Ecosystem Services of Indigenous Kaliwu Agroforestry System in Sumba, Indonesia

Gerson N. Njurumana[1], *Ronggo* Sadono[2], *Djoko* Marsono[2] and *Irham*[2]

[1]Environment and Forestry Research and Development Institute of Kupang, Kupang 85115 Indonesia
[2]Universitas Gadjah Mada, Yogyakarta, 55281, Indonesia

Abstract. Agroforestry is an environmentally friendly land resource management applied by farmers in various countries. The differences in ethnicity, geography, biophysical environment, and socio-economic background influence the application of this agricultural model, known as indigenous agroforestry. However, information on the management and ecosystem services of indigenous agroforestry in semi-arid ecosystems is not widely known. This research examined the management and provision of service for the Indigenous Kaliwu Agroforestry System (IKAS) on Sumba island. It was carried out in the Central Sumba regency using survey and observation methods in 70 sample units of farmer households distributed in 7 villages. Data were collected through interviews and observations on IKAS management initiatives, including provision services for foodstuff, fuelwood, timbers, and fodders. The results showed that IKAS is a local initiative model for the management of flora biodiversity through the replication of natural forest models in traditional cultivation environments. This is reflected by the plant's biodiversity developed at IKAS, including endemic and cultural keystone species. The development of various plant species has implications for the provision services for foodstuff in form of tubers and fruits, fuelwood, timbers, and fodder. In addition, IKAS plays a role in supporting sustainable dryland management, biodiversity conservation, and farmers' livelihoods. This research recommends that the optimization of the IKAS role for community livelihoods and environmental conservation be carried out through the support of its development policies by local government in Sumba.

1. Introduction

Agroforestry is an environmentally friendly land resource management approach applied by most farmers worldwide [1]. The different ethnic, geographic, and socio-economic backgrounds of farmers in various countries influence the diversity of agroforestry development models. The model diversity is due to the different perspectives and actions of each community group in responding to and managing their biophysical environment [1]. Furthermore, this scenario promotes the development of agroforestry approaches in land resource management, one of which is the indigenous agroforestry system [2].

Indigenous agroforestry systems are the result of socio-economic and ecological adaptation processes. These systems reflect the experience and knowledge of local

communities [3]. The systems are in form of natural resource management including spring conservation [4], soil and water conservation [5], and plant utilization [6,7,8]. Understanding the characteristics and value of ecosystem services from indigenous agroforestry systems is necessary to build synergies for specific approaches to conserve land resources and the environment [9,10]. Sufficient knowledge of the nature and specifications of each indigenous agroforestry system facilitates the enactment of management policies. Several research on agroforestry have been carried out, including biodiversity conservation [11], land management innovations [12]; foodstuff sources [13]; ecosystem services [14]; landscape conservation [15], food and wildlife security [16], land fertility [17]. However, there is little research on the practices of indigenous agroforestry systems that are not specific to semi-arid ecosystems.

Indonesia, as one of the countries with various ethnic groups reaching 1,331 [18], has a wealth of agroforestry-based land resource management models, which include the Indigenous Kaliwu Agroforestry System (IKAS) on Sumba island. IKAS is a timber plant-based land resource management model. This model manages the non-timber forest products and various species of food plants that are generally developed in hilly regions adjacent to residential areas. The dynamics of IKAS management have been consistent for a long time as a model of land resource management that provides direct benefits to the livelihoods of the surrounding community. Furthermore, the strong relationship between the community and IKAS underlies research on the management and contribution of ecosystem services in supporting community livelihoods and the conservation of the surrounding environment.

2. Methodology

This research on IKAS on Sumba island was carried out in Central Sumba Regency (Figure 1). Data collection involved several stages, namely: determining 7 village samples randomly, conducting an inventory of household units managing IKAS. The potential respondents were determined through proportional random sampling in each village. Afterwards, a total of 70 households in 7 villages were determined randomly as respondent sample units for field data collection. Structured and semi-structured interviews were performed on the management and field observations in IKAS management units. Data and information obtained include the diversity of plant species in IKAS and their use for food, animal feed, firewood and carpentry wood. Data and information were analyzed descriptively-qualitatively.

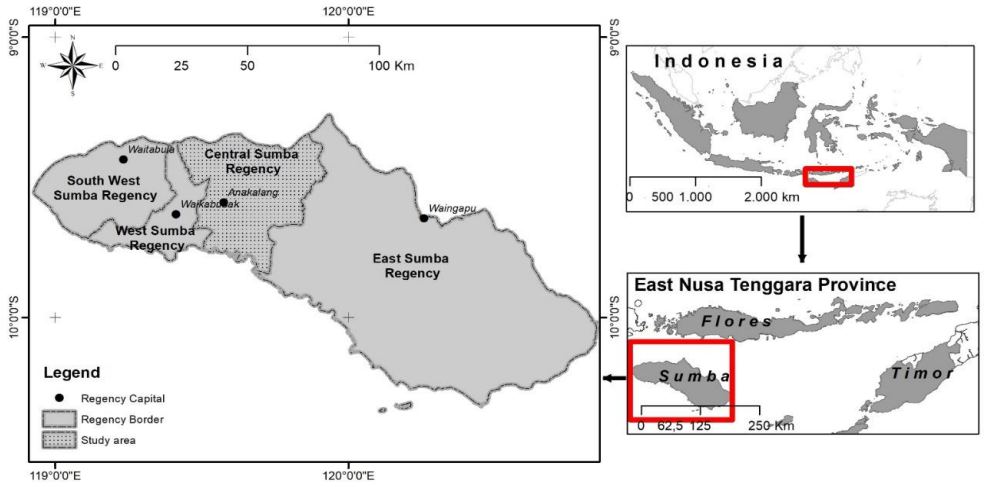

Fig. 1. Research sample in Central Sumba Regency

3. Results and Discussion

3.1. Profile of respondents

The majority of IKAS farmer respondents were men. However, in management practice, there is a balanced role between men and women. They have various levels of education, dominated by secondary education levels (Figure 2). Figure 2 shows that most farmers were included in the productive age group. 92.86% of farmers have relatively long farming experience, but still require technology transfer support to improve the sustainability of IKAS management businesses. Farmers have interacted in the IKAS management since they were children until adulthood because they are local indigenous people. They were born and grew up in rural areas, have a high social kinship and relatively homogeneous customs. This condition enhanced their knowledge of the social, economic, and natural potential conditions around them. Furthermore, this is an opportunity to facilitate the development of IKAS farming in the future.

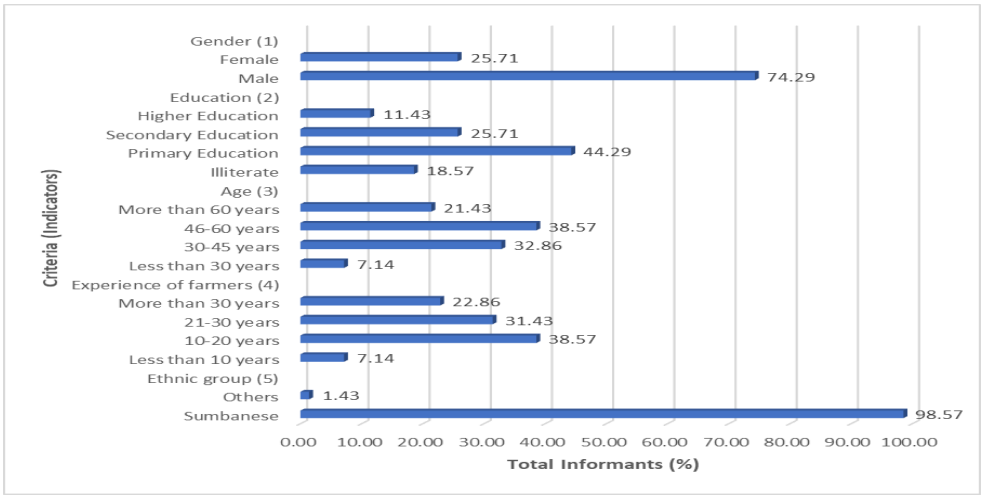

Fig. 2. Demographics of IKAS farmers in Central Sumba Regency

3.2. Biodiversity conservation

IKAS is a land resource management unit that involves the development of plant and crop biodiversity on a small scale according to the land area owned by farmers. The plants developed consist of various types, from seed to tree level (Fig 3).

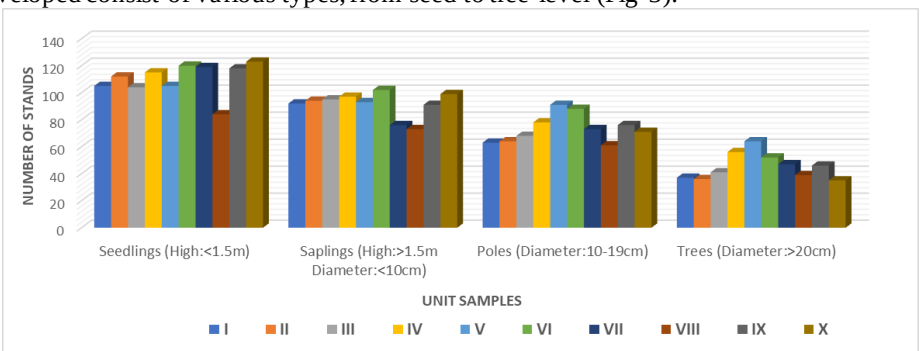

Fig. 3. Potential of plant biodiversity according to growth groups in IKAS

The results showed that the IKAS development is a form of replication of natural forests in the farming environment. Furthermore, the diversity of plant species is high in each observation sample. IKAS acts as a habitat for 145 plant species, with socio-cultural, economic, and religious values for farmers as stated in previous research [19]. Approximately 40 species of timber and non-timber plants constitute the group producing fruits that are directly beneficial to farmers. There are 11 species of food plants producing tubers, and 22 species producing fruits, in line with [20]. The data showed that the distribution rate of plants at each IKAS site ranges from 4.29% -100% [21], including several fiber-producing plant species.

Plant management at IKAS has a multi-aspect impact on the livelihoods of farmers. Most of the plants have a dual function as a source of fuelwood, construction timbers, fodders, medicinal plants, and environmental services for land conservation. Farmers regenerate plants culturally and naturally in the IKAS ecosystem. The analysis on plant vegetation as shown in Figure 3 signified that the plant density of the seedlings group ranged from 26,000-29,250 (± 85.92%), the saplings group ranged from 3,640-3,720 (± 11.44%), and the tillers group ranged from 720-740 (± 2.27%) and the mature trees group ranged from 113-118 (± 0.36%). The dominance of seedlings and saplings is a potential indication for plant regeneration and the sustainability of IKAS management. One of the efforts of farmers to maintain biological diversity is through the domestication of the IKAS ecosystem. 74 (51%) plant species were evenly distributed due to a high preference for use by farmers. Furthermore, there were 71 plants (49%) which were alternative species, cultivated for specific purposes including plants and cultural keystone species, and the ones that grow naturally.

IKAS management has a positive influence on efforts to support the conservation of biological resources that provide multi-benefits for farmers. This promotes the community to improve management, and each IKAS stretch is a community-based biodiversity management unit. The structure and composition of plants at each growth stage are an illustration of their important value and conservation efforts. Furthermore, the domination of undergrowth and saplings in each IKAS unit is an effort to maintain the smooth running of the regeneration process as a successor to mature trees that are harvested.

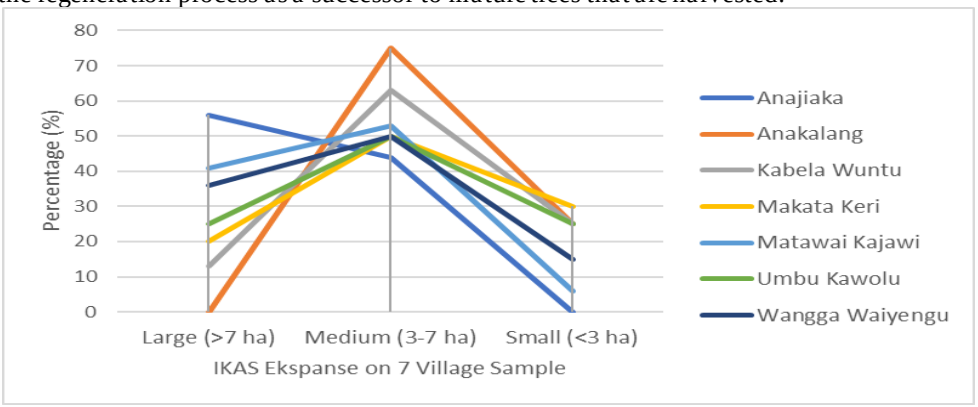

Fig. 4. The classification of the IKAS area in the sample villages

The analysis showed that the role of IKAS as a buffer for the forest ecosystem can be observed from the varying stretch average area (Figure 4). Apart from Anakalang Village, most of the research sample villages had high (> 7 ha) and low (<3 ha) categories, while the medium category (3-7 ha) was found evenly in each sample village. Overall, the IKAS stretch area as a biodiversity management unit is 125,424 ha [22], larger than the forest area in

Central Sumba which is 29,995.43 ha [21]. Referring to the potential of IKAS, it is estimated that there are at least 106,102 mature trees that are cultivated by farmers which support community livelihoods, biodiversity conservation, and buffer forest areas. The existence of IKAS has contributed to the increase in timber production in Central Sumba from 260 m^3 [20] to 466,551 m^3 [23].

3.3. Provision services

Previous research showed that the population majority in Central Sumba is highly dependent on land resources, indicated by 60.15% which rely on the agricultural, livestock, and fisheries sectors [23]. This has implications for an economic reality that relies on dry land farming. Climate conditions and low land productivity affect 14,226 (82.60%) households that are classified as underprivileged, including the poor which total 25,120 (34.62%) in Central Sumba [23].

The results of this research confirmed that the management of plant species diversity through IKAS provides benefits to the community as a source of foodstuff, fuelwood, fodders, and timbers (Table 1). A similar practice is observed in the yard model as a source of protein, carbohydrates, vitamins, and minerals [24,25]. Furthermore, farming development that combines various benefits is one of the characteristics of an environmentally friendly traditional farming system. Farming development is widely practiced by people in various countries of the world such as Africa and Mexico [26,27].

Table 1. The need for resources and provision services from IKAS.

Types of Farmers' Needs	Sample Units		Farmers Consumption	Contribution of IKAS	
	Village	Household		Total	Percentage (%)
Foodstuff (kg/month)	7	70	22.27-23.92	9.14-9.57	39-41*
Fruits (kg/month)	7	70	27.03-28.33	17.95-19.67	66-69*
Fodders (kg/month)	7	70	60-67	27-36	31-32
Fuelwood (m^3/HH/year)	7	70	6.9-14.2	5.4-11.7	74-86
Timbers (m^3/HH/year)	7	70	1.3-4.6	0.9-4.5	59-96**

Source: Primary Data; [22]**, [28]*.

The provision of services for IKAS is the result of farmers' efforts to develop various species of plants. The results showed that they planted and nurtured foodstuff sources from the tuber group, including *Canna edulis* Kerr, *Hanthosoma violaceum* SCHOTT), *Discorea aculcata* LINN, *Ipomoea batatas* POIR and *Manihot utilissima* POHL. Farmers obtain direct benefits from fruit production, including *Ananas comosus* MERR, *Anona muricata* L., *Artocarpus heterophyllus* Lamk, *Artocarpus integra* MERR, *Carica papaya* L., *Citrus maxima* (Burm.) Merr.**,** *Cocos nucifera* L.**,** *Mangifera indica* Blanco and *Persea gratissima* Gaertn.f. They also develop plant species for food flavoring, fiber producing, and material for cultural consumption. Some of these include *Aleurites moluccana* L. Willd., *Arecha cathecu* L., *Capsicum annum* L., *Capsicum frutescens* L., *Citrus hystrix* D.C., *Curcuma domestica* Linn and *Curcuma longa* Linn, *Cymbopogon nardus* (L.) Rendle., *Moringa oleifera* Lamk., *Ocimum* sp., *Piper amboinensis, Piper betle* L., *Sechium edule* Swartz, *Solanum torvum* Swartz and *Zingiber* sp.

Observations also show that IKAS contributes to fulfilling the needs of fodder. The business of raising livestock is a tradition of the Sumba community, which is an economic, socio-cultural, and protein reserve. Livestock cultivation is still performed conventionally with the free range system, especially poultry (native chickens) small livestock (pigs and goats), and large livestock (horses, buffaloes, and cows). Each farmer raises at least 1 small

livestock (goat and pig), and demands the availability of forage as fodder. The demand for fodder is dominated by local pigs with an average of 2 kg/head/day (insufficient). The main sources of fodder ingredients are tubers from the garden and IKAS, including cassava (*Manihot uttilisima*), taro stems (*Caladium bicolor*), sweet potato (yam-stem-leaf), banana (leaf-stem), coconut, canna, jackfruit (fruit-leaves) and several types of forage such as king grass (*Pennisetum purpureophoides*), bananas (*Musa paradisiaca*), agati leaves (*Sesbania grandiflora*), river tamarind leaves and fruit (*Leucaena leucocephala*), white-barked acacia leaves (*Acacia leucophloea*), elephant grass (*Pennisetum purpureum*).

Fuelwood is one of the basic needs of the community. The Socio-Economic Survey [21] showed 81.17% of the population in Central Sumba uses fuelwood for cooking (Table 1). Meanwhile, the low purchasing power of the community causes dependence on fuelwood to remain high. as 94.29% of respondents are fuelwood users. There are several species of firewood sources at IKAS, including *Calliandra calothyrsus*, *Zapateca tetragona*, *Cassia siamea* Lamk., *Melochia umbullata*, *Schleichera oleosa* (Lour.) Oken., *Timonius sericeus* (Desf).K.Schum., *Gliricidea sepium* (Jacg.) Walp., and *Hibiscus tiliaceus* L. They also utilize timber waste in form of branches and twigs as fuelwood. Periodically, they carry out maintenance through pruning tree branches used for fuelwood. The self-reliance on fulfilling fuelwood requires a reduction in pressure on forest resources.

The need for timbers in Central Sumba is projected to be high, as it is estimated that 80.33% of the residents' houses use bamboo and wood walls [28]. The construction of wooden-based traditional house buildings, with an average area of 100 m^2, contributes to the increasing demand for timbers from 12-15 m^3. Some farmers sell timbers to IKAS for education, to help relatives and public facilities in the village. *Swietenia machrophylla* King, *Swietenia mahagony* L. Jacg., *Gmelina arborea* (Burm F.) Merr., *Intsia bijuga* (Colebr.) Kuntze, *Tectona grandis* L.f., *Macaranga tanarius* Muell. Arg., *Toona sureni* (Blume) Merr., *Timonius sericeus* (Desf).K.Schum, *Sterculia foetida* L., *Alstonia scholaris* R.br., *Alstonia spectabilis* R.Br., *Artocarpus heterophyllus* Lamk., *Artocarpus integra* Merr., *Cocos nucifera* L., and *Paraserianthes falcataria* (L) I. C. Nielsen are species of timber produced from IKAS.

The provision of services for IKAS plays a significant role in supporting the livelihoods of farmers, as well as the conservation of land resources and flora biodiversity. Farmers obtain benefits in form of foodstuffs supporting household food security, including reducing costs for fuelwood and timbers. The cultivation of timber helps to provide wood for carpentry periodically for about 15 years, including the use of bamboo to build or renovate houses. Furthermore, biodiversity in IKAS also plays a role in supporting the traditions of the Sumba community in raising livestock as one of the economic reserves.

This research suggests that the IKAS model should be one of the inspirations for a number of government programs to consider the diversity of plant species resembling the IKAS model which has been tested for sustainability. The existence of IKAS is expected to inspire an approach to environmental and forestry development. Therefore, it starts from what exists and develops in the community. A superior local ecosystem management model unit in each region should be promoted as regional branding in community-based environmental conservation approaches. IKAS is an example of best practice replication and representation of forest plant community models cultivated in the built environment as a superior local ecosystem management model.

According to IKAS management, the development of plant biodiversity can be carried out with the concept of multi-purpose tree species management, with implications for multi-product and multi-impact. Multi-product is related to providing of services used by farmers, with a positive impact on income, environmental services, socio-culture, and spirituality. These benefits can be a consideration for integrating management with government programs in environmental conservation, community forest development, and community-based

reforestation. Furthermore, strengthening agricultural cultivation, forestry, livestock, and environmental conservation can be carried out simultaneously, thereby increasing their function in maintaining the stability of ecosystem services. The social, economic, and ecological functions of IKAS management are to become the basis for its development. The IKAS management also aims to facilitate the local wisdom of the community in managing it as one of the superior local ecosystem management models with a strong sociological foundation.

4. Conclusion and Implication

IKAS is a model of natural forest replication in the management of biodiversity in dryland farming. It provides benefits, independence and resource fulfillment for the farmers' livelihood. Various plant species management initiatives have enhanced the important role of IKAS in conserving biodiversity, natural resources, and the environment. The benefits and sustainable management places IKAS as an identity symbol of the Sumba community in developing environmentally friendly farming models.

The IKAS farming model has implications as a model for superior ecosystem management based on land resources and biodiversity. Furthermore, policy support from the local government to promote its development on Sumba island is very necessary. It also has the potential to scale up at the national level to accommodate and promote the development of indigenous agroforestry. This is in line with the spirit of "Unity in Diversity", where various indigenous agroforestry models can be synergized in supporting sustainable natural resource management, both at local, national, and international scales.

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