according to the treatment assigned.

Sweet potato stems were cut into 25-30 cm in length with 4-5 nodes each was used in the experiment. The cutting stems were produced from two months old purple sweet potato plant. Each plot was planted with 5 cuttings with a spacing of 50 cm within the plot. Each planting hole was planted with one cutting. One-third or 1-2 nodes of lower part of the cutting were inserted into the planting hole, and the remaining two-thirds of the cutting was left above the ground. Irrigation was done twice a day to reach a field capacity level. Weeding was carried out manually using hand or knife. Harvesting was done four months after planting.

*Soil sampling and laboratory analysis*

Sampling of soil for chemical analysis was done before planting and after harvesting period. Chemical property analysis of cattle manure was done before planting sweet potato. Soil samples were taken from each planting plot.

Soil samples and cattle manure were sieved (1.0 mm). pH-$H_2O$ (1:10 w/v) was measured using a pH meter (Jenway 3305), C-organic was determined based on the Walkley and Black method (Association of Official Agriculture Chemists 2002), total nitrogen was determined – using the Kjeldahl method (American Society of Agronomy and Soil, 1982), Available-P was determined using Olsen method and measured by using a spectrometer (Spectronic 21 D), K was extracted based on the basic oxidation method with $HNO_3$ and $HClO_4$ (Association Official Agriculture Chemists 2002) and measured by using an AAS

### Variables and data analysis

Observed data included chemical properties of soil before planting and at harvest, nutrients content (N, P, K) of cattle manure, and fresh tuber yield of sweet potato. Fresh tuber yield was harvested from each planting plot and weighed. Only the marketable tuber yield (≥200 g each) was included in the measurement of tuber yield. Observed data were subjected to Analysis of Variance (ANOVA) according to the assigned treatment following the procedure in Gasperz (1992). A Duncan Test (DMRT) (5% significance level) was used to separate the treatment means.

## RESULTS AND DISCUSSION

### Chemical properties of soil and cattle manure (before experiment)

Chemical properties of the soils and cattle manure are presented in Table 1. This table shows that before planting, the soil pH ($H_2O$) was 7.7, C-organic content was 0.26%, available P (Olsen) was 9.28 ppm, CEC was 31.67 cmol $kg^{-1}$ and K content was 0.87 cmol $kg^{-1}$. The chemical properties of cattle manure used were pH ($H_2O$) 7.8, organic-C content was 30.9%, total-N was 1.66%, available

P was 0.22%, CEC was 113.33 cmol kg$^{-1}$ and exchanged K was 110%. The chemical characteristics of soil and cattle manure are presented in Table 1.

**Chemical properties of soil at harvest and sweet potato yield**

The effect of combination of cattle manure and NPK mineral fertilizer treatment on soil chemical properties and sweet potato tuber yield is presented in Table 2. ANOVA results showed that cattle manure and mineral NPK fertilizer significantly or highly significantly affected both soil chemical properties at harvest as well as purple sweet potato tuber yield.

The experimental results presented in Table 2 show that the application of cattle manure and inorganic fertilizer into the soil increased the content of organic-C, total N, available P, exchanged-K contents as well as soil Cation Exchange Capacity (CEC). The highest content of C, N, P, K, and CEC was observed in the treatment of $P_1$ (20 t ha$^{-1}$ cattle manure) and $P_2$ (15 t ha$^{-1}$ cattle manure + 25 kg urea ha$^{-1}$, 25 kg SP-36 ha$^{-1}$ and 37.5 kg KCl ha$^{-1}$).

The organic-C content of manure used was 30.86%, so the application of cattle manure at a dosage of 20 t ha$^{-1}$ was equivalent to 6,172 kg org-C ha$^{-1}$, while the dose of 15 t ha$^{-1}$ of manure was equivalent to 4,629 kg org-C ha$^{-1}$. Decomposition of organic matter is a fundamental process that occurs when the material is immersed in the soil. Some of the immersed organic material will be utilized by soil microorganisms as an energy source; some are oxidized and produce $CO_2$ emissions into the atmosphere, some of the organic matter, altogether with microorganisms, will die and become residues left in the soil. In line with the decomposition process of manure occurs in the soil, Nur et al. (2014) reported that decomposed cattle manure lost about 1.42 ln(t)% organic-C per day, and after 120 days, the loss of organic-C reached 36.5%, meaning that 63.5% of organic-C are still stored in compost material. Therefore, manure that is immersed in the soil will undergo a gradual decomposition, and after 120 days, it will leave a residue thereby increasing the soil's organic-C content.

The data in Table 2 also shows that the use of manure as a soil conditioner affects the soil total N content. The highest soil total N content was observed in treatments $P_1$ and $P_2$ (application of cattle manure at a dosage of 20 t ha$^{-1}$ and 15 t ha$^{-1}$). This is because the nitrogen content of cattle manure is 1.66% so that a dosage of 20 t ha$^{-1}$ is equivalent to 332 kg N ha$^{-1}$ or similar to 738 kg urea ha$^{-1}$. Meanwhile, cattle manure at a dose of 15 tons ha$^{-1}$ is equivalent to administering 249 kg N ha$^{-1}$ or 554 kg urea ha$^{-1}$. Manure applied to the soil will undergo decomposition, some of the Nitrogen is used by microorganisms for its growth, some will be absorbed by plant roots, some will be washed away with drainage water and some others will experience volatilization into the atmosphere in the form of $NH_3$. According to Tiquia and Tam (2000), initial C:N ratio of composted material below 20:1 contributed significantly to Nitrogen loss through $NH_3$ volatilization. (C: N ratio of manure used was 18.59). When soil organisms die, together with N residues from existing manure will contribute to soil total N. In line with the process of decomposition of manure that occurs in the soil, Nur et al. (2014) reported that decomposed manure experienced a total N-loss of 39.1% during 120 days of decomposition, implying that 60.9% of total N was still stored in compost material. Manure that is immersed in the soil, therefore, will undergo a gradual decomposition, and after 120 days, it will leave a residue, thus, increases the soil's total-N content.

**Table 1.** Chemical properties of soil (before planting) and cattle manure

| Chemical property | Soil | Cattle manure |
|---|---|---|
| Organic- C (%) | 1.30 | 30.86 |
| Total N (%) | 0.26 | 1.66 |
| C/N ratio | 5.00 | 18.59 |
| P-available (Olsen) (ppm) | 9.28 | - |
| (%) | - | 0.22 |
| Exchangeable-K (cmol kg$^{-1}$) | 0.87 | - |
| (%) | - | 1.10 |
| CEC (cmol kg-1) | 31.67 | 113.33 |
| pH ($H_2O$) | 7.75 | 7.8 |

**Table 2.** Effect of combined treatment of cattle manure and NPK mineral fertilizer on soil chemical properties and tuber yield of purple sweet potato

| Treatment | Org-C (%) | Total-N (%) | Available-P (ppm) | Exch-K (cmol kg$^{-1}$) | CEC (cmol kg$^{-1}$) | Tuber yield (kg per plant) |
|---|---|---|---|---|---|---|
| $P_0$ | 1.25 a | 0.14 a | 20.95 a | 0.68 a | 33.67 a | 0.85 a |
| $P_1$ | 1.67 b | 0.29 c | 33.96 d | 1.16 d | 41.76 b | 0.95 a |
| $P_2$ | 1.60 b | 0.28 c | 32.16 cd | 1.15 cd | 41.38 b | 0.93 a |
| $P_3$ | 1.53 b | 0.26 bc | 29.25 c | 1.11 b | 38.99 a | 1.36 b |
| $P_4$ | 1.46 ab | 0.22 b | 25.89 b | 0.99 b | 35.71 a | 0.94 a |
| $P_5$ | 1.22 a | 0.16 a | 22.53 a | 0.74 a | 33.51 a | 1.06 a |

Note: Numbers within the same column followed by the same letter(s) are not significantly different at 0.05 DMRT. $P_0$ : without manure and without mineral fertilizer. $P_1$ : 100% recommended dosage of manure (20 tons ha$^{-1}$). $P_2$ : 75% recommended dosage of manure (15 tons ha$^{-1}$) + 25% recommended dosage of mineral fertilizer (25 kg urea ha$^{-1}$, 25 kg SP-36 ha$^{-1}$ and 37.5 kg KCl ha$^{-1}$). $P_3$ : 50% recommended dosage of manure (10 tons ha$^{-1}$) + 50% recommended dosage of mineral fertilizer (50 kg urea ha$^{-1}$, 50 kg SP-36 ha$^{-1}$ and 75 kg KCl ha$^{-1}$). $P_4$ : 25% recommended dosage of manure (5 tons ha$^{-1}$) + 75% recommended dosage of mineral fertilizer (75 kg urea ha$^{-1}$, 75 kg SP-36 ha$^{-1}$ and 112.5 kg KCl ha$^{-1}$). $P_5$: 100% recommended dosage of mineral fertilizer (100 kg urea ha$^{-1}$, 100 kg SP-36 ha$^{-1}$, 150 kg KCl ha$^{-1}$)

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The application of manure also increased the available P content of the soil (Table 2), and the highest increase in available P occurred in treatments $P_1$ and $P_2$ (application of cattle manure at a dosage of 20 t $ha^{-1}$ and 15 t $ha^{-1}$, respectively). The phosphorus content in manure was 0.22%, thus, a dose of 20 t $ha^{-1}$ is equivalent to 44 kg P $ha^{-1}$ or 140 kg SP-36 $ha^{-1}$. Whereas, a dose of 15 t manure $ha^{-1}$ is equivalent to 33 kg P $ha^{-1}$ or 105 kg SP-36 $ha^{-1}$. The soil of the experiment site was calcareous with a very high total P content (417.28 ppm). Although the total P content of the soil was very high, the available P was very low (9.28 ppm) or only about 2.2% of the total P (Nur 2014, 2015). Manure applied to the soil during decomposition will produce humic acid and fulvic acid, which can chelate calcium in the soil so that the P sorption by Ca decreases and, hence, the availability of P increases. Nur et al. (2014) reported that the P content available in calcareous soil could be increased by 43.6% by applying cattle manure compost.

Data in Table 2 also shows that the use of manure as soil ameliorant affected soil exchangeable K content. The highest soil exch.-K content was observed in $P_1$ and $P_2$ treatments (application of cattle manure at a dosage of 20 t $ha^{-1}$ and 15 t $ha^{-1}$, respectively). High exch-K content in these two treatments did occur because the potassium content of manure was 1.10%, thus, a dose of 20 tons $ha^{-1}$ is equivalent to application of 220 kg K $ha^{-1}$ or 530 kg KCl $ha^{-1}$. A manure dose of 15 t $ha^{-1}$ is equivalent to application of 165 kg K $ha^{-1}$ or 398 kg SP-36 $ha^{-1}$.

The application of manure also increased soil CEC content (Table 2). The highest increase in CEC occurred in treatments $P_1$ and $P_2$ (application of cattle manure at a dosage of 20 t $ha^{-1}$ and 15 t $ha^{-1}$, respectively). The increase in CEC of soil fed with manure is thought to originate from oxidation of the carboxyl, phenolic and alcoholic groups possessed by humic and fulvic acids produced in the decomposition process of the manure. According to Stevenson (1994), humic acid and fulvic acid have a chemical structure similar to the same OH-phenolic acidity (310 cmol $kg^{-1}$), however, fulvic acid has higher OH-alcoholic acidity (500 cmol $kg^{-1}$) than humic acid (260 cmol $kg^{-1}$).

Although the improvement in soil chemical properties (increase in content of C, N, P, K and CEC) occurred the best in $P_1$ and $P_2$ treatments (application of cattle manure at a dosage of 20 t $ha^{-1}$ and 15 t $ha^{-1}$, respectively), data in Table 2 shows that the highest purple sweet potato tuber yield was produced not in $P_1$ and $P_2$ treatments but in $P_3$ treatment (application of 50% manure or 10 tons $ha^{-1}$ + 50 kg Urea $ha^{-1}$, 50 kg SP-36 $ha^{-1}$ and 75 kg KCl $ha^{-1}$). These results indicate that a combination of 50% recommended dosage of manure + 50% recommended dosage of mineral fertilizer was able to provide a nutrient balance in an adequate amount of sweet potato requirements from the early growth to the formation of tubers, and created a physical condition of the soil that supports tuber development. In the early period of sweet potato growth, the cattle manure was just started to decompose (mineralization), thus, it has not been able to provide sufficient quantity of nutrients to support optimum plant growth; the role of manure as a nutrient source is carried out by inorganic fertilizers or mineral fertilizers. In this circumstance, the role of fertilizer as nutrient provider can be prepared through a combination of organic fertilizer and inorganic fertilizer throughout the vegetative growth phase until tuber formation and enlargement phases.

In conclusion, based on the present study results and discussion, it can be concluded that the treatments of $P_1$ (20 tons $ha^{-1}$) and $P_2$ (15 tons manure $ha^{-1}$ + 25 kg urea $ha^{-1}$ + 25 kg SP-36 $ha^{-1}$ + 37.5 kg KCl $ha^{-1}$) produced the highest C-organic, total N, available P, and exch-K and CEC. However, the highest tuber yield was obtained at $P_3$ treatment (10 tons manure $ha^{-1}$ + 50 kg urea $ha^{-1}$ + 50 kg SP-36 $ha^{-1}$ + 75 kg KCl $ha^{-1}$). A combination of 50% recommended rates of manure (10 t $ha^{-1}$) + 50% recommended rates of mineral fertilizer (50 kg Urea $ha^{-1}$, 50 kg SP-36 $ha^{-1}$ and 75 kg KCl $ha^{-1}$) was able to provide nutrient balance in a sufficient amount of purple-fleshed sweet potato requirements from the initial growth period to the tuber formation period, and created soil physical conditions that support the tuber development.

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# Adaptation strategies of small-scale agriculture production to climate change impacts in Micheweni, Tanzania

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**Abstract.** *Bakari MS, Abdallah JM, Hella JP. 2018. Adaptation strategies of small-scale agriculture production to climate change impacts in Micheweni, Tanzania. Trop Drylands 3: 60-75.* The impacts of climate change in the form of prolonged drought, low rainfall, increasing temperature and sea level rise are predicted to affect developing nations especially in the dryland region such as in Africa. This study was conducted in three Shehias within Micheweni district, Pemba, Tanzania to assess the extent of climate change impacts and crop yields. Specifically, the study aimed to identify and assess climate change impacts to small scale farmers, assess the link between precipitation, temperature, sea-level rise, crop/fish production, identify and assess climate change adaptation strategies by small-scale farmers in the District. Primary data were obtained through focus group discussions, key informants, and households. Household questionnaires and checklists were used to collect both qualitative and quantitative data to obtain information from respondents. In each Shehia, a sample of 30 households was randomly selected from the register for household interviews. Climate data were obtained from Pemba Meteorological Headquater at Chake Chake Airport and the Matangatuani station. Secondary data were extracted from literature review. Data analysis was done using Excel (to get descriptive statistics), Statistical Package for Social Sciences (SPSS), correlation analysis and content analysis methods. The trend of climate measured for the last 30 years showed decreasing precipitation and increased temperatures. The highest annual average rainfall was 196.2 mm (1986) and the lowest 72.5 mm (2001) measured at the Matangatuani Meteorological station. Crop failure, low crop production, soil infertility, crop pests/diseases and seawater intrusion were major climate change impacts. Results indicated annual decrease in crop production in the past 10 years, with pests and diseases, uneven distributed low rainfall and extended drought periods. Crop rotation, use of improved seeds and new crop varieties, fertilizer application, irrigation, mixed cropping, and adjusting sowing dates were some of adaptation strategies. Seawater rise and intrusion constrained paddy farm production where fish and salt farming contributed to environmental degradation in farming areas. The decrease in crop production resulted mostly from climate variations; hence community should establish short-term and drought-resistant crops.

**Keywords**: Adaptation strategies, climate change, small scale farming

## INTRODUCTION

Climate change is a global problem; although the associated impacts and adaptation strategies vary across the world (Ehrhart and Twena 2006; New et al. 2006). Developing countries are expected to be severely affected by climate change (Kurukulasuriya and Mendelsohn 2008). These countries, especially in Africa, are reported to be more vulnerable to climate change impacts because majority of the population depends on rain-fed agriculture for food and livelihoods at large (Boko et al. 2007; IPCC 2007; Morton 2007). Climate variability has a direct adverse influence on agricultural production in Africa because nearly 80% of agricultural production in these countries is rainfall and temperature-dependent (Thornton 2011).

Over the past few decades, the continent has experienced increased number of warm days and decreased number of extremely cold days (New et al. 2006). Spatial and temporal variability of rainfall and temperature, more intense and widespread droughts and aggravated floods have been common during the period (Deressa and Hassan 2009). These changes alter the type of agricultural crops, cropping patterns and lead to emergence of crop diseases (Bosire 2009). For poor rain-fed agriculture-dependent communities, change in rainfall and temperature patterns compound existing vulnerabilities. Heavy dependence on natural climate places livelihoods at risk of climate parameters (i.e. in situ rainfall and temperature) as the stability of the trends of these climatic parameters declines, so does the security of their livelihoods (Suryavanshi et al. 2012).

Limited resources and capacities to respond to stresses (floods, drought and emergence of crop diseases) caused by instability of these climatic parameters constrain the ability to meet basic needs and move out of poverty. In recent years, Tanzania has experienced crop failure due to low rainfall and emerging crop diseases in many parts (Mtalo et al. 2005). Likewise, in other developing countries the climate change impacts have been unavoidable and can lead to widespread poverty if community has not been prepared to adapt to the situation. Currently, this climate is found to be highly variable and unpredictable and the country is prone to extreme weather conditions, including droughts and floods (Agrawala et al. 2003).

Recent data shows that temperature has increased and precipitation decreased in many areas of Tanzania. The average annual temperature is projected to increase by

2.2°C and rainfall to decrease by 100 mm by year 2100 (Houghton et al. 2001; Agrawala et al. 2003; URT 2003, 2007). In this country, where irrigation is very limited and almost the production of all food and cash crops depends on rainfall, changes in climatic parameters are expected to severely have affected crops and cropping pattern. However, little attention has been paid to relate climatic parameters variation with changes in type of crops and emergence of crop diseases.

The objectives of the study were: (i) To identify and assess climate change impacts on small-scale farmers in Micheweni District, Tanzania. (ii) To assess the link between precipitation, temperature, sea level rise and crop/fish production in the District. (iii) To identify and assess climate change adaptation strategies undertaken by small-scale farmers in Micheweni District.

## MATERIALS AND METHODS

### Study area

*Location and climate*

This study was conducted in Micheweni Constituency which is comprised of three Shehias/villages: Mjini wingwi, Majenzi and Micheweni (Figure 1). Micheweni District is located in the North-Eastern part of Pemba Island comprising of 27 administrative Shehias. Pemba Island is part of Zanzibar archipelago along with the other sister island of Unguja and numerous small islands and islets. Pemba is located in the Indian ocean about 60 km East of Tanzania mainland and lies between longitude 39° and 40° East and between latitude 4°50' and 6°30'South, covering 920 km² (Figure 1).

Temperature ranges between 21°C at the coolest and 34°C at the warmest. Traditionally, two rain seasons occur in the area: long rains between March and May and short rains between November and December. The mean annual rainfall is about 1860 mm; the long rains averaged 363 mm per month and short rains averaged 175 mm per month.

*Population*

According to the 2012 Census report, Micheweni District has a population of 103,816 inhabitants with an average household size of 5.3, women making up 51%) of the population (URT (2013). The study area population is 13 088 inhabitants, women making 49.5% of the population (URT (2013) (Table 1).

*Culture*

The culture of Micheweni people is almost the same as that of all parts of Zanzibar. Being Muslims, they wear pleasant dresses that identify and differentiate them from other foreign cultures. They live cooperatively in their daily life and this is easily recognized during traditional, wedding and funeral ceremonies. *Khanga* and headscarf (kilemba) are the most conspicuous, enjoyable and appreciated dress for women and dishdasha (*Kanzu*) with sewn caps for men. On all occasions, it is very rare to see the naked head of a mature woman. Apart from being sent to school for basic education, *Madras* and Islamic education is a necessity for children. Dances and drama are normal performances during weddings, public, religious holidays and political ceremonies. The long-time hospitality of the people is still recognized and valued. Men mostly appear to be household heads performing large parts of the daily work particularly farming and fishing activities while women engage in paddy farming, house chores handicrafts, and child caring.

*Economic activities*

According to ZBS (2010) report, Micheweni people depend mostly on subsistence agriculture as the major income-generating activity for their livelihoods. Other economic activities of the District include fishing, livestock and poultry farming, sea-weed farming, small business enterprises and lime making. Most of the land is coral rag supporting the growth of shallow-rooted cereal crops such as millet, sorghum, maize, finger millet, cassava, bananas among others. Tree planting for household consumption and sale, stone and brick mining are other socio-economic activities of the population. Paddy farming, which is highly affected by seawater intrusion, is also a common practice in lowlands. Information from DADO office shows that for 2013, Micheweni comprised 2317 farmers practicing subsistence farming in various areas.

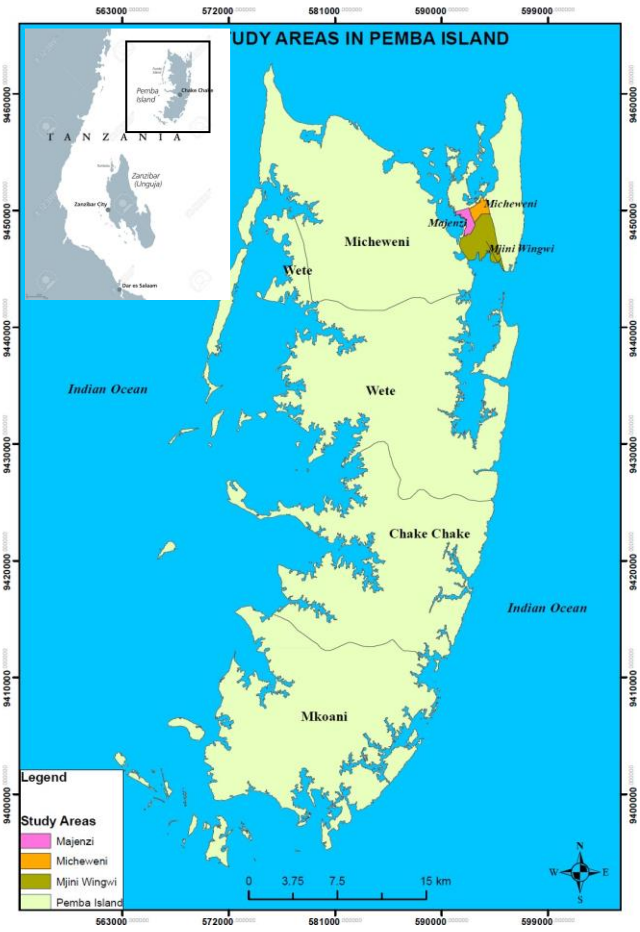


**Figure 1.** Map of Pemba Island, Tanzania showing study areas in Micheweni District

*Fishing*

Fishing which is mainly practiced by men is the second income-generating activity of Micheweni people after agriculture. Fish constitutes the most important source of protein in Zanzibar, and fisheries are an important economic sector on the island as well as sustaining many livelihoods. The impacts of climate change on fisheries potentially include shifts in species, food chain effects, diseases, and increased ocean acidity. Fish production is so far fluctuating at times, showing increasing and decreasing rates on a monthly and annual basis. Harvesting of fish is permissible to almost all species at maturity although this differs from species to species. The only restricted fish types to harvest are the known endangered and threatened species including dolphins (*Pomboo)*, turtles (*Kasa*), etc. According to Hassan (2010), the fisheries activities were found to be affected by severe wind change to the extent that fishermen have to shift from normal fishing grounds instead to deep-sea though they face acute gear problems.

**Justification of the study area**

Micheweni is the poorest District in Zanzibar with most of the population living at a minimum income of less than 1 US$ per day per household (ZBS 2010). Due to its poor economic condition, the District has been identified as the only Millennium village/District in Zanzibar among other villages in Tanzania. Most economic donations and aids are regularly year after year directed towards this District to combat their livelihood problems believed to be caused by climate variations. Apart from supporting different types of staple and cash crops, the eastern part of Micheweni, where this study was conducted, does not support the growth of Zanzibar's main cash crop (cloves); the highly dependent Zanzibar crop for foreign exchange earnings, economic growth and community livelihoods.

**Research design**

The study used cross-sectional design. Creasey (2006) and Miller (2006) recommended the use of this design because of its high degree of accuracy and precision in social science research. A cross-sectional research design allows the researcher to effectively describe change over time and to identify the various mechanisms associated with those changes. This design allows for relative quick and easy collection of variables only at once.

**Sampling methods**

Purposive sampling was employed to select farmers of both sexes and age not less than 45 years. Higher age group respondents are thought to provide valuable information taking into consideration that climate change data variation needs long periods of time. Respondents included in the study were drawn from three villages divided into strata depending on their level of income; high income (>3000 TZS per day), middle income (1000 to 3000 TZS per day), and low income (<1000 TZS per day). Random sampling was used to select members from each level, thus allowing for equal chances of members participation. Also, the key informants were selected to gather more information with regard to changes in climate change patterns. This included District Agricultural Development Officer, Subject Matter Specialists (Environment and Agriculture) and Village Government leaders representing all the three villages in the area.

**Sample size**

According to information from DADO, Micheweni is comprised of 2317 farmers and it was expected that only 25% of all farmers were at the age of >45 years which is approximately 579 farmers. Matata et al. (2010) argue that a sample size ranging from 80 to 120 is adequate for most of social-economic studies in Sub-Saharan Africa, hence a sample size for this study was 90 respondents representing 30 members from each of the three villages of Micheweni, Mjini wingwi and Majenzi.

According to the District administration plan, each Sheha (Shehia leader) has got ten assistants each representing one of the villages forming the Shehia. In the selection of these 30 members from each Shehia, three members were randomly selected from each village, making a total of 90 members for all three Shehias of the study (Table 1).

**Data collection methods and analysis**

*Identification and assessment of climate change impacts*

Primary data were collected through Questionnaires and Focus group discussions (FGD). Questionnaires were administered to the randomly selected households within each level of income. Both close-ended and open-ended questions were prepared to allow for better responses from the selected respondents. The collected data included identified climate change impacts for the entire period of 30 years and the assessment of the climate change production results per hectare today compared to the past (30) years production data. These data were then analyzed using Statistical Package for Social Sciences (SPSS) to generate descriptive statistics like frequency, mean, percentage and standard deviation while correlation and multiple linear regression analysis were used to test the magnitude of the relationship and influence among dependent variables (crops) and independent variables (climate variables). Qualitative data were analyzed by involving the communities through group discussions where immediate feedback was produced.

In FGD with farmers and Key informants, interview checklists were used to collect information. Key informants included 15 members in each village. The checklists aimed to collect data on the types of climate change impacts they faced with regard to their daily crop production. The impacts were then assessed to check their relation to small scale farming in the District.

**Table 1.** Demographic characteristics in Micheweni District, Pemba Island, Tanzania and sample were drawn

| | Population | | | | |
|---|---|---|---|---|---|
| **Shehia** | **Male** | **Female** | **Total** | **Households** | **Sampled h/h** |
| Micheweni | 3134 | 3063 | 6197 | 1127 | 30 |
| Mjini wingwi | 2305 | 2216 | 4521 | 853 | 30 |
| Majenzi | 1166 | 1204 | 2370 | 423 | 30 |
| Total | 6605 | 6483 | 13088 | 2403 | 90 |

Source: URT (2013)

*Link between climate variables and products in the district*

Secondary data were obtained from literature reviews and other secondary sources to supplement the primary information. Data on temperature and rainfall were collected from the Micheweni District Meteorological Station at Matangatuani while data on sea-level rise were collected from the TMA headquarters at the Chake Chake airport-Pemba. Production data of four crops (i.e., cassava, banana, millet and rice) was collected from District Agricultural Development Office (DADO) while data on fish production were collected from the District Fisheries Office. All information collected on temperature, rainfall, sea-level rise, fish and crop production reflected a period of 30 years back.

Data on temperature, rainfall and sea-level rise were analyzed using Trend analysis method to present patterns and trends of climate in the form of graphs and showing time series on the data collected. Collected information at district level on crops and fish production was analyzed using Statistical Package for Social Sciences (SPSS), while data on the relationship between temperature, rainfall, sea-level rise, and changes in crop production in the district were analyzed using Correlation analysis method.

Correlation analysis method:

$$r = \frac{\sum (X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum (X-\bar{X})^2 \sum (Y-\bar{Y})^2}}$$

Where,

r : Correlation coefficient

X : Independent variables (Temperature, rainfall and sea-level rise)

Y : Dependent variables (Crop yield)

*Assessment of climate change adaptation strategies*

The unit of analysis for this objective was households at Shehia, Ward, District and Region. Households were stratified and within each stratum, a sample of households was selected randomly. Data on identified adaptation practices against climate change impacts were collected from households and assessment was done to check their performance in the last 30 years using household questionnaires.

In-depth interview was done with relevant authorities from Shehia, Ward, District and Region to provide information on adaptation strategies using a checklist (Appendix 3). The required information included the short and long term analysis undertaken by small scale farmers on the use of improved seed varieties (maize, rice, millet, sorghum, etc.) enduring different soil and salt characteristics, drought and unexpected climate regimes. Analysis was also carried out on changes of farming practices and timing of farm operations, increased use of manure and fertilizer, use of cropping mixes, better use of management tools including climate information, use of agriculture extension activities and education on climate change, awareness creation on climate change and adaptation strategies and changes in governmental and institutional policies and programs.

At all administration levels, information was collected on how responsible officers effectively communicate with the Tanzania Meteorological Agency on any early warning systems and issues related to changes in climate patterns and how TMA communicates to regional and lower-level authorities on providing such information to farming communities for implementation. Analysis of these data was done using Content Analysis method.

## RESULTS AND DISCUSSION

### Household Socio-Economic Profile

This entails socio-economic characteristics of the respondents in the study area. It involves respondents' age, education level, sex and marital status, household dependents and income of respondents, type of agricultural crops, land ownership and size of land used for production. These factors are considered to be important when assessing the impacts of climate change and adaptation strategies at household level.

*Demographic characteristics*

The study indicated that 53% of the respondents' age ranged from 45 to 55 years old. This age range is considered to be an effective human capital age as opposed to 2% aged above 76 years (Table 2).

Majority of the sample households were male-headed (73%) the rest were headed by females (27%). About (70%) of the sample households had a primary level of education. The higher number of households with primary education is attributed to a slight increase in the number of educational facilities countrywide. Households with no formal education were about 23% where Mjini wingwi ranked higher for people with no formal education (30%) than other villages in the area, where only (7%) of the respondents had secondary education attainment. This situation automatically brings negative implications towards future development of the District as a whole. The lower the level of education households possess in the area the higher the negative impacts to climate change as far as experiences and skills on adjustment are concerned.

About 78% of the respondents were married compared to only 2% singles with more couples found in Micheweni village (36%). More males were reported in Micheweni village (35%) as compared to more females in Mjini wingwi (38%) and more divorcees were recorded in Micheweni and Majenzi than Mjini wingwi where the highest level of widowed respondents was found in Mjini wingwi village (Table 2). Indications of more divorces in former villages were a result of being closer to district headquarter as compared to Mjini wingwi which is a bit far from the district. This shows the strictness of community in rural villages in preserving their marriage ties than in the urban villages.

*Household incomes*

The study revealed that of the 532 household members from the total surveyed households (90), 442 members were dependants who are almost 83% of the total household members. There were more female dependants

(54%) against 46% of male dependants in the area. More male dependants were observed in Majenzi (35%) compared to more female dependants (37%) in Mjini wingwi (Table 3).

Furthermore, Table 3 shows that most of the income of the respondents was earned from crops production (41%) followed by fishing (20%) and formal employed sector by 18% (Table 3). Agriculture is still the main income-generating activity (IGA) in this District followed by other important IGAs including petty business, seaweed farming, tree planting, stone/bricks mining, salt farming and lime making. Results indicate that Mjini wingwi earn more in crops farming (36%) as compared to Micheweni and Majenzi (33% and 31% respectively), whereas Micheweni earnings are more directed from fishing (40%) and formal employed sector (58%) than Mjini wingwi and Majenzi villages (Table 3).

Similar results were reported by Kangalawe et al. (2009) on climate change and variability impacts, vulnerability and adaptive capacity in Kasulu indicating that majority of the respondents (96.6%) accrued their income from crop cultivation as their main occupation but followed by livestock keeping. Petty business and self-employment were also dominant practices in Micheweni village while in Mjini wingwi income sources were also from bricks mining, beekeeping, and sale of lime and building poles from woodlots for building purposes. The average income per household per day was TZS 1 579 equivalent to 0.71 United States Dollar (Table 3).

*Land ownership and size*

There was a negligible difference between size of land owned and used by community for crop production, where 37% of all respondents were found to own 1 ha of land for cultivation. Community in Micheweni District possesses just small portions of land for crop production due to land scarcity relative to population increase. Further, it was found that 92% of the respondents cultivated their farms twice a year compared to those who farm only once per year. Almost 42% of the respondents have been identified to cultivate on the same piece of land for a period of 21 to 30 years, whereas 27% and 15% were those respondents who cultivated their farms for a duration of 11 to 20 and 31 to 40 years respectively (Table 4).

*Types of agricultural crops*

Results identified millet and cassava as the main staple food crops accounting for almost 54% of all crops grown by households in these Shehias followed by cassava and bananas (13.3%). These crops are widely grown in the area due to the fact that the coral nature of the soil supports well the growth of these crops. Further, the area is semi-arid supporting drought-resistant crops grown at minimum and maximum rainfall and temperatures respectively. Other staple food crops grown at small scale in the District include maize and bananas, rice and millet, rice with bananas, rice and cassava, bananas and millet, millet with maize, cassava and maize and rice with maize (Figure 2). These crops are mostly grown for household consumption, although selling is sometimes also practiced.

**Table 2.** Respondents' characteristics in surveyed villages in Micheweni District, Pemba Island, Tanzania (n=90)

| Socio-economic attributes | Category | Responses | | | |
|---|---|---|---|---|---|
| | | Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. Total (n=90) |
| Age | 45-55 | 18 (60) | 16 (53) | 14 (47) | 48 (53) |
| | 56-65 | 8 (27) | 11 (37) | 9 (30) | 28 (31) |
| | 66-75 | 3 (10) | 2 (7) | 7 (23) | 12 (13) |
| | Above 76 | 1 (3) | 1 (3) | 0 (0) | 2 (2) |
| Gender | Male | 23 (77) | 21 (70) | 22 (73) | 66 (73) |
| | Female | 7 (23) | 9 (30) | 8 (27) | 24 (27) |
| Education level | No formal | 4 (13) | 9 (30) | 8 (27) | 21 (23) |
| | Primary | 23 (77) | 19 (63) | 21 (70) | 63 (70) |
| | Secondary | 3 (10) | 2 (7) | 1 (3) | 6 (7) |
| Marital status | Single | 0 (0) | 1 (3) | 1 (3) | 2 (2) |
| | Married | 25 (83) | 22 (73) | 23 (77) | 70 (78) |
| | Divorced | 2 (7) | 1 (3) | 2 (7) | 5 (6) |
| | Widowed | 3 (10) | 6 (20) | 4 (13) | 13 (14) |

Note: Numbers in parentheses indicate percentages

**Table 3.** Household incomes in Micheweni District, Pemba Island, Tanzania

| Variables | Category | Responses | | | |
|---|---|---|---|---|---|
| | | Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av.Total (n=90) |
| Dependants | Male | 68 (33) | 65 (32) | 72 (35) | 205 (46) |
| | Female | 79 (33) | 88 (37) | 70 (30) | 237 (54) |
| Income (Tshs) | Crops | 6862545 (33) | 7531972 (36) | 6669483 (31) | 21064000 (41) |
| | Fishing | 4235073 (40) | 3190654 (31) | 2961273 (29) | 10387000 (20) |
| | Petty business | 1523000 (36) | 1368100 (32) | 1359800 (32) | 4250900 (8) |
| | Employment | 5349250 (58) | 1256380 (14) | 2554370 (28) | 9160000 (18) |
| | Others | 1969741 (28) | 2908750 (41) | 2143509 (31) | 7022000 (13) |
| | Total | 19939609 | 16255856 | 15688435 | 51883900 |

Note: 1 US$ = 2210 TZS; 1 Year = 365 days

**Table 4.** Land ownership and cropping in Micheweni District, Pemba Island, Tanzania

| Variables | Category | Responses | | | |
|---|---|---|---|---|---|
| | | Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av.Total (n=90) |
| Farm area owned (ha) | 0.5 | 11 (37) | 12 (40) | 9 (30) | 32 (35) |
| | 1 | 11 (37) | 11 (37) | 11 (37) | 33 (37) |
| | >1 | 8 (27) | 7 (23) | 10 (33) | 25 (28) |
| Cultivation seasons | Once | 2 (7) | 1 (3) | 4 (13) | 7 (8) |
| | Twice | 28 (93) | 29 (97) | 26 (87) | 83 (92) |
| Cropping duration (years) | 1-10 | 2 (7) | 3 (10) | 3 (10) | 8 (9) |
| | 11-20 | 8 (27) | 9 (30) | 7 (23) | 24 (27) |
| | 21-30 | 15 (50) | 12 (40) | 11 (37) | 38 (42) |
| | 31-40 | 2 (7) | 4 (13) | 8 (27) | 14 (15) |
| | 41-50 | 2 (7) | 2 (7) | 1 (3) | 5 (6) |
| | 51-60 | 1 (3) | 0 (0) | 0 (0) | 1 (1) |

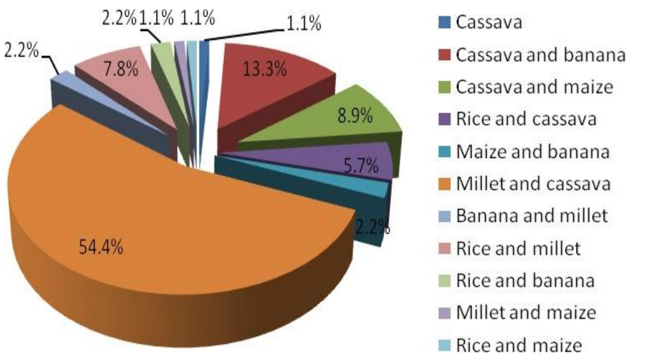


**Figure 2.** Types of agricultural crops grown in Micheweni District, Pemba Island, Tanzania

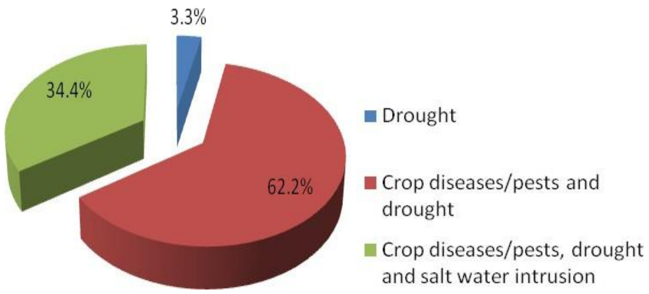


**Figure 3.** Reasons for decreasing crop production in Micheweni District, Pemba Island, Tanzania

## Crop production improvement

*Fertilizer application in respondents' farms*

Of the total respondents interviewed, more than half (57%) reported using fertilizer in their farms while 43% do not use any type of fertilizers. About 45% of those who use fertilizer were reported from Micheweni village against 46% who completely refused the use of any type of fertilizer in their farms reported from Majenzi. The most common fertilizer in use in the District is organic fertilizers (82%) (Table 5). This indicates that most farmers have enough awareness and are oriented on the use of less costly livestock and poultry manure plus other important organic fertilizers locally available within their surroundings. The average crop production per year for those who applied fertilizers in their farms was found to be 1895.3 kg as opposed to 529.3 kg for non-fertilizer users indicating that fertility is a very important factor for high crop production.

*Trends of crop production*

Almost all respondents commented on the annual decreasing trend of crop production in the past 10 years, caused by various factors either under community controls or not. About 23% of the respondents reported crop pests and diseases as the major factors causing the decrease in crop production followed by land/soil infertility and low rainfall (21%), low rainfall per se (18%) and land/ soil infertility associated with crop pests/diseases (18%).

Either, it was observed that 100% of all respondents interviewed face major problems in crop production leading to decreased food security in the district (Table 6). Specifically, 1987, 1994, 1998, 2000, 2004, 2009, and 2010 were reported by the community as years of high food decrease in the area.

Furthermore, all Shehias reported crop diseases/pests and drought (62.2%), and crop diseases/pests associated with drought and saltwater intrusion (34.4%) as among the major reasons for crop decreases (Figure 3).

**Table 5.** Type of fertilizer used by respondents in Micheweni District, Pemba Island, Tanzania

| Variables | Category | Responses<br>Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av.Total (n=90) |
|---|---|---|---|---|---|
| Fertilizer | Yes | 23 (77) | 16 (53) | 12 (40) | 51 (57) |
| | No | 7 (23) | 14 (47) | 18 (60) | 39 (43) |
| | | (n=17) | (n=17) | (n=17) | (n=51) |
| Type | Inorganic | 1 (6) | 5 (29) | 3 (18) | 9 (18) |
| | Organic | 16 (94) | 12 (71) | 14 (82) | 42 (82) |

**Table 6.** Production trend, causes and problems in crop production in Micheweni District, Pemba Island, Tanzania

| Variables | Category | Responses<br>Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av.Tota l (n=90) |
|---|---|---|---|---|---|
| Production | Increasing | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| | Decreasing | 30 (33) | 30 (33) | 30 (33) | 90 (100) |
| Causes | Land/Soil infertility | 1 (1) | 1 (1) | 1 (1) | 3 (3) |
| | Low rainfall | 5 (17) | 6 (20) | 5 (17) | 16 (18) |
| | Crop pests and diseases | 9 (30) | 5 (17) | 7 (23) | 21 (23) |
| | Land/soil infertility and low rainfall | 4 (13) | 8 (27) | 7 (23) | 19 (21) |
| | Drought | 5 (17) | 2 (7) | 3 (10) | 10 (11) |
| | Land/soil infertility and crop pests/diseases | 3 (10) | 7 (23) | 6 (20) | 16 (18) |
| | Land fragmentation | 2 (7) | 0 (0) | 0 (0) | 2 (2) |
| | Unavailability of improved seeds | 0 (0) | 1 (3) | 0 (0) | 1 (1) |
| | Sea level rise during high tides | 1 (3) | 0 (0) | 1 (3) | 2 (2) |
| Problems in production | Yes | 30 (33) | 30 (33) | 30 (33) | 90 (100) |
| | No | 0 (0) | 0 (0) | 0 (0) | 0 (0) |

*Solution to decreased crop production*

With regard to finding best solutions against problems on decreased crop production more than two-thirds of the respondents (67%) were found to have no adopted solution with almost 38% from Mjini wingwi village. Solely use of improved seeds and use of improved seeds with fertilizer application were other suggested solutions for decreasing crop production at 19% and 6% respectively (Table 7). It was learned from this study that most of the households were still lacking appropriate agricultural extension awareness from extension officers at district level.

*Climate trends*

**Rainfall.** Figure 4 shows that there was a decrease in precipitation over the last 30 years. In 1986 the annual rainfall was about 196.2mm compared to 72.5mm in 2001 as recorded at Matangatuani Meteorological Station. In some seasons, rainfall starts earlier while in other seasons comes late and thus interferes with crop schedules and production.

Household surveys revealed the same phenomena. About 90% of the households reported that rainfall has shown a decreasing trend over the past 10 years. Almost, all Shehias (Micheweni, Mjini wingwi, and Majenzi) reported low annual rainfall intensity, unreliable, and uneven distribution during farming seasons (Table 8). All these phenomena contribute to the decrease in crop production (as observed in Section 4.2.2). Other factors believed to contribute to this decrease include loss of nutrient levels damage, use of unqualified seeds and salt intrusion due to pumpage of groundwater.

A study carried out by the University of Pretoria (Lina Häckner, 2009) that sampled 8000 farmers in 11 countries in Africa showed that half of the African farmers perceived a long term decline in precipitation. One-third of the respondents perceived a change in the timing of the rains, and one-sixth perceived droughts to be more frequent compared to the past. Likewise, Lina Häckner (2009) interviewed 9500 farmers in 10 countries in Africa and found that significant number of farmers reported decrease in precipitation. Both studies support the decrease of rainfall in Micheweni district for the past 30 years.

**Temperature.** The recorded temperature for the last 30 years at Matangatuani Meteorological Station varies across the period. In the first half of the period, the trend presented relatively uniform average minimum temperatures. In 1997 the mean temperature dropped to 19.2°C with an abrupt increase to 20.7°C in 1998, while in the second half of the period (1999-2012) the trend of the mean temperature presents a gradual increase of up to 24.4°C in 2012. Figure 5 shows these mean temperatures.

The temperature records were in line with responses from the sampled households where 97% of the respondents reported increase in temperature over the period of the last 10 years (Table 9). Extended periods of temperatures, crop pests, and diseases, soil infertility and decreased rainfall in Micheweni District is the main cause of diminishing crop production (Table 9). The situation has either caused prolonged drought periods leading to death or failure of most crops depended by the community for their livelihood.

**Table 7.** Solution to crop production problems in Micheweni District, Pemba Island, Tanzania

| Variables category | Responses<br>Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av.Total (n=90) |
|---|---|---|---|---|
| Adoption of new farming technology | 0 (0) | 0 (0) | 1 (3) | 1 (1) |
| Use of improved seeds and fertilizers | 2 (7) | 1 (3) | 2 (7) | 5 (6) |
| Solely application of fertilizers | 1 (3) | 1 (3) | 1 (3) | 3 (3) |
| Use of improved seeds | 8 (27) | 3 (10) | 6 (20) | 17 (19) |
| Applying mixed cropping system | 0 (0) | 1 (3) | 1 (3) | 2 (2) |
| Improved seeds and crop rotation | 1 (3) | 1 (3) | 0 (0) | 2 (2) |
| No suggested solution | 18 (60) | 23 (77) | 19 (63) | 60 (67) |

**Table 8.** Response on rainfall characteristics in Micheweni District, Pemba Island, Tanzania (n=90)

| Rainfall | Category | Responses<br>Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av.Tota l (n=90) |
|---|---|---|---|---|---|
| Trend | Increase | 0 (0) | 0 (0) | 1 (3) | 1 (1) |
| | Decrease | 30 (100) | 30 (100) | 29 (97) | 89 (99) |
| Intensity | High rain and for a long time | 0 (0) | 1 (3) | 0 (0) | 1 (1) |
| | High rain and for a very short time | 26 (87) | 24 (80) | 26 (87) | 76 (84) |
| | Low rain and for a long time | 1 (3) | 1 (3) | 0 (0) | 2 (2) |
| | Low rain and for a very short time | 3 (10) | 4 (13) | 4 (13) | 11 (12) |
| Distribution | Even distribution | 0 (0) | 1 (3) | 1 (3) | 2 (2) |
| | Uneven distribution | 27 (90) | 26 (87) | 26 (87) | 79 (88) |
| | No change | 3 (10) | 3 (10) | 3 (10) | 9 (10) |

**Table 9.** Temperature trend and effects to agricultural crops in Micheweni District, Pemba Island, Tanzania (n=90)

| Temperature | Category | Responses | | | |
|---|---|---|---|---|---|
| | | **Micheweni (n=30)** | **Mjini wingwi (n=30)** | **Majenzi (n=30)** | **Av. total (n=90)** |
| Trend | Increase | 29 (97) | 29 (97) | 29 (97) | 87 (97) |
| | Decrease | 0 (0) | 1 (3) | 1 (3) | 2 (2) |
| | No change | 1 (3) | 0 (0) | 0 (0) | 1 (1) |
| Effects | High temperatures | 14 (47) | 8 (27) | 7 (23) | 29 (32) |
| | Death of crops | 0 (0) | 2 (7) | 1 (3) | 3 (3) |
| | Crop pests and diseases | 6 (20) | 11 (37) | 9 (30) | 26 (29) |
| | Low rainfalls | 4 (13) | 5 (17) | 5 (17) | 14 (16) |
| | Sea water rise | 0 (0) | 0 (0) | 1 (3) | 1 (1) |
| | Infertile land | 5 (17) | 4 (13) | 6 (20) | 15 (17) |
| | No effects | 1 (3) | 0 (0) | 1 (3) | 2 (2) |

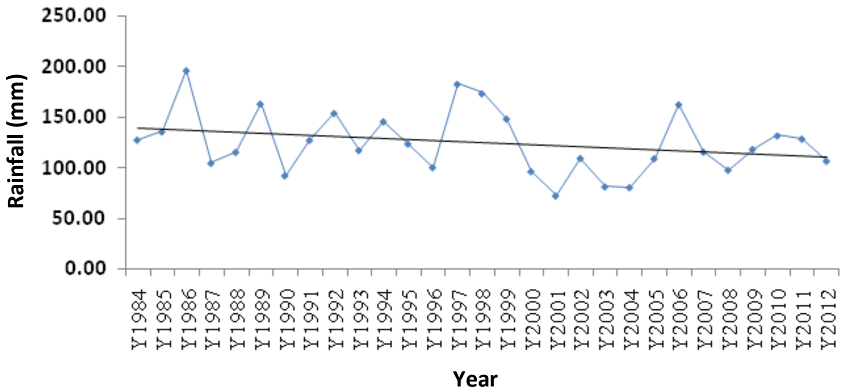


**Figure 4.** Mean annual rainfall (1984-2012) Matangatuani, Micheweni District, Pemba Island, Tanzania (TMA 2014)

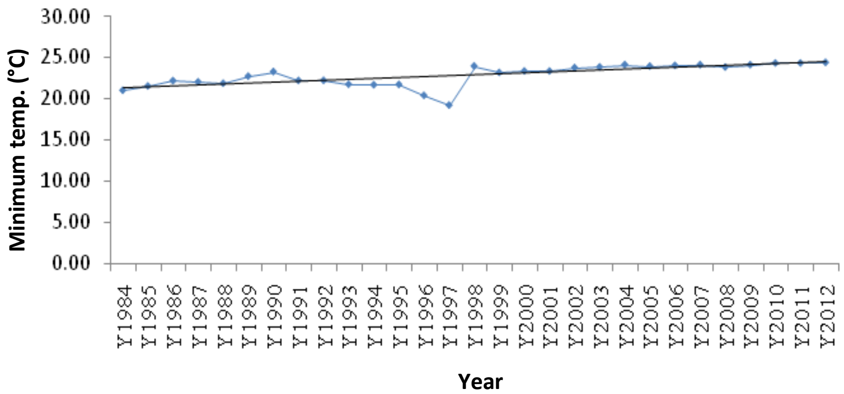


**Figure 5.** Mean annual minimum temperature (1984-2012) Matangatuani, Micheweni District, Pemba Island, Tanzania (TMA 2014)

Results from the temperature measurements reported the increase of mean annual maximum temperatures from 29.5ºC in 1984 to 30.2ºC in 1987 followed by a quick temperature decrease of up to 29.2ºC recorded in 1989. The mean annual temperature increasing trend reached to maximum in 1992 recording a peak of 31.4ºC. This increasing trend of temperatures stipulates signs of crop failure and/or low crop production in the district (section 4.2.2). Figure 6 indicates that although there were relative increasing and decreasing trends of temperatures, the last 18 years up to 2012 recorded almost a regular temperature increasing trend. Results show maximum temperatures with significant correlation to cassava and millet production indicating that whenever there is an increase in maximum temperatures, there is a decrease in crops production. The crops are the two most common food crops in the community. Also, there was a decrease in banana production though it was insignificantly correlated to temperature (Table 10). For the other food crops, for instance, rice and fish products, there was no observed significance between the maximum temperatures and productions. This may be caused by other variable factors like soil infertility, timing of planting, etc.; factors that were not put into considerations.

**Sea level rise.** During the initial years (1985-1997), there was a periodic decrease and increasing rise of sea level followed by an abrupt decreasing and increasing rate between 1997 and 2001 before recording the increasing trend between 2001 and 2011 (Figure 7). Results showed the highest annual average sea level rise of 2110 mm reported in 2010 whereas the lowest was 1980 mm recorded in 2001 with an average increase of 5mm/year (Figure 7). The rise in sea level affected mostly paddy farming in lowland areas as compared to other crops grown in different areas resulting in decrease in rice production. However, for the last 30 years results (Table 10) indicated that fish catch was found to have a significant correlation to sea rise showing the actual decrease in production. In contrast, the highest fish catch (11,400 tons) recorded in 2012 was not reported on the same year of minimum sea-level rise and as well the lowest catch was not observed in maximum sea level season, hence contradicting. In addition to climatic variables collected, the implication of this scenario might be a result of some other variables not put into considerations during data collection. The provision of various advanced fishing gears to fishing community and rise in price of fish products within the internal and external markets could have contributed to this insignificance.

**Comparison of monthly mean sea level height**

For the period of 26 years, Zanzibar experienced a rising trend of sea-level rise which affected most of the paddy farms. The trend shows a slight variation between the long term monthly mean sea level at 20 years and the 2003 monthly mean sea level rise (Figure 8). There was a decrease of long term monthly mean sea level against 2003 means sea level. As well, Figure 9 depicts a big variation between the long term and 2001monthly mean sea level rise where the long term monthly mean sea level was higher than 2001 mean sea-level records.

**Table 10.** Relationship between climate and agriculture/fish production

| Agricultural produces | Sea level | Rainfall | Max. temp | Min. temp |
|---|---|---|---|---|
| Cassava | -0.214 | 0.123 | -0.441* | -0.409* |
| Banana | 0.007 | 0.144 | -0.245 | -0.248 |
| Millet | 0.083 | 0.176 | -0.401* | -0.364 |
| Rice | -0.016 | 0.225 | -0.238 | -0.432* |
| Fish | 0.426* | -0.086 | 0.005 | 0.157 |

Note: *. Correlation is significant at the 0.05 level

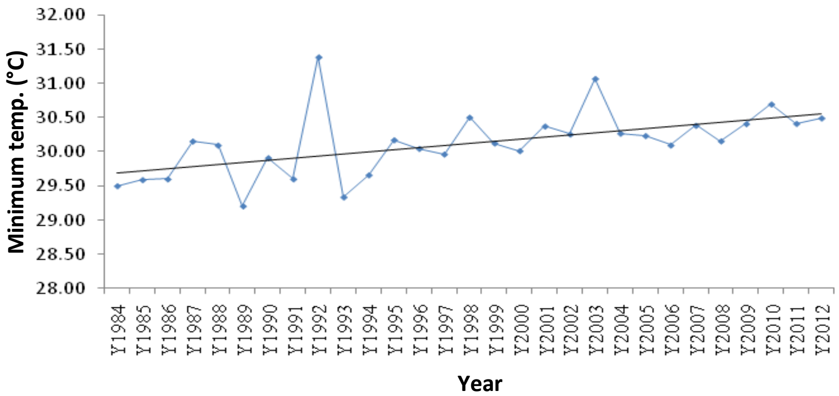


**Figure 6.** Mean annual maximum temperature (1984-2012) Matangatuani Micheweni District, Pemba Island, Tanzania (TMA 2014)

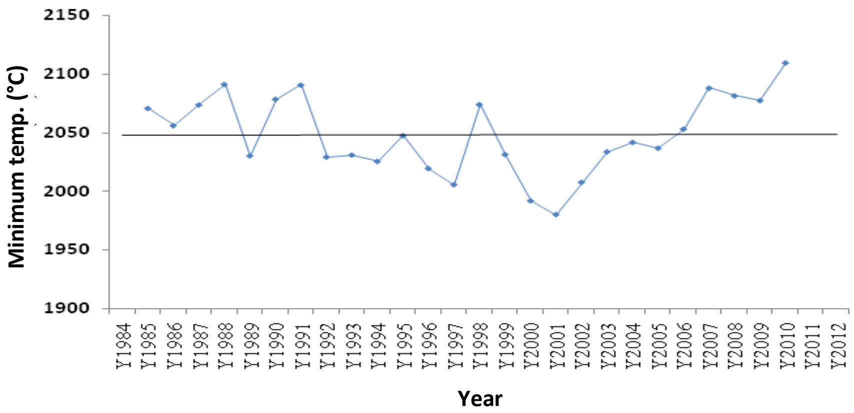


**Figure 7.** Mean annual sea level (1985-2010) Chake Chake Airport, Pemba Island, Tanzania (TMA 2014)

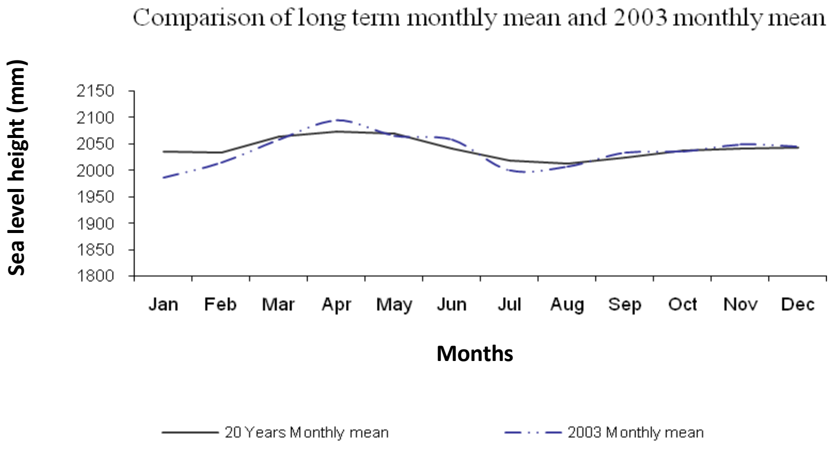


**Figure 8.** Comparison of long term and 2003 monthly mean sea level

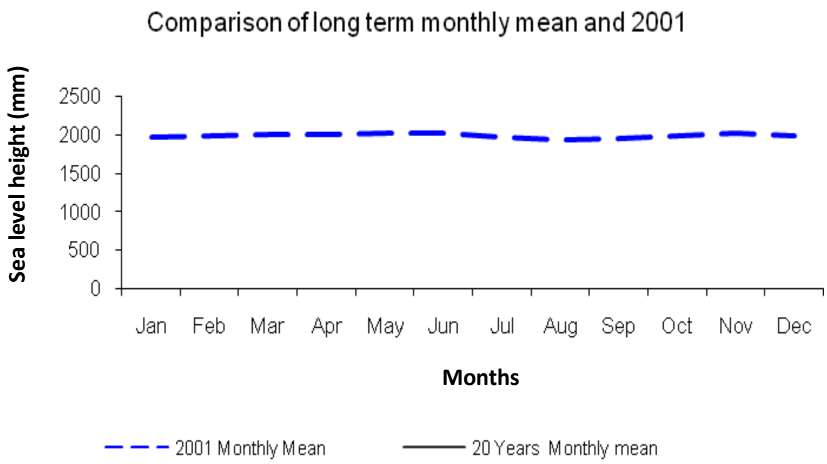


**Figure 9.** Comparison of long term and 2001 monthly mean sea level

## Effects of climate change on crops

*Crops disappearance, affected crops and causes*

Survey findings showed that 99% of all respondents from the study area agreed on the disappearance of some important food crops being grown before by farmers in the District and so far the community has lost interest to continue raising these crops (Table 11). The crops have been found to cost farmers in terms of time, energy and financial resources. The most affected crops include pumpkins, pigeon peas, cassava and green grams as well as banana and millet varieties (Table 11). In the past, these crop varieties were found to be plenty in the District as their growth was well supported in semi-arid climates and coral rag areas. Community used to depend on these crops as the most staple food varieties and sometimes sold for cash income, but as time went on they slowly started to disappear in the vicinity, believed to be as a result of climate change. This is supported by Sanga et al. (2013) in small-scale farmers' adaptation to climate change effects in Pangani river basin and Pemba where 72.8% of farmers asked to report on the changes happening in their respective areas and what they think could be the reason. The farmers believe that the disappearance of crops that used to be produced in their areas is a result of climate change.

**Table 11.** Crop disappearance and effects in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Category | Responses | | | |
|---|---|---|---|---|---|
| | | Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. total (n=90) |
| Crops affection | Yes | 30 (100) | 30 (100) | 29 (97) | 89 (99) |
| | No | 0 (0) | 0 (0) | 1 (3) | 1 (1) |
| Affected crops | Cow peas | 1 (3) | 0 (0) | 0 (0) | 1 (1) |
| | Banana | 3 (10) | 5 (17) | 3 (10) | 11 (12) |
| | Green grams | 4 (13) | 4 (13) | 4 (13) | 12 (13) |
| | Pineapple | 2 (7) | 2 (7) | 1 (3) | 5 (6) |
| | Millet | 3 (10) | 3 (10) | 5 (17) | 11 (12) |
| | Sweet potatoes | 2 (7) | 2 (7) | 2 (7) | 6 (7) |
| | Cassava | 4 (13) | 5 (17) | 3 (10) | 12 (13) |
| | Pumpkins | 5 (17) | 5 (17) | 5 (17) | 15 (17) |
| | Sorghum | 1 (3) | 1 (3) | 0 (0) | 2 (2) |
| | Cocoyam | 0 (0) | 0 (0) | 1 (3) | 1 (1) |
| | Pigeon peas | 5 (17) | 3 (10) | 6 (20) | 14 (16) |

Among the reasons for crop disappearance reported by farmers include low rainfall by 34.4% of the respondents, 23.3% crop pests/diseases and 22.2% extended drought periods. Other reasons mentioned in the District were land infertility, high temperatures, and the use of unimproved seeds that are not capable of growing (Figure 10).

## Climate change impacts and disasters to crop farming in the district

*Climate change awareness and impacts*

Results from the study observed that 96% of all respondents were knowledgeable and aware of the term climate change through long period experiences with 100% from Mjini wingwi agreeing and 75% from Majenzi disagreeing on the term. Similar results were reported by Nyanga et al. (2011), Rao et al. (2011) and Osbahr et al. (2011) on studies assessing farmer perceptions in semi-arid environments of Africa. Almost 100% of the respondents agreed that their farming activities have been affected by change in climate year after year. Community cropping is still being seriously impacted by change in climate leaving farmers with less or no access to food for their livelihood.

Respondents also concluded on the results of these impacts being contributed entirely by low rainfall trend (Majenzi), high temperature (Mjini wingwi), sea-level rise (Micheweni) and drought claimed by all of the respondents (Table 12). Juana et al. (2013) also mentioned the climate change impacts being low rainfall patterns, high temperatures and drought affecting most of the Sub Sahara African countries. However, Hassan (2010) reported the available land for agriculture as increasingly in short supply due to salinity as a result of climate change and sea-level rise where people now experience low yield of agricultural crops accompanied by unpredictable flowering and fruiting.

Seawater intrusion in Micheweni District has also shown a big threat to agricultural production especially in rice fields where during high tides sea water enters into farms and forces farmers to vacate the area until situation prevails (Figure 13). Of the most known severe climate change effects noticed by respondents in the last 10 years were the low level of crop production, crop/seed death, and soil infertility reported by Micheweni, Mjini wingwi, and Majenzi community respectively (Figure 11).

Figure 12 depicts that almost 70% of all surveyed households reported the duration of these climate change effects occurring more than three times in 10 years of cropping period and thus cause decreasing production rate of food crops in the District.

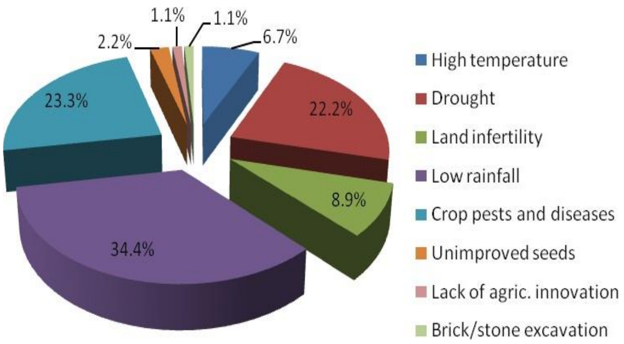


**Figure 10.** Reasons for crop disappearance

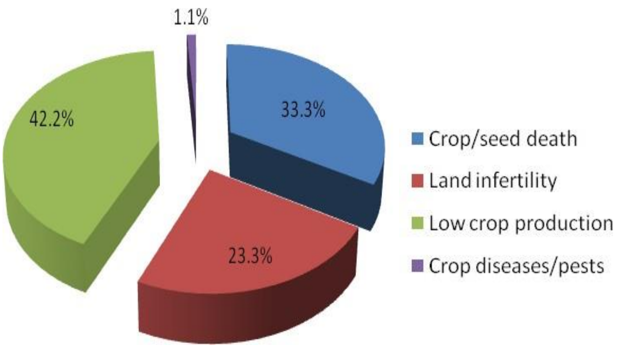


**Figure 11.** Climate change effects in Micheweni District, Pemba Island, Tanzania

**Table 12.** Climate change impacts on crop production in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Category | Responses<br>Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. total (n=90) |
|---|---|---|---|---|---|
| Awareness on CC | Yes | 29 (97) | 30 (100) | 27 (90) | 86 (96) |
| | No | 1 (3) | 0 (0) | 3 (10) | 4 (4) |
| Effects of CC | Yes | 30 (100) | 30 (100) | 30 (100) | 90 (100) |
| | No | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Effect of CC impacts | Low crop production | 7 (23) | 8 (27) | 13 (43) | 28 (31) |
| | Crop pests/diseases | 12 (40) | 9 (30) | 6 (20) | 27 (30) |
| | Soil infertility | 7 (23) | 11 (37) | 9 (30) | 27 (30) |
| | Seawater intrusion | 4 (13) | 2 (7) | 2 (7) | 8 (9) |
| Contributing factors of CC | Low rainfall | 7 (23) | 9 (30) | 12 (40) | 28 (31) |
| | High temperature | 9 (30) | 11 (37) | 7 (23) | 27 (30) |
| | Sea level rise | 6 (20) | 2 (7) | 3 (10) | 11 (12) |
| | Drought | 8 (27) | 8 (27) | 8 (27) | 24 (27) |

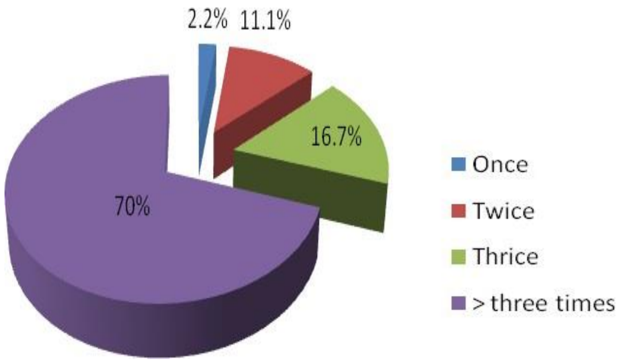


**Figure 12.** Duration of climate change effects in Micheweni District, Pemba Island, Tanzania

*Information sharing on climate change impacts in the district*

Most of the interviewed respondents reported that for the last 10 years, the District did not formulate any information network among Shehia leaders, agricultural extension officers and district officials to convey alert messages whenever climate change impacts and disaster reports were revealed from Tanzania Meteorological Authority (TMA). This lack of reliable information systems and networks created ill coordination among officials and farmers as they were unable to gain the required information in time and hence farmers invested energy to prepare their fields for cropping for nothing. Table 13 shows that about 83.3% of the surveyed respondents commented on the poor information system that existed in the District with 35% support from Majenzi community and therefore exposing community agricultural activities open to climate change impacts. Besides the problem of community missing timely and reliable climate change information, no injuries and /or deaths were reported during the past El Niño and tsunami disasters (Table 13).

*Seawater rise and intrusion into community farms in the district*

Findings of the study show that about 56% of the surveyed respondents in the area responded negatively against 44% who agreed on problems they face associated with seawater rise in their farms (Table 14). Rise in seawater has affected mostly the rice farms which are in lowland areas practiced by a few farmers compared to farmers of other crops whose farms are less affected by seawater. Repercussion of seawater rise was the increased salinity to rice farms, therefore, vacating the area for long time until the coming rainfall seasons to dilute excessive salts. The effect of seawater intrusion into farmers' fields (rice) was claimed by 100% of the surveyed respondents as being source of decreasing yield in the crop production for years (Table 14).

## Climate change adaptation strategies in Micheweni district

*Strategies and limiting factors to adaptation*

Climate change in Micheweni poses a lot of negative impacts to general agricultural production, contributing to decrease in crop production and threatening food security of the people. Prior to this situation, the community has managed to apply reliable and sound strategies to overcome the problem. According to this study, various adaptation strategies were recommended by respondents aimed at eliminating or otherwise reducing the impacts to the extent that crop production in the District would be otherwise enhanced. About 20% of the respondents recommended the use of improved seeds as the most adaptation strategy followed by crop rotation/diversification (18%), the use of new crop varieties (18%), the adjustment of sowing dates (14%), fertilizer application (11%) and the use of mixed cropping (10%) among others.

In addition to adaptation strategies undertaken to combat climate change impacts, there were some limitations that hindered implementation of the steps taken by the community in the study area. These limitations include low-income levels of the community, fish/salt farming in mangroves, lack of appropriate skills and technology among farmers and lack of improved seed varieties (Table 15). Otherwise, government policy reforms could be given special considerations to climate change adaptation. Juana et al. (2013) on the other hand indicated barriers to climate change adaptations as being high cost of adaptation measures and population growth among Africa countries.

Another important adaptation strategy commonly and widely used by the community in the area involves planting of mangroves along farm banks to reduce impacts and speed of seawater to enter the rice farms during high tides (Figure 14).

In supporting the community efforts to combat impacts of climate change, the Revolutionary Government of Zanzibar (RGoZ) through Tanzania Social Action Fund (TASAF) supported the construction of 800 m long ridge at Ukele paddy farms as an adaptation strategy. This construction saved 49 hectares of paddy farms in the area costing 269 988 560 TZS; 150 000 000 TZS from TASAF and 119 988 560 TZS from RGoZ (Figure 15).

**Table 13.** Responses on information sharing in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Category | Responses Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av.Total (n=90) |
|---|---|---|---|---|---|
| Information sharing | Yes | 5 (17) | 6 (20) | 4 (13) | 15 (17) |
| | No | 25 (83) | 24 (80) | 26 (87) | 75 (83) |

**Table 14.** Effects of seawater rise and intrusion in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Response Category | Responses Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. Total (n=90) |
|---|---|---|---|---|---|
| Sea water rise | Yes | 16 (53) | 13 (43) | 11 (37) | 40 (44) |
| | No | 14 (47) | 17 (57) | 19 (63) | 50 (56) |
| Seawater intrusion | Increase yield | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| | Decreased yield | 30 (100) | 30 (100) | 30 (100) | 90 (100) |

**Table 15.** Respondents views on climate change impacts and adaptation in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Response category | Responses Micheweni (n=30) | Mjiniwingwi (n=30) | Majenzi (n=30) | Av.Total (n=90) |
|---|---|---|---|---|---|
| Adaptation Strategy | Crop rotation/diversification | 8 (27) | 3 (10) | 5 (17) | 16 (18) |
| | Use of improved seeds | 3 (10) | 8 (27) | 7 (23) | 18 (20) |
| | Fertilizer application | 4 (13) | 3 (10) | 3 (10) | 10 (11) |
| | Irrigation/community migration | 3 (10) | 2 (7) | 2 (7) | 7 (8) |
| | Use of indigenous crop species | 0 (0) | 1 (3) | 0 (0) | 1 (1) |
| | Adjustment of sowing dates | 4 (13) | 5 (17) | 4 (13) | 13 (14) |
| | Employing mixed cropping | 3 (10) | 3 (10) | 3 (10) | 9 (10) |
| | Use of new crop varieties | 5 (17) | 5 (17) | 6 (20) | 16 (18) |
| Limitation factors | Human population increase/growth | 0 (0) | 1 (3) | 1 (3) | 2 (2) |
| | Low income levels | 10 (33) | 8 (27) | 7 (23) | 25 (28) |
| | Lack of adequate arable land | 1 (3) | 2 (7) | 1 (3) | 4 (4) |
| | Cultural/traditional backgrounds | 1 (3) | 3 (10) | 2 (7) | 6 (7) |
| | Lack of appropriate skills and technology | 3 (10) | 5 (17) | 5 (17) | 13 (14) |
| | Lack of improved seed varieties | 3 (10) | 4 (13) | 4 (13) | 11 (12) |
| | Lack of alternative support | 2 (7) | 2 (7) | 2 (7) | 6 (7) |
| | Frequencies of crop disease outbreaks and pest Infestations | 1 (3) | 1 (3) | 2 (7) | 4 (4) |
| | Fish and salt farming | 9 (30) | 4 (13) | 6 (20) | 19 (21) |

Low income level of the community is one of the big challenges towards climate change adaptation strategies in the district where people rush to engage themselves in non-environmental friendly activities. Illegal tree felling/fishing, charcoal and lime making are among the most IGAs practiced by the community to increase household incomes but, so far are exposed to environmental degradation. Although seaweed, fish and salt farming are legally permitted by the government for improvement of livelihoods, they are not friendly to environment. Fish and salt farming practices are characterized by clear-felling of several mangroves resulting in land left bare and exposed to severe environmental impacts (Figure 16).

**Figure 14.** Adaptation strategies of seawater rising through mangrove planting

**Figure 13.** Paddy plot vacated by farmers due to seawater intrusion

**Figure 15.** Adaptation strategy of climate change through ridge construction at Ukele, Micheweni District, Pemba Island, Tanzania

**Figure 16.** Salt farms contribute severe cutting of mangroves in Micheweni District, Pemba Island, Tanzania

*Adjustments against climate change adaptation barriers*

To employ proper adjustments against climate change adaptation barriers, 30% of respondents' suggestions were directed towards construction of dikes (ridging) along farm boundaries, 27% establishment of tree-planting programs, 18% employed awareness and sensitization programs, and 11% adjusted planting times plus protection of existing community and natural forests (Table 16). Tree planting programs are expected to reduce community future firewood and building poles shortages while awareness and sensitization programs could raise community understanding on climate change education (Table 16).

Nevertheless, these adjustment efforts were constrained by a number of factors as reported by the respondents. Most of the constraints claimed by all respondents in the area involved inadequate working facilities, human population growth and lack of cohesion and unity among community members. Other constraints to adaptation involved inadequate cropping/environmental skills and illiteracy (Majenzi), deliberate uprooting of transplants and absence of strong by-laws within the community (Mjini wingwi), and low income levels and unavailability of improved seeds among farmers as reported by Micheweni village (Table 17).

**Assisting institutions to climate change victims**

Results from this survey showed that for the last 10 years in the district the community has suffered a lot from various impacts, especially those associated with climate change. Nonetheless, no reliable contributions towards the impacts were provided to help the affected families. Only 36% of respondents responded to have been provided with sorts of assistance as compared to 64% who completely denied receiving any type of assistance during climate change impact occurrences (Table 18). Mostly, the types of assistance provided were in the form of funds by 57%, foodstuff (23%), seeds (17%), and inorganic fertilizers (3%) originating mainly from relatives, government institutions, and NGOs/CBOs (Table 18).

**Table 16.** Adjustment responses on climate change adaptation barriers in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Category | Responses | | | |
|---|---|---|---|---|---|
| | | Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. total (n=90) |
| Adjustments | Change of the cropping pattern | 0 (0) | 2 (7) | 0 (0) | 2 (2) |
| | Ridging | 15 (50) | 7 (23) | 5 (17) | 27 (30) |
| | Tree planting programs | 5 (17) | 8 (27) | 11 (37) | 24 (27) |
| | Use of organic fertilizers | 0 (0) | 0 (0) | 1 (3) | 1 (1) |
| | Awareness and sensitization programs | 5 (17) | 7 (23) | 4 (13) | 16 (18) |
| | Protection of existing forests | 2 (7) | 2 (7) | 0 (0) | 4 (4) |
| | Use of different sectoral laws enforcement | 1 (3) | 3 (10) | 2 (7) | 6 (7) |
| | Adjusting planting times | 2 (7) | 1 (3) | 7 (23) | 10 (11) |

**Table 17.** Constraining factors to climate change adaptations in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Response factors | Responses | | | |
|---|---|---|---|---|---|
| | | Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. total (n=90) |
| Constraints | Inadequate cropping/environmental skills | 5 (17) | 8 (27) | 12 (40) | 25 (28) |
| | Inadequate working facilities | 7 (23) | 7 (23) | 7 (23) | 21 (23) |
| | Deliberate uprooting of transplants | 1 (3) | 3 (10) | 1 (3) | 5 (6) |
| | Human population growth | 1 (3) | 1 (3) | 1 (3) | 3 (3) |
| | Lack of cohesion and unity among community members | 2 (7) | 2 (7) | 2 (7) | 6 (7) |
| | Low-income levels | 8 (27) | 6 (20) | 2 (7) | 16 (18) |
| | Absence of by-laws | 1 (3) | 1 (3) | 0 (0) | 2 (2) |
| | Illiteracy | 1 (3) | 2 (7) | 3 (10) | 6 (7) |
| | Unavailability of improved seeds | 4 (13) | 0 (0) | 2 (7) | 6 (7) |

**Table 18.** Type and source of assistance to households in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Category | Responses<br>Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. total (n=90) |
|---|---|---|---|---|---|
| Assistance | Yes | 14 (47) | 7 (23) | 11 (37) | 32 (36) |
| | No | 16 (53) | 23 (77) | 19 (63) | 58 (64) |
| Type | Funds | 23 (77) | 16 (53) | 12 (40) | 51 (57) |
| | Food | 7 (23) | 7 (23) | 7 (23) | 21 (23) |
| | Seeds | 0 (0) | 7 (23) | 8 (27) | 15 (17) |
| | Inorganic fertilizers | 0 (0) | 0 (0) | 3 (10) | 3 (3) |
| Origin | Not applicable | 18 (60) | 15 (50) | 13 (43) | 46 (51) |
| | Government | 3 (10) | 3 (10) | 9 (30) | 15 (17) |
| | NGOs/CBOs | 3 (10) | 0 (0) | 1 (3) | 4 (4) |
| | Relatives | 6 (20) | 12 (40) | 7 (23) | 25 (28) |

**Table 19.** Food shortages in Micheweni District, Pemba Island, Tanzania (n=90)

| Variables | Category | Responses<br>Micheweni (n=30) | Mjini wingwi (n=30) | Majenzi (n=30) | Av. total (n=90) |
|---|---|---|---|---|---|
| Relationship | Increase | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| | Decrease | 30 (100) | 30 (100) | 30 (100) | 90 (100) |
| Food shortage status | Yes | 28 (93) | 30 (100) | 30 (100) | 88 (98) |
| | No | 2 (7) | 0 (0) | 0 (0) | 2 (2) |
| Shortages factor | Drought | 8 (27) | 9 (30) | 14 (47) | 31 (34) |
| | Low rainfall | 11 (37) | 9 (30) | 7 (23) | 27 (30) |
| | High temperatures | 9 (30) | 11 (37) | 8 (27) | 28 (31) |
| | Others | 2 (7) | 1 (3) | 1 (3) | 4 (4) |

### Climate change impacts crop production and food shortages

The findings show that 100% and 98% of all respondents claim decrease in crop production and food shortages for the last 10 years respectively (Table 19). According to the respondents, the causes of this food shortage in the District are mostly drought, high temperatures and low rainfall. Other causes mentioned include lack of agricultural inputs, technology and improved seed (Table 19).

### Focus Group Discussions (FGD) and Key Informants

Information from these groups was gathered through formal and informal discussions using a checklist (Appendix 2 and 3) involved District extension officers (environment, fisheries and agriculture), village government leaders (Shehas), conservation clubs and some village influential people. Reports from group discussions showed that all members have lived in the area for more than 45 years with long experiences on climate change and its impacts where 100% of the respondents reported the decrease of agricultural crop production for the last 10 years in the District. With regard to climate change impacts, it was observed that 98% and 96% of the respondents admitted the presence of low rainfall and high-temperature trends respectively, while 98% of the respondents claimed food production decrease.

Furthermore, the results indicated that 80% and 100% of the FGD respondents reported decrease in rainfall and increase in temperature respectively, associated with prolonged drought periods and food shortages for the last 10 years in the District. To solve the problem of food shortages, 93% of the respondents proposed fertilizer application as the best option against the use of disease-resistant seeds, use of crop rotation and use of crop mixes.

As it was shown in the discussion in the case of food shortages, for those who were given such assistance, 91% of them admitted to get assistance from government sources and their relatives. It was found that all of the respondents were, in one way or another affected by climate change in crop production and 56% highlighted tree planting as a means to overcome the impact followed by ridge/wall construction around seashores or cropping sites bordered by sea. With respect to early warning alerts during climate change disasters, 51% of the respondents admitted to get reliable information from the media as opposed to 49% who completely refused to get any early warning information and from nowhere. Those who acknowledged getting such information on climate disasters realized their roles of reporting such information to their village leaders and agricultural officers and sharing the knowledge and experiences among others for further considerations.

### Conclusion

Extended periods of high temperatures and low rainfall were found to cause major climate impacts to crop production in Micheweni District resulting into food insecurity. Drought periods associated with crop pests and diseases, land infertility, uneven rainfall distribution and seawater intrusion in farmers' plots were claimed as major causes of decreasing food production, disappearance and death of some important food crops in the District.

There is no strong correlation between climate factors and crop production in the District and this can be due to other factors that were not considered during data collection. Factors like higher price of fish catch and provision of improved fishing gears could have increased fish production without considering impacts of sea waves and high currents as a result of changing climate.

Apart from being limited by other factors, various climate change adaptation strategies were suggested by community to minimize and/or otherwise eliminate climate change impacts to the extent that crop production in the District would be enhanced. The use of improved seeds and new crop varieties, crop rotation practice and diversification, adjustment of sowing dates, mixed cropping and fertilizer application were a priority. However, these communities are lacking a strong organization to distribute climate change information to them when need occurs. Community initiatives through government support so far have been directed toward ridge construction and mobilizing community through tree planting among the strategies, though fish and salt farming constrain the adaptation efforts.

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