The Ecosystem Approach of Wanatani Semi Arid Equatorial to Sustainable Agricultural Management (in Amarasi District, Kupang Regency, NTT)

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Abstract. The existing condition of the wanatani management in Amarasi District, Kupang Regency, NTT, has not optimized the welfare of the farmers yet, and the land degradation keeps happening. The objectives of this research was to analyze and obtain information on the ecological, social, and economic benefits of sustainable wanatani in dry land management. The research result shows that based on the observation from the ecological function including vegetation, land fertility, micro climate, erosion, and land suitability, wanatani is at present not optimal and not sustainable in supporting productivity and land conservation. From the economic function, the productivity in wanatani should be optimal, but the lack of institutional support and social function causes the agricultural management to be not optimal and not sustainable.

1. Introduction
Sustainable development is the conscious and planned effort, combining life environment including bio-natural resources into the development process to guarantee the capability, welfare, and quality of life of the present and future generations with the ecosystem approach and its environmental supporting power. Article 2 of the Bio-Natural Resources Conservation Law Number 5 of the Year 1990 states that bio-natural resources conservation and its ecosystem are having the principles based on preservation of the ability and the establishment of bio-natural resources and the ecosystem harmoniously and in balance. Furthermore, the conservation principle as contained in Article 2 is in accordance with the life environmental principle as put forward in Article 3 of the Life Environmental Protection and Management Law No.32 of the Year 2009 stating that the life environmental management is conducted with the principle of the state’s responsibility and the principle of environmentally-friendly sustainability for the development Indonesian people and society entirely.

Moreover, Notohadiprawiro \cite{1} explains that the land resources conservation is not meant to maintain the form or its appearance, but it is to maintain the use. The land form can be changed, the soil can be treated with numerous ways which alter its characteristics, and/or the cropping...
can be replaced as long as all those treatments aim to maintain or increase the land resources sustainably.

Most of the land in the semi-arid ecosystem like in NTT has a limited use for agriculture. The forms of the area are mountainous, having slopes and shallow soil, and still developing. The low precipitation and the long dry season limit the land productivity. Traditionally, most agricultural systems in NTT combine the commodity of forestry, agriculture, cattle food with or without animal husbandry/fishery on a piece of land known with the term agroforestry or wanatani. Theoretically, the activities of wanatani are conserving the agricultural resources, increasing the welfare of the farmers, and preserving the environment. However, in reality the wanatani management in Amarasi District of NTT has not reached an optimal and sustainable result.

Land degradation and critical land keep happening, and the poverty rates have not been reduced either. Land degradation tends to increase marked with more critical land found. Based on the Agreement on Forest Use Procedure (the Forestry Service of the East Nusa Tenggara Province 1999), the forest area width in NTT is 1,689,423 ha or 35.5% out of the area width, and out of that land width around 667,601 ha (40.62%) is the protected area. Until today, the total of the critical land width has reached 1,313,897 ha or 28% out of the area total width (4,735,000 ha). The spreading of the critical land is in 14 Regencies and Towns, consisting of 297,322 ha in the forest area and 1,016,575 ha outside the forest area. Based on the landsat image information, in 2004 around 2.1 million ha out of the area width was already in a critical condition.

The use of firewood as the source of energy is still utilized by most people in NTT, especially in the rural areas or among the weak economic community, who generally use the wood for household need (cooking). This happens because the cost spent for kerosene is bigger than the cost for obtaining firewood. Based on the research result Widhana Susila et. al [2], the firewood use in Amarasi District is 1.13 kg per capita/day and in Kupang District is 1.11 kg/capita/day. The firewood used by the community is obtained from various places surrounding them, such as house yards, gardens, and the forest area.

The fact shows that the amount of poor population in NTT is relatively high. The number of poor people (BPS measurement) increased in 2004 to 20.86%. In 2007, the number of poor people was 27.58% out of the total amount of the population which was 4,448,873 people (BPS of NTT Province). Amarasi District had 15,302 residents. The number of the Family Heads was 3,677 or 3,677 households. From that household number, the percentage of the poor family was 65.62% of the total number of Households (Annual Report of Amarasi District, 2007). The low income of the residents was connected to the low productivity, stability, and sustainability of the wanatani in Kupang Regency (NTT Forestry Balitbang, 2005). Therefore, the concept to manage the land resources with planning is required by paying attention to the aspects of production, quality, and preservation, so that at the same time the community can fulfill their economic needs, without ignoring its environmental and social roles.

The activity of wanatani which produces the commodity of forestry, agriculture, cattle food with or without animal husbandry/fishery formed artificially should not only provide environmental benefits but also provide economic and social benefits. Failure to combine those aspects will cause some obstacles to appear for the sustainable wanatani pattern development/application. Therefore, the formulation of the wanatani management concept should be more site-specific. The cultural, economic, and social reality empirically influences the land productivity. The wanatani management concept should also be sensitive with the segments of culture, economy, political characteristics, society, and scientific technical changes in the applied social context. The introduction of the wanatani management concept referring to the wet land ecosystem is admitted that it has not influenced the land management and use in NTT. This can make the planning and the application of the wanatani management concept not refer to the settlement of the roots of the problems, both biophysical and economic-cultural-local problems. The implication of the condition is it will be normal if then there is a process of a wrong adaptation, such as the force of applying the wet land wanatani management concept, which is generally not suitable with the dry
land condition. This condition will lead to a situation where it is not success which appears, but instead clashes of values will often occur in a form of conflicts of interest.

Based on the explanation above, the study of wanatani ecosystem with the integration of all its ecological, social, and economic functions in managing dry land is necessary to be done so that a sustainable concept can be realized. This condition is supported with the non-existence of the research which formulates a concept of sustainable wanatani management in the semi-arid ecosystem.

Ecosystem Approach Concept

The management activity with the ecosystem approach requires the understanding of the ecological system entirely, parts constituting it, and the interaction among the components inside it. Bruce Mitchell et al. [3] explains that the ecosystem concept is marked with the study of kinds of living creatures and their physical environment as an integrated unity. In managing environment, the importance of the ecosystem approach lies in the comprehensive, overall, and integrated approach. This definition also covers a system concept, including parts constituting it and the relations among those parts.

Furthermore, Jatna Suprijatana [4] states that the management with the ecosystem approach is knowledge about ecosystem and how every organism functions in it, limited by its physical environmental limitation. The objectives are to maintain the ecological process, bio diversity, and its complexity, to reduce external input, and to maintain the existing output.

Ideally, in the ecosystem management, the ecological process is expected to be able to keep continuing, although the area is exploited. In order that the ideal expectation can be realized, plenty of scientific and accurate information is required. Grumble in Jatna Suprijatana [4] explains that the management with the ecosystem approach is the management activity integrated with the scientific knowledge on ecological processes in the socio-political framework and complex values with the aim to protect the integrity of local ecosystem and the continuity in the long term. Grumble in Jatna Suprijatana [4] also identifies 10 dominant tasks in the management with the ecosystem approach, which are (a) diversity system stages, (b) ecological limit knowledge, (c) ecological integrity, (d) research systematics and data collection, (e) monitoring, (f) adaptive management, (g) intersector cooperation, (h) organization change, (i) humans as the ecosystem component, and (j) humans’ values in accomplishing goals.

The Wanatani Management Concept

The wanatani management concept refers to the environmental management concept. The environmental management is none other than the integrated resources management. The characteristics of resources based on the composition and based on the behavior in the use need to be observed in determining the sufficient environmental management ways. Because the kinds, availability, and capability of resources existing in an area can differ from the ones existing in another area, and because the importance of resources for humans can change from time to time, the environmental management system requires to have the special features of time and space.

Wanatani is a new name from the use system which has long been done practically. This system, according to King [5], is to avoid mistakes from the definition of agriculture and forestry, and at the same place and time to produce food ingredients and firewood. The modern concept from wanatani now is being developed, but the universal wanatani definition is not yet approved. In the beginning 1977 the Royal Tropical Institute in Amsterdam, the Netherlands, gave a definition of wanatani, and this definition was suggested by Bene et al. [6] which was then expanded by King and Chandler [7] as follows:

Wanatani is a land management system which can preserve and increase land productivity entirely, and is the combination of activities of agriculture (cultivation plants), forestry (tree plants),
and animal husbandry, simultaneously or sequentially on the same land, by using practical management adjusted with the local cultural pattern. This definition was then developed again by Vergara in APY. Djogo [8] by adding a social factor, the economic condition of the local people, and the environmental ecology. It is also to accommodate all types of land use combining annual cultivation plants and parenial wood plants with cattle.

**Dry Land Concept**

Based on the formulation result of *Seminar Nasional Pengembangan Wilayah Lahan Kering* (the National Seminar of the Dry Land Area Development) in May 2002, the dry land area covers: rice field dependent on rainwater for irrigation, dry field, not irrigated rice field, mixed farming, plantation, forest, bushes, meadow, and ranch. Dry land is a spread-out area of land which is not welled up or inundated with water in most of the time in a year (Hidayat *et al.* 2000). One of the characteristics of dry land according to Rukmana [9], among others, is being sensitive to erosion, especially if the slopes are not covered with vegetation.

Dry land is differentiated based on precipitation as the following:

a) Wet climate dry land can be found in an area which has precipitation more than 200mm/month for 6 to 7 months, and its dry months have precipitation less than 100mm/month for 3 to 4 months, or the precipitation is minimally less than 2000mm/year.

b) Dry climate dry land can be found in an area having dry months for 7 to 9 months and wet months for 3 to 4 months.

According to Soil Survey Staff (1960) dry land is the land which more than half the time (for seven months) suffers from drought. Dry land is the land which can be used for agriculture business by using limited water, and usually the water comes from the rain.

2. **Materials and Method**

The population of this research is all farmers applying wanatani in Amarasi District, Kupang Regency, NTT. The research samples were determined with purposive sampling, which is 9 groups of wanatani farmers (8 villages and 1 sub-district) along with their land and vegetation owned. The technique of taking samples with purposive sampling is by taking the board and the members of the group of farmers joining the group of farmers in each village. The research samples are determined with the Slovin equation, which is:

\[ n = \frac{N}{(1 + Ne^2)} \]

Explanation: \( n \) = sample size; \( N \) = farmer’s household size; \( e \) = percentage of thoroughlessness (10%). Based on the above equation, out of 3,461 farmer’s households joining the group of farmers in Amarasi District, around 100 respondents were selected to become the targets of interview.

Sample compartment for soil analysis and vegetation was decided through 2 phases with purposive sampling. The first phase was to determine 3 sample areas, which were Iay, IIay, IIIay based on AEZ map. Every area is not similar with one another, but inside each area it is similar. The second phase was to determine 8 points of sample compartments for each area by using GPRS so that the number of all sample compartment points would be 24 sample compartments. Data analysis is an important part in this research because through this process the raw data collected could be given meanings and definitions in order to be useful to solve formulated problems (Table 1).
| Objective | Data | Data Collection Method | Data Analysis |
|-----------|------|------------------------|--------------|
| 1) To analyze the ecological | a. Precipitation | Observation Station Climatology | Climate data tabulation Statistical Test |
|          | b. Micro climate | Observation Station Climatology | Climate data tabulation Statistical Test |
|          | c. Land texture | Measurement of Land Composite | Pipette Method |
|          | d. KTK | Laboratory Analysis | Extract of NH4O AC pH7 |
|          | e. pH | Laboratory Analysis | Electrode Glass |
|          | f. Base saturation | Laboratory Analysis | Extract of NH4O AC pH7 |
|          | g. C-organic | Laboratory Analysis | Walkkey and Black |
|          | h. N-tot | Laboratory Analysis | Kjeldahl |
|          | i. Available P2O3 | Laboratory Analysis | Bray I |
|          | j. Available K2O | Laboratory Analysis | Extract of NH4O AC pH7 |
|          | k. Ca | Laboratory Analysis | Extract of NH4O AC pH7 |
|          | l. Mg | Laboratory Analysis | Extract of NH4O AC pH7 |
|          | m. Microorganism (Total fungi SPK/g) | Laboratory Analysis | Total plate count (TPC) |
|          | n. Relative Density (RD) | Map observation of land use Sampling observation & measurement | |
|          | o. Relative Frequency (RF) | Sampling observation & measurement | SVI = RD+RF |
|          | p. Significant Value Index (SVI) | Sampling observation & measurement | (S-1) |
|          | q. Type Diversity Index of Margalef (R) | Sampling observation & measurement | R = --------- NL\cdot N |
|          | r. The number of types observed (S) | Sampling observation & measurement | |
|          | s. The number of individuals (all types) observed = N | Sampling observation & measurement | |
|   | Natural Logarithm (NL) | Sampling observation & measurement |   |
|---|-----------------------|------------------------------------|---|
| u. | $\pi_i$ = proportion of the number of species | Sampling observation & measurement |   |
| v. | Ratio Distribution Index of Hill (E) | Sampling observation & measurement | $(1/\lambda - 1)$ \[ E = \frac{1}{e^{H'} - 1} \] |
| w. | The number species individual number $i$ ($n_i$) | Observation Measurement Parameter Calculation of |   |
| x. | Abundance Index of Simpson ($\lambda$) | Sampling observation & measurement | $\lambda = \sum_{i=1}^{S} \frac{n_i(n_i-1)}{N(N-1)}$ |
| y. | Diversity Index of Shannon ($H'$) | Sampling observation & measurement | $H' = \sum_{i=1}^{S} \pi_i \ln \pi_i$ |

**2) To analyze the socio-economic of the wanatani ecosystem**

$X_2$ = Knowledge of farmers  
$X_3$ = Farmers’ motivation to accomplish success in farming effort  
$X_1$ = Counselling frequency  

Survey:  

$Y=a+b_1X_1+b_2X_2+b_3X_3$  

$\Pi = $ Benefits  
$TR=Total$ $income$  
$TC = Total$ $cost$  

Survey:  

$\Pi = TR - TC$  

**3) To compare ecological, social, and ecological function**

Ecological Function: Land fertility Vegetation, erosion, &climate Socio-economic function  

Table of land fertility rating of IPB laboratory  

Categorize: Optimal and sustainable if in accordance with the indicator  

AEZ map of Kupang Regency and requirements of growing plants in the semi-arid  

sustainable if not in accordance with the indicator.
3. **Results and Discussions**

*The Sustainability of the Ecological, Social, and Economic Functions of Wanatani*

The wanatani ecosystem approach has empirically been analyzed including the ecological, social, and economic functions. The sustainability indicator of the wanatani ecosystem function refers to the land supporting power and the semi-arid natural forest ecosystem function. The sustainability of those functions holistically is elaborated in Table 2.

| Ecosystem Function | Measurement                  | Sustainability Indicator                             | Explanation       |
|--------------------|------------------------------|------------------------------------------------------|-------------------|
|                    |                              | Research Result                                      | Reference         | Explanation       |
|                    |                              |                                                      | (Semi-Arid Climax Forest) |                  |
| **I. Ecological**  |                              |                                                      |                   |
| 1. Vegetation Diversity (Distribution Index/E) |                              |                                                      |                   |
| a. Tree            | 0.55                         | >0.5                                                 | Sustainable       |
| b. Sapling         | 0.37                         | >0.5                                                 | Not Yet Sustainable |
| c. Seedling        | 0.28                         | >0.5                                                 | Not Yet Sustainable |
| 2. Micro climate   |                              |                                                      |                   |
| a. Air temperature | 25.36°C                     | <27°C                                                | Sustainable       |
| b. Soil temperature| 25.5°C                      | <27°C                                                | Sustainable       |
| c. Humidity        | 88%                          | >80%                                                 | Sustainable       |
| 3. Soil Fertility  |                              |                                                      |                   |
| a. Macro nutrients: N, P, Mg | Medium | Medium | Sustainable |
| b. Micro nutrient: | Very low                     | Medium | Not Yet Sustainable |
| c. Na              | High                         | Medium | Sustainable |
| e. C/N, KTK, Base  | Medium-high                  | Medium | Sustainable |
| d. Land microorganisms (The Number) | 3 | >5 | Not Yet Sustainable |
| e. Erosion level  | 60-480                       |                                          | Not Yet Sustainable |
Descriptively, the ecological, social, and economic functions presented in Table 2 are relatively the same between semi-arid natural forest and wanatani. The finding shows that wanatani application in Amarasi is not yet sustainable. Observed from the ecological aspect, variety of vegetation cultivated by farmers fall into the category in accordance with the land suitability, but it is not yet optimal. This happens due to the fact that the food plants still dominate the wanatani land. It will cause the micro nutrient elements contained in the wanatani land to be completely gone so that its content is relatively low. On the other hand, wanatani orientation for food supply from seasonal plants still becomes the main goal. The fact is very far different from the semi-arid natural forest ecosystem, whose primary food can be obtained from breadfruit trees and other seasonal plants which are relatively rare, even non-existent. Besides the breadfruit plant and other seasonal plants which have been extinct, NTT area is grown with endemic plants, such as the sandalwood plant.

This sandalwood plant is a plant which can only be discovered in NTT area, and it is not found in other areas. This is caused by the influence of some environmental factors, such as 1) temperature, 2) precipitation, 3) types of land, and 4) topography in NTT area. In a macro scale, the logical consequences from the influence of those four factors result in a lot of vegetation having different natural biota. In an environment generally we discover that a plant only grows in one area and cannot be found in other areas; this is called endemic, which means the plant only exists in one area and its spreading is limited. The endemic plant for NTT area is, among others, the sandalwood tree. There are a few things influencing the spreading of living creatures. The environmental factors, such as temperature, precipitation, types of land, and topography, really influence the distribution pattern of living creatures. The presence of these factors causes many plants to have different natural biota.

The sandalwood plant is a local specific plant which is more adaptive. This plant has a high economic value, so that it becomes the NTT export mainstay commodity. There are at least 4 obstacles and 1 solution offered by previous researchers on the development of the sandalwood plant in West Timor of NTT area, and they are:

a. The sandalwood resources in the West Timor Island have been completely gone all being cut down.
b. Although it is endemic and has a long history with Timor community, the regeneration, the seed quality, and the techniques of sandalwood plantation are still problematic.
c. The policies and regulations governing the classification and ownership of sandalwood trees become a big obstacle based on the effort of a more effective replantation.
d. The cultivation of sandalwood trees in a big scale does not succeed.
e. The research in the future is expected to develop a small scale farmer-based system which integrates sandalwood trees in synchronized wanatani with the provisions of agro-ecology; the determination of good quality seeds and minimalism of in-breeding; and on-farm research with the supportive government regulations which assist poor farmers.

The farmers’ tendency to harvest trees (for the wood) whose age is still young to be used for energy (as firewood) and building material makes those trees lose the potential as the erosion control. This condition causes the erosion level to become high exceeding the total erosion level which is tolerable. The high erosion level also causes the big runoff of the land surface to occur, which dissolves the land nutrients and leads to the decrease of land fertility. Moreover, erosion happens on the farmers’ land which is managed for food plants and vegetables, such as corns, tomatoes, beans, chillies, and garlic & shallot. The monoculture practice on the agricultural land provides an opportunity for erosion to occur.

To obtain harvesting results in a year, the farmers will do numerous ways, including cutting down certain production plants and burning them. The practice is done by the farmers so that the food plants can grow well. The land clearing by cutting down trees and burning them on the wanatani land leads to the potential of erosion to occur. The field burning causes the loss of vegetation as land covering, and the smoke released is a harmful pollutant for environment and farmers’ health.

The solution offered to deal with the problems above (on the sandalwood plant and other kinds of wood) is to have the technology which is suitable with the local wisdom, cheap, and easily done by farmers, and it is wanatani. Wanatani empirically can improve the micro climate and the land nutrient cycle because of the interaction of trees and other plants. Consequently, the land productivity will be better.

The reality shows that due to relatively wide land ownership it becomes an obstacle to manage the land (because of the limited work force). That obstacle can be overcome by applying wanatani. With wanatani, the spirit of helping one another and working together which has been inherited traditionally from one generation to another and is something positive can be applied in the land management so that the load of work can be lighter. The behavior of the farmers in applying wanatani land conservation is the inherited habit which is continuously applied. The farmers really understand the custom related to land conservation. However, their low level of education and skills make the conservation behavior not yet optimal.

The economic aspect is the wanatani economic function which provides direct and indirect advantages. The economic analysis from the research result shows that wanatani productivity potential can afford to cover the high costs of food plant cultivation, but it cannot guarantee the sustainable condition. The high production cost for agricultural production facilities spent by the farmers requires improvement with the environmentally friendly and easily applied agricultural production facilities by farmers, such as the composting technology of cattle waste and harvest remains as the source of fertilizer. According to the researcher, the natural resources existing surrounding the land have not been used optimally by the farmers.

Food plants (rice and corn) are the basic necessity which must exist. The ecological obstacle is less considered by the farmers in cultivating these two kinds of plants so that the high cost which they have to spend is not a problem for them. If this condition keeps happening, the land productivity will be lower and lower, and this will lead to low income (life quality keeps decreasing) so that the poverty rates will keep increasing. This condition also does not become the concern of the farmers because they rely on other wanatani productions. Every year farmers also gain some fruits, plantation productions such as betel nuts and coconuts, and once in a while they will get some wood and some cattle.

The sustainable agricultural management by wanatani application empirically can be accomplished by the effort to optimize the positive interaction among the various constituting components (trees, agricultural plant production, cattle/animals) or the interaction among those components with the environment referring to the semi-arid natural forest ecosystem. Observed from
the principles of environmental science, several wanatani advantages in Amarasi compared with the other land use systems are:

i) Productivity
Based on the research result, it is proven that the total products of the combined systems in wanatani are much higher than the food plants (monoculture). This happens because the output is from one land field which is in diversity and is evenly all year long. The combination of plants provides advantages because the failure of one component/kind of plants can be covered up by the success of other components/kinds of plants.

ii) Diversity
The combination of more than two components in the wanatani system produces high diversity, covering both products and service. Observed from the economic aspect, it can reduce the risk of losses due to market price fluctuation. From the ecological aspect, it can prevent the failure from happening in the monocultural cultivation. More than one species can live in a hollow, and every species creates a condition to maintain the life of other species. The agroecosystem with many different hollows and inhabited by various kinds of species tends to be more stable than the one inhabited by one species in the monocultural environment. Reducing the diversity of species and increasing the variety through genetic methods make the agricultural land unstable. The functional diversity in agroecosystem is accomplished by combining species of plants and animals having complementary characteristics in the positive-synergetic interaction resulting in ecosystem stability, supporting the hydrological function, and making the community of farmers survive.

iii) Self-regulation
High diversification in wanatani is expected to be able to fulfill the farmers’ basic necessity and to release them from their dependence on outside products. The system independence to function will be better; in other words, it will not require much input from outside (fertilizer, pesticide) with high diversification compared with the monocultural system.

iv) Stability
Wanatani practice having optimal diversity and productivity will be able to provide balanced results as long as the land is exploited so that it can guarantee the income stability and sustainability of the farmers. Even though the wanatani diversity in Amarasi has fulfilled the criteria, in reality the productivity is not yet optimal.

The principles of sustainability start by having two basic foundations, ecoliteracy and ecodesign. Ecoliteracy is the understanding of organizational principles developed by ecosystems through evolution to support life networks, such as moving the ecological cycles, as diversity guarantees resistance. Ecodesign is to introduce an era which is not based on what we can obtain from the nature but on what we can learn from it. For sustainable development, what needs to be preserved is not the suitability and the balance but the environmental supporting power which can support sustainably the growth and the development. The increase and the decrease of the supporting power depend on the factors influencing it. Those factors, among others, are: (1) the geographical factors, which are climate, land fertility, erosion, and others; (2) the sociocultural factors, which are knowledge, technology, and behavior influencing environment.

The ecological supporting power is to optimize the food productivity by minimizing the use of agricultural production facilities, such as chemical fertilizer and pesticide observed from the volume, time, and frequency aspects. The implication is the production cost and land degradation are expected to decrease. Moreover, optimizing wanatani productivity is by determining the proportion of various kinds of trees, plantations, and fruits with the balanced combination. Cutting
down trees will not be the priority, and the advantages of the positive interaction between trees and other vegetation will be prioritized more so that the direct and indirect advantages of wanatani will be also optimal. The ecological supporting power is the support system of the semi-arid ecosystem with the application of agriculture with forest ecosystem.

The socio-economic supporting power is to optimize the income of the farmers by increasing the capacity of the social and financial institutions. The social institution includes the customary institution roles in increasing the conservation behavior so that land degradation decreases and the land becomes productive and increases income. Besides that, the capacity improvement of human resources is by enhancing knowledge and introducing innovation and local specific technology in utilizing resources surrounding the land. The financial institution is to provide funding by soft loan so that it can optimize the farming capital. Increasing the capital in a form of funds and human resources quality is expected to raise income and reduce the poverty in the population.

Based on the research result, it can be proven that what causes land degradation and the high rates of poverty in Amarasi is the non-optimal socio-economic supporting power. The ecological supporting power is actually quite optimal to support the wanatani productivity. However, the farmers’ behavior is not yet optimal to apply conservation making the ecological function disturbed, as it can be shown especially with the high total erotion value in Amarasi. Observed from the ecological supporting power, the wanatani development is very suitable and potential in increasing the income and the welfare of the farmers compared with the food productivity including paddy and nonstaple food crops. The fact is also supported by BPS data (2003) that the agricultural productivity in Indonesia provides a clear picture that there is a pretty wide economic disparity between the farmers of food plants and the horticultural farmers.

Time series data of Susenas for the period of 1996-2002 show that the demand of the consumers based on high value food grows fast, while the demand of food ingredients sourced from various seeds suffers from stagnation. The 2003 Agricultural Census Data also show the pretty fast growth of farming in Indonesia is from the horticultural subsector. The number of the horticultural farmers also increased sharply, from 23% in 1993 to 36% in 2003, out of the total number of farmers. On the other hand, the number of the farmers of paddy and nonstaple food crops decreased from 84% in 1993 to 71% in 2003.

The productivity development of several agricultural commodities, especially in the last 20 years, indicates that the productivity growth trend has kept decreasing, although the level of productivity itself still increases (Table 3).

Table 3. Agricultural Productivity Development in Indonesia

| Productivity (tonnes/ha) | Average 1980-1985 | Trend (%) | Average 1986-1995 | Trend (%) | Average 1996-2000 | Trend (%) |
|--------------------------|-------------------|-----------|-------------------|-----------|-------------------|-----------|
| Paddy                    | 3.70              | 3.55      | 4.22              | 0.91      | 4.34              | 0.45      |
| Corn                     | 1.62              | 3.98      | 2.10              | 1.89      | 2.63              | 2.30      |

Source: Data managed from BPS (2011)

The agricultural sector requires media or a quite wide area in a form of plain land, and the requirements of growing plants, especially the main food ingredients, are pretty complicated. With a quite wide area, the complicated requirements lead to also a pretty high opportunity cost for agriculture. The requirements required, for example, are physical structure and land chemistry, topography, nutrient elements, water content, climate, and others, so that not all land is proper and appropriate or suitable to be developed for certain plants. The ecology of NTT is empirically very
suitable for wanatani, which is agriculture with the forestry system compared with food plant development, especially paddy and nonstaple food crops.

The literature study result explains that main food plants (paddy and corn) cannot be entirely called as the indigenous variety of Indonesia since all of those come from and have been mixed with the products from outside. Based on the history, the place of birth or the Motherland of paddy was in the Southwest border of China, Yung Nan – Sour Hill, India, in 7000 B.C. The first batch of rice diffusion happened along Mekong river and other rivers connecting Indochina peninsula followed with human migration. The second batch occurred from the Sour Mountain entering Brahmaputra, Gangga, Bengal to Chennai, Bengal Bay, Melayu peninsula, and Indonesia. The third batch went through Himalaya Route. The fourth batch went through Yangtze river flowing from Yung Nan as long as 6,400 km heading to Shanghai and then to Korea and Japan. Corn comes from South America, and after the arrival of Europeans, it was spread to all over the world. It means what we consume now is the result of ethnic, race, and cultural cross scientific breeding.

Based on the prioritized food plant kinds, especially paddy in NTT, it causes the farmers to give all their funds and energy to manage very wide land. The single crop approach forces the farmers to use pesticide and chemical fertilizer which, on one hand, have been proven to be able to increase production but, on the other hand, can cause environmental problems. In line with the research result of Nurmalina R. (2008), she states that the sustainable index value of the rice availability system (ecological, economic, socio-cultural, institutional, and technological) between areas in Indonesia really varies in the range of 33.37-67.23. NTT area is included in the category of ‘less sustainable’. The daily solar (sun) radiation energy in Indonesia is around 20 mega joule (MJ) every square meter of land. The energy will be lower and lower if the sun is covered with cloud. The dilemma faced in the agriculture is the high solar energy happening in the dry season when the precipitation is relatively low, unless there is irrigation.

On the contrary, the planting season is done in the rainy season as the solar radiation energy is less because the sun is covered with cloud so there is tradeoff between water necessity and the solar energy availability for photosynthesis. Generally, the fruit quality and plantation commodities are higher in the dry area because the growth of fruit or sugar content happens during the dry season when the solar energy is high. In contrast, several plants are very vulnerable to drought, whereas some can adapt like teak which has its leaves fall during the dry season to reduce the transpiration speed.

The long-day variation for a year in Indonesia is not too big (11 to 12 hours) if compared with temperate areas like in Europe which can reach 18 hours. For certain long-day plants, although farmers plant them three times in a year and in Europe they can only be planted once in a year, by using the plant seeds with the same quality, the result obtained will be far higher if they are planted in Europe which has a long day longer and lower temperature compared if planted in Indonesia. The long day controls the change of plant development phases, while the interphase time will then determine the period of plant biomass accumulation which eventually determines not only the productivity but also the quality of plant result. Therefore, the farmers need to consider the agricultural commodities which will be developed or produced in certain climate environment.

In Indonesia, the solar radiation energy received on the surface can support agricultural production for the whole year as long as water is not an obstacle. NTT has low precipitation so that water availability is an obstacle, but this area has bigger solar radiation energy than other areas. The energy is the main energy source in the photosynthesis process to support plant growth and also is the factor which limits and filters which kinds of plants are really suitable for certain areas (local specific).

In the ecological principle, the use of agricultural technology, such as chemical fertilizer, pesticide, excellent seeds, is basically the process of energy subsidy increase towards the human-made ecosystem which has some side effects that must be considered. To maintain the preservation of the life environmental function and to prevent pollution and environmental damage, it is necessary to propose an economical agricultural system in using energy subsidy whose basic
foundation can be searched from the local wisdom. Wanatani is one of the local wisdom which has been applied from one generation to the next by the local farmers, and the research result proves that it is ecologically, socially, economically suitable and requires management improvement to achieve its sustainability.

With the tendency of fuel price increase, the energy problem in agriculture becomes a more serious and interesting discussion because modern agricultural technology cannot be separated from the use of high energy production inputs, such as excellent variety, artificial fertilizer, irrigation, pesticide, and mechanism. Those production inputs are categorized as high energy since the process of finding, setting, making, distribution, and use of those requires high energy, especially from oil. It is common if those agricultural production energy inputs are used economically, efficiently, and optimally by remaining to do the effort for the optimal productivity goal to be accomplished. This can be done by using the energy economical agricultural system, which is the agricultural system using efficient energy, such as wanatani in Amarasi.

Food availability is not identical with rice availability, and food resistance is not identical with self-supporting in rice. The food balance inequality means challenges in food supply in the future will be harder and more complex. Therefore, it is necessary to have technological innovation, conventionally and biotechnologically. NTT has variety of ecosystems and biological resources. This is the basic capital in providing food supply in the future. It is necessary to have a dynamic agricultural system, depending on commodity diversification having a more advantageous market prospect by integrating variety of plants and cattle.

4. Conclusions and Recommendations

Conclusion

Wanatani management has not completely referred to the semi-arid natural forest ecosystem concept. Observed from the ecological function including vegetation, land fertility, micro climate, dan land suitability, the wanatani is not yet optimal and not yet sustainable to support land productivity and conservation. From the economic function, the wanatani productivity is already optimal, but it is lack of institutional support, and the social function makes the management not yet optimal and not yet sustainable. Based on the empirical testing in the field and the analysis done, it can be formulated that the sustainable agricultural management is the application of wanatani referring to forest ecosystem by integrating the ecological, social, and economic functions.

Recommendations

This needs to be implemented, especially for the relevant institutions, such as the Ministry of Agriculture and the Ministry of Forestry, done cross-sectorally involving other institutions (the Ministry of Life Environment, the Ministry of Research and Technology, Higher Education, Regional Governments, and Society Self-Funding Institutions) to formulate various technologies and agricultural productivity increase programs with the agricultural pattern applying the local specific forest ecosystem.

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