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RECLASSIFICATION OF AGROECOLOGICAL ZONES: CASE STUDY AT NANGAPANDA, ENDE, EAST NUSA TENGGARA

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ABSTRACT
An agroecological zone can be one of the agricultural planning assessments that consider the environment's physical conditions and the commodities suitable for those conditions. Mapping of agroecological zones in Indonesia has been carried out by the Ministry of Agriculture but on an extensive coverage (small scale) so that it is not representative at the district level. This study aims to update the spatial map of agroecological zones in Nangapanda District so the agroecological zones map becomes more detailed and more representative to be used as a reference for development at the district level, especially for agriculture. The assessment of agroecological zones will be based on the 2013 AEZ module of the Agricultural Research and Development Agency (BPPP) and carried out with spatial overlay analysis using a geographic information system. The results showed that on a scale of 1:50.000, the agroecological zones formed in Nangapanda were dominated by Zone IIay (dry lowland annual crops) with 9.120,87 ha (47,93%) followed by Zone I (forestry) with 8.432,29 ha (44,31%), Zone IIIay (dry lowland annual and food crops) 690,58 ha (3,63%), Zone IIby (dry midland annual crops) 517,69% (2,72%), and Zone IVay (dry lowland food crops) 270 ha (1,42%). These updated agroecological zones are very different from the 1:250.000 scale BPPP 2013 agroecological zones in terms of zoning, detail, dan spatial patterns. The results of this study are expected to help in planning and decision-making for planting commodities following the environment's physical conditions.

Keywords: agroecological zones, gis, overlay, agriculture commodities, sustainable agriculture.

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INTRODUCTION

Indonesia has various agro-environments, and most of the local people are still employed by agriculture-related businesses, which continue to play a significant part in the local economy (Syuaib, 2015). The diversity of agro-environments can have an impact on the diversity of suitability levels and potential land resources, types of agricultural commodities that can be developed, as well as the technical inputs needed for their development (Ahmed et al., 2016); (Chen et al., 2022). Whether or not a type of commodity or technology can be applied to an area will be known if accurate data and information on the potential of land resources are available (Kumalawati et al., 2020).

To support land use planning following its carrying capacity, FAO 1978 introduced the concept of compiling an agroecological zone map to assist integrated agricultural land planning and management for developing countries in Africa, Asia, and Latin America (Saidi & Suryani, 2019). FAO has developed and applied the agroecological zone method approach for more than two decades to support land planning and management for sustainable agricultural development at regional, national, and provincial levels (Soeparno & Heriawan, 2021). The AEZ approach can be used for planning, managing, and monitoring land resources, such as inventorying potential land resources,

land use types and production systems, land suitability, and evaluating land productivity (Yao et al., 2022).

Nangapanda Subdistrict, located at East Nusa Tenggara, offers the potential for dry land agriculture. Nearly all of Nangapanda consists of dry land with a composition of 99,77% and a wetland composition of just 0,23% (Nangapanda, 2023). The dry land is mainly used for agriculture, forestry, and plantations, while the wetland is focused on rice field development (Nangapanda, 2023). There was a national movement program in 2009-2011 by the Ministry of Agriculture to improve the production and quality of cocoa under the control of the Director General Plantation, conducted in 9 provinces in Indonesia, including East Nusa Tenggara province at Sikka Regency and Ende Regency (Tola, 2016). Since the national movement program, the community of Nangapanda has focused more on cocoa than other commodities; this is also due to the relatively higher selling price of cocoa commodities than food commodities and is still an agricultural trend to date in the community. However, many other commodities have competitive selling prices and relatively easy maintenance compared to cocoa, which is environmentally suitable and can be developed on drylands, such as in Nangapanda.

Based on this, guidance is needed on suggesting what commodities can be developed in the Nangapanda area so that agriculture is not focused on a monoculture system or relying on just one commodity. Agroecological zone mapping has become essential because it can be used to assess land suitability for agricultural commodities based on climate, terrain, and soil parameters (BBSDLP, 2013). FAO recommends the use of agroecological zone maps at the national and provincial levels compiled at a scale of 1:1.000.000-1:500.000. In Indonesia, agroecological zone maps are arranged at a scale of 1.000.000 for main islands and a scale of 1:250.000 for provinces (Julianto et al., 2021). The regional scale agroecological zone map at 1:250.000 is still classified as very general. It needs to be further detailed in its delineation if it is used as a reference for agricultural development at levels below the province, such as regencies and districts (Hikmatullah & Ritung, 2014). This paper aims to arrange an updated map of agroecological zones so that it is relevant to be used as a reference for agricultural plans for Nangapanda District.

METHOD

Study Area

The study was carried out in Nangapanda District, Ende Regency, East Nusa Tenggara Province at the beginning of 2023. Nangapanda District is located at 08°39'12"-08°48'35" S and 121°23'39"-121°34'26" E (Figure 1), about 35 km straight to the west of Ende City. According to remote sensing calculations, Nangapanda District has a total area of 190.31 km^2. Nangapanda District is surrounded by several districts nearby. Maukaro District and Nagekeo District border north and west, while Sawu Sea and Ende District border south and east (Figure 1). The field observations show that Nangapanda District consists mainly of dry land with a variety of topographic types of land, such as mountains, hills, valleys, and beaches. Based on the rainfall intensity and climatic season zone, which show eight dry months and four wet months, the climate conditions in Nangapanda District are classified as dry.

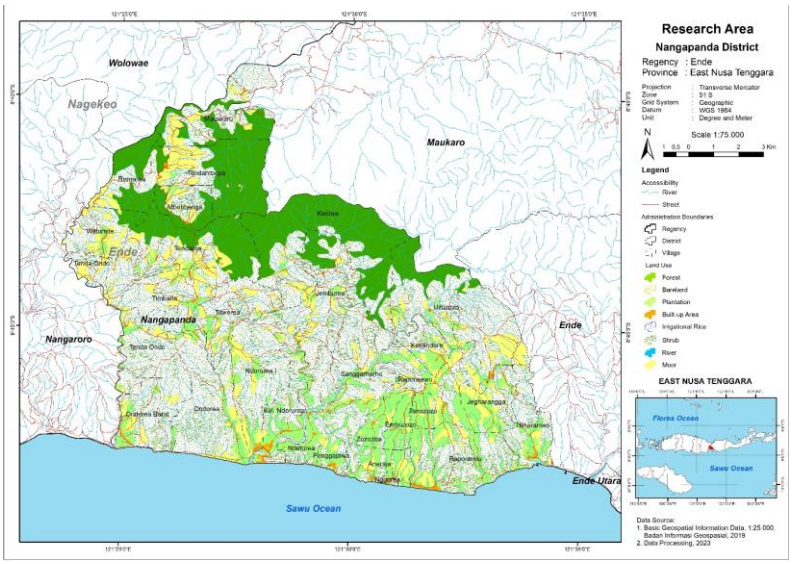

Figure 1. Research Area

Nangapanda District is administratively divided into 28 villages, with most people dependent on agriculture for subsistence (Nangapanda, 2023). They take advantage of the dry land environments of Nangapanda by preserving the forest and cultivating food crops suited to dryland circumstances as well as longevity plants for plantations. Additionally, Nangapanda is developing lowland rice, representing a small portion of the wetland's agricultural potential. In order to ensure that their agricultural land is sufficiently irrigated throughout the year, wetlands are developed explicitly in locations close to the possibility of plenty of water sources. However, the majority of the villages in Nangapanda were located distant from water sources. Therefore, these villages developed agricultural and food crops that could thrive in arid climates and are suitable for dry areas.

Data

There are several data used in this research, primarily for arranging the agroecological zone. The data used in this study are:

a. Imagery data of the national digital elevation model (DEMNAS) in tiff format with a vertical resolution of 8 meters from Badan Informasi Geospatial/Geospatial Information Agency (BIG), which can be downloaded via http://tides.big.go.id/DEMNAS/ with sheet number 2107-32, 2107-34, 2207-11, and 2207-13.
b. Map of soil type data at the scale of 1:50.000 from Balai Penelitian Tanah/Soil Research Center (Balittanah) in shapefile (.shp) format. Soil type, soil drainage, and soil moisture regime will be derived from this map of soil type data.
c. Rainfall measurement data with mm units was obtained from three measurement stations: Badan Meteorologi, Klimatologi, dan Geofisika/Meteorology, Climatology and Geophysics Agency (BMKG) at two stations, namely the Frans Sales Lega Meteorology Station and the Xaverius Seda Meteorology Station, and rainfall measurement data from the office of Agricultural Instructor Agency (BPP) Nangapanda Subdistrict from 2009 to 2018. These rainfall data are then interpolated using ArcMap 10.4 map data processor to be converted into spatial data.
d. ZOM (climatic season zone) data from Badan Meteorologi, Klimatologi, dan Geofisika/Meteorology, Climatology and Geophysics Agency (BMKG) to obtain dry months combined with rainfall measurement data.

Spatial Analysis of Agroecological Zone

After the required data has been collected, data processing is carried out to obtain derived data, which will then be reclassified. Agroecological zones were carried out by considering several physical environmental conditions that refer to the technical guidelines of agroecological zones by the Agricultural Research and Development Agency, Ministry of Agriculture, published in 2013. The 2013 technical guidelines of agroecological zones used in this research refine the 1994 agroecological zones module, where the zone groupings are arranged consistently and have a good correlation between their polygons (BPPP, 2013).

DEMNAS data will be used to obtain slope data and topographical elevation data. Combinations of ZOM data and rainfall measurement data will be used to obtain dry months. Soil type, soil drainage, and soil moisture regime will be derived from a map of soil type data. The derived data are then grouped according to the need for and sub-zoning. The parameters and criteria to reclassify for the formation of zones and sub-zones refer to Table 1. Agroecological zones will be formed by combining and overlaying the zone and sub-zones data. The overall analysis procedure can be summarized in a schematic diagram (Figure 2).

Table 1. Parameters and Criteria on Agricultural/forest system for Agroecological Zoning

Parameter	Zone						
	I	II	III	IV	V	VI	VII
Slope (%)	>40	>15-≤40	≥8-≤15	<8	<8	<8	<8
Soil type	-	-	-	-	Fibrist, hemist, saprists	Halaquepts, Sulfauepts	Spodosols, Quatzip-samments
Soil drainage	-	-	-	-	-	-	Very excessively drained, excessively drained, somewhat excessively drained

Parameter	Sub-Zone						
	Temperature Regime				Moisture Regime		
	a	B	c	d	x	y	q
Temperature (°C)	>20	19-≤20	15-18	≤15	-	-	-
Elevation (masl)	≤700	>700-≤1200	>1200-≤2000	>2000	-	-	-
Soil drainage	-	-	-	-	well-drained, moderately well drained	well-drained, moderately well drained	somewhat poorly drained, poorly drained, very poorly drained
Soil moisture	-	-	-	-	Moist (udic)	somewhat dry (ustic)	Wet (aquic)
Dry months (<100 mm)	-	-	-	-	0-3	4-8	-

Source: Agricultural Research and Development Agency, Ministry of Agriculture (2013)

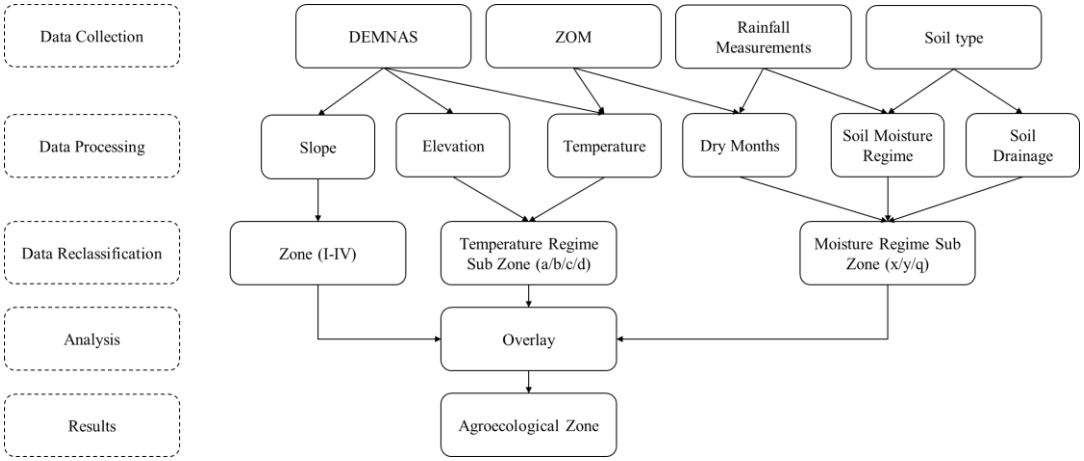

Figure 2. Schematic Diagram of Analysis Procedure

The agroecological zones formed from the overlay process of the physical characteristics of the environment will result in 7 agroecological zones consisting of 3 zones for the development of food crops and horticulture commodities and four zones for forestry, plantation, fishery, and pasture areas. This zone is then combined with the sub-zones, and each zones and type of land use are as follows:

Table 2. Agroecological Zones and its commodity Suggestion

Zone	System	Subsystem	Suggestion
I	Forestry	Non-agriculture	Forestry, production forest, and protected forest
IIax	Annual crops	Dry lowland with wet climate	Palm, rubber, coconut, robusta coffee, pepper, clove
IIay		Dry lowland with a dry climate	Cocoa, cashew, castor, clove, cottonwood, nutmeg
IIbx		Dry midland with a wet climate	Robusta coffee, cacao, durian, oranges, clove
IIby		Dry midland with a dry climate	Cacao, cottonwood, nutmeg, candlenut
IIcx		Dry highland with wet climate	Robusta coffee, cinnamon, gambier, longan, apple, grape, tea, quinine
IIIax	Annual crops or food crops	Dry lowland with wet climate	Rubber, coconut, palm, robusta coffee, pepper, vanilla, petal, star fruit, jackfruit, duke, durian, rose apple, orange, mangosteen, corn, soya bean, mung beans, peanuts, cowpea, sweet potato, cassava, banana.
IIIay		Dry lowland with a dry climate	Cashew, vanilla, castor, cacao, cottonwood, nutmeg, sorghum, corn, cotton, mango, orange, grapes, sugarcane, tobacco, soya bean, peanuts, cowpea, long beans, cassava, sweet potato
IIIbx		Dry midland with a wet climate	Robusta coffee, vanilla, petal, star fruit, rose apple, orange, mangosteen, corn, soya bean, mung beans, peanuts, cowpea, sweet potato, cassava, and banana.
IIIby		Dry midland with a dry climate	Apple, orange, avocado, jackfruit, breadfruit, kedondong, longan, robusta coffee, tobacco, guava
Iraq	Food crops	Wet lowland with wet climate	Irrigation paddy

Zone	System	Subsystem	Suggestion
IVax		Dry lowland with wet climate	Upland rice, corn, soya beans, mungbean's, peanuts, cowpea, sweet potato, cassava, tobacco, red onion, cayenne pepper
IVay		Dry lowland with a dry climate	Upland rice, corn, soya bean, mung beans, peanuts, cowpea, sweet potato, cassava, red onion, sugarcane, cayenne pepper
IVbq		Wet midland with a wet climate	Irrigation paddy
IVbx		Dry midland with a wet climate	Corn, soya bean, mung beans, peanuts, cowpea, sweet potato, cassava, red onion, red chili pepper, tomato
IVby		Dry midland with a dry climate	Upland rice, corn, soya bean, mung beans, peanuts, cowpea, sweet potato, garlic, spring onion, red chili pepper
IVcx		Dry highland with wet climate	Wheat, corn, long beans, red onion, red chili pepper, cucumber, pineapple, ginger, aromatic ginger, turmeric, galangal
V	Annual crops/horticulture if peat thickness <3m with hemist and saprist soil types. Nonagricultural use or natural vegetation if the peat thickness >3m with soil type of fibrist.	-	
VI	Forestry or coastal fisheries.	Nonagricultural	Mangrove
VII	Forestry or pasture	Nonagricultural	Forestry, pasture

RESULTS AND DISCUSSION

Agroecological Zones in Nangapanda by Agricultural Research and Development Agency

Based on agroecological zone data on a scale of 1:250,000 sourced from the Agricultural Research and Development Agency (BPPP), there are three zones in Nangapanda District Zone I, Zone IIay, and Zone IVay. Based on the agroecological zone data (Figure 3), it can be seen that Zone I is the most dominant zone in Nangapanda District, with an area of 18,694.50 ha (98.2%). This is because the land formations in Nangapanda District are relatively hilly to mountainous with quite steep slopes. In general, the Nangapanda District area is directed to forestry crop systems. Meanwhile, Zone IVay is a food crop system found in coastal areas. A small area on the north of Nangapanda in the highlands with an area of 188.26 ha (1.0%), and Zone IIay, which is a system of annual crops or plantations, is located in the northern part of Nangapanda District with an area of 148.68 ha (0.8%).

If using the agroecological zone map from BPPP as a reference for agricultural activities, it can be said that agricultural activities cannot be carried out in the Nangapanda because it refers to the

suggestions that Zone I is a forestry system. This is because the BPPP agroecological zone data is very general because of its small scale (1:250,000), so the agroecological zone data is not detailed even though based on field observations, not all Nangapanda areas have a slope of 40% (for Zone I determination). So then, an updated agroecological zone was arranged using data on a scale of 1:50,000.

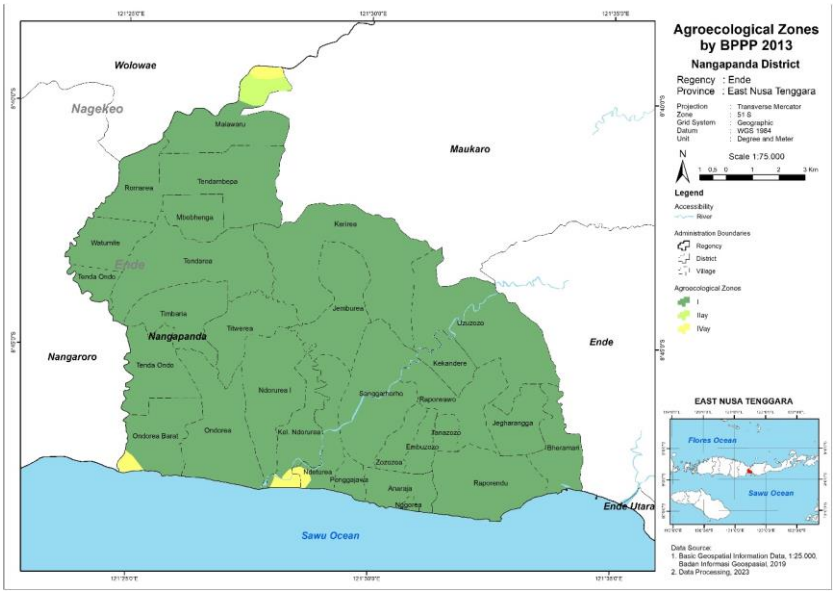

Figure 3. Agroecological Zones by BPPP 2013

Updating of Agroecological Zones in Nangapanda

The more accurate slope mainly influences the level of detail for updated agroecological zones compared to the slope for the spatial data used on the agroecological zones by BPPP in 2013. The detail and accuracy of the slope is a significant factor when mapping agroecological zones because it determines the zone. Generalization problems related to map scale will be challenging, especially in relief representations. This also applies equally to the topographic elevation factors, where the height will not be illustrated in detail and only becomes a morphological picture on a smaller scale (Samsonov, 2022).

The next thing that determines the level of detail is the type of soil. Two soil characteristics are used in determining agroecological zones: soil moisture and soil drainage. These characteristics can be determined if soil type data is available so that moisture and drainage characteristics can be traced. The considerable spatial and temporal variability of soil properties at big scales and the high expense and difficulty of obtaining laboratory-based soil studies make it challenging to obtain correct soil information (Maynard et al., 2023). Based on detailed polygon delineation from the 1:250.000 survey soil map to the 1:50.000 scale supported by inheritance data and limited field verification, a new soil type database is formed at a more detailed scale. It can analyze agroecological zones (Hikmatullah & Ritung, 2014).

The climatic factor used in the agroecological zones mapping is the number of dry months; in this case, it has little effect because the entire Nangapanda region has the same number of dry months, which is four months. In the agroecological zones assessment by BPPP in 2013, climate resource map data on a scale of 1:1.000.000 was used, sourced from the Agroclimate and Hydrology Research Institute (Balitklimat) 2003. The results of data analysis will be different if the required data

is rainfall because even though the number of dry months is the same, there are differences in annual rainfall in several different areas in Nangapanda, where at the higher altitudes, the rainfall is also higher. The detailed rainfall measurement data level is influenced by the map's scale and the number of measuring stations (Gutowski Jr et al., 2003).

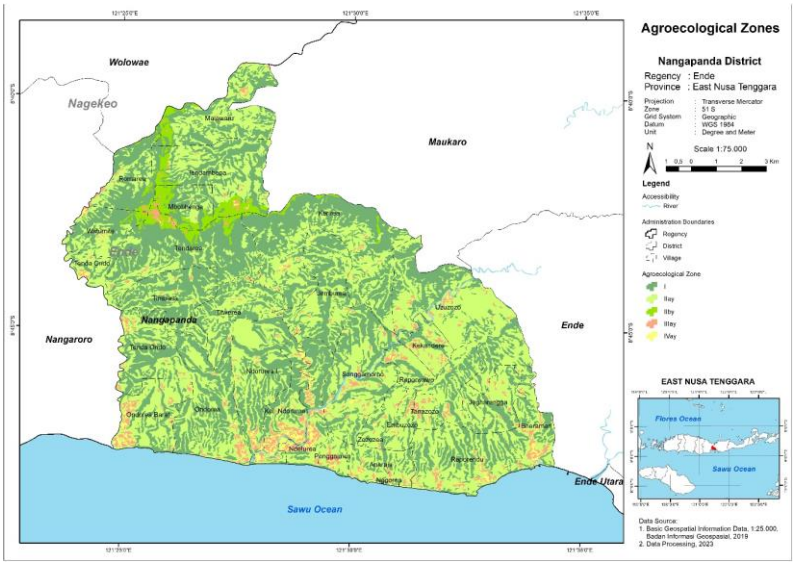

Figure 4. Agroecological Zones After Updating

Based on the agroecological zone data from this compilation, there are five classes of agroecological zones, with Zone, I still dominating the Nangapanda District area of 8,432 hectares or 44.3% but currently together with Zone IIay covering 9,120.87 hectares or 47.93% (Table 3). Two new zones previously did not appear in the agroecological zones compiled by BPPP 2013; there are Zone IIby and Zone IIIay.

Table 3. Areas of Updated Agroecological Zones in Nangapanda

Zone	System	Subsystem	Suggestion	Area (ha)	%
I	Forestry	Nonagricultural	Forestry, production forest, and protected forest	8432,29	44,31
IIay	Annual crops	Dry lowland with a dry climate	Cocoa, cashew, castor, clove, cottonwood, nutmeg	9120,87	47,93
IIby	Annual crops	Dry midland with a dry climate	Cacao, cottonwood, nutmeg, candlenut	517,69	2,72
IIIay	Annual or food crops	Dry lowland with a dry climate	Cashew, vanilla, castor, cacao, cottonwood, nutmeg, sorghum, corn, cotton, mango, orange, grapes, sugarcane, tobacco, soya bean, peanuts, cowpea, long beans, cassava, sweet potato	690,58	3,63
IVay	Food crops	Dry lowland with a dry climate	Upland rice, corn, soya bean, mung beans, peanuts, cowpea, sweet potato, cassava, red onion, sugarcane, cayenne pepper	270,00	1,42
				19031,44	100,00

Source: Data Processing, 2023

After updating, Zone IIay, initially only found at the northern tip of Nangapanda, has become scattered and dominates in the Nangapanda area along with Zone I. This is influenced, in particular, by the slope condition, which is relatively steep but not excessively steep. It is suitable for planting plantation crops following the agroecological zones' suggestion. Meanwhile, highly steep areas with a slope of >40% will be identified as Zone I. Zone IIby is concentrated north of Nangapanda, which passes eight mountain peaks with an average height of 800 meters above sea level. This area is the highest in Nangapanda District, with the highest point being on Keli (mountain) Mbumbu in Romarea village at 936 meters above sea level. Zone IIIay and Zone IVay spatially appear in areas with relatively flat terrain such as valleys, coasts, river banks, or on flat mountain peaks and ridge tops.

Based on zoning formed after updating the agroecological zone, the agricultural system that can be applied in Nangapanda are the system of annual crops and food crops with annual crops as the central system. The dominant subsystem is dry lowland with a dry climate. In contrast, development in dry midland is centered on mountainous areas that pass through the villages of Mbobhenga, Romarea, Tendaera, and Tendambepa.

CONCLUSION

The agroecological zone data sourced from the Agricultural Research and Development Agency (BPPP) needs to be updated and further detailed so that it can be used as a relevant reference for agricultural planning and implementation at the village or district level. Based on data analysis and the arrangement of agroecological zones that have been carried out, Nangapanda is dominated by Zone IIay or dry-lowland plantation subsystem. Commodities suggested to be developed in these zones are cocoa, cashew, castor bean, cloves, cottonwood, and nutmeg. This zone dominates Nangapanda because of the relatively steep slope conditions in the low altitude areas that spread across the Nangapanda. There are several other zones which, although the area is relatively small, should also pay attention to for the development of commodities following the commodities suggested by the zoning so agriculture becomes more effective. The selection of commodities to be developed also needs to consider non-physical aspects of the environment related to the socio-cultural community and economic improvement to achieve sustainable agriculture.

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