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Designation of Traditional Agroforestry Clusters for Handling Climate Change Based on the Sustainability Index in the Archipelago

Jan Willem Hatulesila and Gun Mardiatmoko

Abstract

Many people already understand that the impact of climate change is directly related to forestry, agroforestry, and agricultural crop production, as well as the preservation of biodiversity in small islands, which supports the local community's economy by producing various types of plants. According to studies, the dynamics of climate change directly impact the availability of food and island communities' readiness to maintain local economic resources. Therefore, agroforestry clusters can be determined based on the agroecological conditions directly related to the distribution of plant species, such as their ecological, conservation, landscape, and economic aspects. Furthermore, the area of land and the composition of the types of agricultural crops grown were taken into account based on the form of cluster analysis variables, in the villages on the small island of Maluku, which are only in the good (average sustainability index score is 89.2) and moderate (average sustainability index score 69.7) categories. Agroforestry also contributes to climate change mitigation and adaptation, therefore, to determine the magnitude of the contribution of agroforestry in absorbing carbon, it is necessary to measure biomass using non-destructive and destructive methods.

Keywords: sustainability index, traditional agroforestry, local wisdom, biomass, sasi, masohi

1. Introduction

The adequate management of the biodiversity and biological resources of natural products in a sustainable manner is one of the efforts used to maintain their benefits in such a way that they do not cause damage to the ecosystem. The application of a forest management system is based on the principle of sustainability by increasing the overall land yield. This is also achieved by sequentially combining the production of agricultural crops (including trees), forest plants, and animals on the same land unit, using management methods that are culturally appropriate to local residents, are a feature of the traditional agroforestry [1].

Environmental damage occurs due to biophysical or ecological related global climate change, such as resource depletion, deforestation, and agricultural and forestry land degradation in rural landscapes. Ecosystem diversity is similar to the landscape, which consists of various patches and corridors (such as rice fields, moor, crops, grazing fields, lakes/reservoirs/poolponds, plantations, mixed gardens, residential areas, rivers, irrigation channels, village roads, footpaths, *etc.*). Therefore, the diversity of agricultural landscapes (agrobiodiversity), forestry (Agro-forestry), fisheries (Agro-Fishery), and livestock (Agro-Silvopasture) supports biodiversity when facing climate change as a central issue.

Agroforestry has two main functions, namely (1) Socio-economic function, which reflects human efforts in trying to meet their needs in the social and economic fields. It is generally, in the form of forest products, food plants, animal husbandry, *etc.* (2) Environmental function, in the form of components, is inseparable from agroforestry and acts as a system that includes hydrological, ecological, and conservation functions. This is usually the form of services, quantified using existing parameters, such as using agroforestry functions to prevent soil erosion through land cover and canopy strata, storing groundwater reserves, and using carbon binding to reduce greenhouse gas emissions, and conserving or protecting certain flora and fauna.

The current impact of climate change that threatens all bio-ecology and natural resources has encouraged people worldwide to carry out processes of mitigation and adaptation to deal with the occurrence of various natural disasters. This is because of the degradation of natural resources, pollution, and loss of biodiversity which disturbs and increases the vulnerability of health systems to damages, thereby reducing resilience. All forms of agricultural systems on large and small islands in Indonesia are sensitive to climate change variations [2].

The sustainability of ecosystems, especially in small islands, is determined by the land's biodiversity. In Asian society, including Indonesia, traditional farming practices known as agroforestry have been passed down from generation to generation. They have been proven to be able to develop and fill the context of sustainable agricultural development. Applying a forest management system based on the principle of sustainability increases the overall land yield. This is achieved by combining the production of agricultural crops (including tree crops), forest plants, and animals on the same land unit. Furthermore, various methods and management efforts are culturally applied as appropriate local populations for the current traditional agroforestry [3].

Agroforestry models have become a prioritized choice in cropping systems because they have several advantages compared to forestry and agricultural systems (monoculture). This advantage can be seen from the multiple products produced throughout the management of both wood and non-timber, including environmental services. The development of an agroforestry system is dependent on the structure of the constituent components. A decrease is experienced in the annual crop products when the agroforestry system component dominates the number of trees. Therefore, silvicultural action in agroforestry is the key to success. In addition, the agronomic regime chosen also has a positive correlation to tree development. The spatial dynamics in an agroforestry system are determined by how these constituent components use existing resources. It is important to ensure a balance between the interests of trees and seasonal plants using the resource sharing system. Agroforestry dynamics directly affect seasonal crop cultivation, with some able to provide support for seasonal crop cultivation throughout the year. However, it needs to be noted that other agroforestry models have limitations, therefore, the presence of seasonal crops can only be carried out at certain times, such as during the rainy season.

The land's carrying capacity can be represented by the condition or level of fertility of the site. Therefore a fertile land tends to possess a better carrying capacity and vice versa. The principle of the agroforestry model in terms of land management that needs to be understood is the addition of other plants or trees as a single system with various components [4]. In agroforestry systems, the fallow period is highly dependent on spatial dynamics, which tend to depend on the type of constituent. The selection of constituent tree species in an agroforestry system needs to consider the characteristics or basic information, such as physiognomy, distribution, and application of silvicultural recipes.

Agroforestry can be grouped into two systems, namely simple and complex [3]. In a simple agroforestry system, trees are intercropped with one or more seasonal crops. Meanwhile, a complex agroforestry system permanently involves various types of trees that are intentionally or naturally planted. The main characteristic of complex agroforestry is its physical appearance and the dynamics similar to forest ecosystems, therefore, it is also known as agroforest. Generally, they are massive mosaic forests that consist of several 1–2 ha plantations owned by individuals or groups and located far from their homes and village boundaries.

2. Traditional “*Dusung*” agroforestry patterns in the Maluku Islands

The traditional land-use practices by communities in Maluku Province in terms of culture and customs are proven to answer ecological, economic, and socio-cultural problems, such as the land use pattern known as *dusung*. This process is used to plant short-term subsistence agricultural crops (vegetables, tubers, and spices), fruit crops (*Durio* sp., *Lansium* sp., *Myristica* sp., *Mangifera* sp., *Nephellium* sp., etc.), and forestry plants (*Pterocarpus* sp., *Paraserianthes* sp., *Anthosepalus*, *Alstonia* sp., etc.) in the long run. The condition of small islands in Maluku is geophysically undulating to hilly areas and dominated by dry land agroecosystems. The developed agricultural pattern is a “multi cropping” or “mixed” agroforestry system obtained by combining tree crops, such as plantation, industrial and forest plants in several strata. Food crops are also obtained as intercrops, usually carried out by the community at the end of the rainy season and into the dry season as a form of practice building *dusung*.

The combination of plants in *dusung* agroforestry is characterized by several forms of land use, which are also different in each agroecosystem because they have *dusung* types from the simplest composition to the more complex ones. The cropping pattern of annual crops is the main business, while forest plants are secondary. The main types of perennial crops are coconut (*Cocos nucifera*), cloves (*Eugenia aromatica*), nutmeg (*Myristica fragrans*), sago (*Metroxylon sago*) and fruit trees such as durian (*Durio zibetinus*), langsung (*Lansium* sp), duku (*Lansium domesticum*), advocate (*Anona muricata*), gandaria (*Buea macrophylla*), mangosteen (*Garcinia mangostana*), mango (*Mangifera* spp) and guava (*Eugenia jambolana*), etc. Furthermore, there are several types of forestry plants, such as samama wood (*Anthosepalus macrophylla*), pule (*Alstonia scholaris*), salawaku (*Paraserianthes falcata*), forest guyawas (*Duabanga mollucana*), and community planted wood such as teak (*Tectona grandis*), titi (*Gmelina mollucana*) and lenggua (*Pterocarpus indicus*). Annual crops are dominated by cassava (*Manihot utilisima*), sweet potato (*Xanthosoma sagittifolium*), taro (*Calocasia esculenta*), bananas (*Musa* spp), peanuts (*Arachis hypogaea*), corn (*Zea mays*), etc. Vegetable plants cultivated are genemo (*Gnetum gnemon*), spinach (*Amarantus* sp), long beans (*Vigna sinensis*), mustard greens (*Brasica* sp), eggplant (*Solanum tuberosum*), cucumber (*Cucurbita* sp), tomato (*Solanum lycopersicum*), etc.

The cultivation process adapted by the local community, led to a change in secondary forest which was covered by a very dense plant canopy comprising of various bird species, and various types of insects as indicators of a forest ecosystem few years later. The *dusung* farming pattern is shown in **Figure 1**.

The *dusung* farming pattern is still well-practiced, and till date, where the traditional agroforestry with the archipelago's geographical conditions can maintain the ecological and ecosystem functions. Furthermore, biophysical conservation efforts used to cultivate various plants are maintained and function as a buffer zone for water management and soil conservation. The *dusung* farming pattern also provides social sustainability where there is the customary practice of “*sasi*,” which prohibits harvesting before time and economic sustainability. The yields of various types of plants can be sold to the sub-district or district market. In addition, the *dusung* management is carried out together, starting from land preparation to harvesting called “*masohi*.” Generally, there are several *masohi* systems, namely: (1) *Masohi Bilang*: in this *masohi* the first person individually invites another to help in carrying out the job at the initial stage, (2) *Masohi Balas*: the second person replies to the first to help carry out a job. In other words, there is an exchange of the same work assistance in the implementation of the construction of the *dusung* on the two lands belonging to that person, (3) *Masohi Kumpul*: several people work together by taking time to carry out a job. More than 10 people sequentially carried out this activity.

This activity ended after all the landowners that participated in the “*masohi* gathering” had finished the work of producing *dusung*. Therefore, in this case, there was no known work wage, rather there was the exchange of labor assistance in the work of the hamlet [5]. *Dusung* is a traditional conservation system where the regulatory pattern is applied in the village due to the management and utilization of natural resources and the environment. Furthermore, the vegetation that forms in this pattern forms layered canopy strata from various types of plants that have economic value and productivity (multi-cropping). A social value guarantees and improves the need for foodstuffs and the quality of life for rural communities, especially those below the poverty line. For instance, the availability of local energy (firewood) and the ecological value of the diversified forest and agricultural products. Furthermore, there are conservation values associated with improving environmental quality with the provision of products and services in a sustainable manner. In order to measure the extent of the role and function of the *dusung* agroforestry pattern in the Maluku islands, a study needs to be carried out on the following: (1) the pattern's diversity on the island of Ambon, (2) its analysis according to small island agroecological conditions, (3) determining the sustainability index, from the ecological, conservation, landscape, economic and policy implementation aspects and (4) determining the cluster pattern according to the yield sustainability index value in the Maluku islands. Therefore, by examining the profile of the

Figure 1.
Dusung pattern agroforestry use.

agroecological zone as a buffer for the ecosystem in the archipelago from the coast to the mountains, the traditional agroforestry formed in the Maluku Islands needs to be maintained and preserved from generation to generation and sustainably.

3. Models and concepts of *Dusung* farming

The concept of *dusung* is a modification of an ever-changing ecosystem due to the formation of new agricultural activities with greater benefits. In terms of ecology and economy, *dusung* (traditional agroforestry) is more complex than a monoculture system because it is local in nature and need to be in accordance with the ecological and socio-economic conditions of the area. *Dusung* is used as a land system with specific productivity objectives capable of improving rural communities' welfare over a prolonged period. It is the "Science and Art" of planting trees and other plants on available land both inside and outside the forest to produce various objects and services for individuals and the general public. It is also a method used to manage forests and their environment on community land to achieve a better socio-economic condition for the rural population and overcome environmental problems, erosion, and soil fertility deterioration. *Dusung* is a traditional pattern of natural resource use (forest), which shows local wisdom of sustainable management of natural resources and their ecosystems. The traditional conservation process in its regulatory pattern runs and applies in rural communities (*Negeri*) with proper management and utilization. In *dusung* farming pattern, the vegetation that forms a layered canopy strata pattern has a productivity value throughout the year (multi-cropping). The *dusung* pattern is a traditional land use system in the form of local wisdom similar to agroforestry [6], as shown in **Table 1**.

The *dusung* farming pattern is a modification of a new ecosystem with greater agricultural benefits, such as (1) ecologically maintaining the quality of natural resources and the whole agroecosystem, which includes animals, plants, and micro-organisms. The plants have various root depths, crown heights, and canopy spacing. It also comprises of different requirements for temperature, light intensity, soil,

No	Farming pattern	Region	Agroforestry concept
1	Fruit crops and root crops	Maluku Tengah, Maluku Utara	Agrisilviculture
2	Planting spices and tuber crops	Maluku Tengah, Maluku Utara	Agrisilviculture
3	Mixed perennial crops dominated by coconut, nutmeg, and cloves	Maluku Tengah, Maluku Utara	Agrisilviculture
4	Mixed perennial crops dominated by coconut and cacao	Maluku Utara	Agrisilviculture
5	Mixed crop dominated by fruit trees	Maluku Tengah	Agrisilviculture
6	Walnuts and nutmeg	Banda island	Agrisilviculture
7	Coconut, tubers, and bananas	Maluku Tengah	Agrisilviculture
8	Cajuput, <i>Imperata cylindrica</i> , <i>Andropogon ambonensis</i> , and Bali cattle	Buru Utara	Silvopasture
9	Sago	Maluku Utara, Maluku tengah	Silviculture
10	East Nusa Tenggara tangerines	Island of Teon, Nila, Serua, Leti, Moa, Lakor, Kisar&Wetar	Agrisilviculture

Table 1.
Dusung farming pattern in Maluku.

air humidity, and land quality, (2) economically sustainable for farmers with the ability to meet all the necessities of life. The *dusung* system is regulated to produce all year round crops, such as coconut, cocoa, nutmeg, and walnuts as well as some are seasonal ones, including cloves, durians, duku, gandaria, *etc.*, (3) fair and humane as *dusung* is capable of providing benefits to people without basic dignity of all living things, such as plants, animals, and humans. Regulations regarding business (picking up those that fall on the ground) and *sasi* (harvesting rules) contain elements of justice and humanity [6].

4. Landscape sustainability index model: agroforestry pattern *Dusung*

The study was carried out in 8 villages of South Leitimur and Leihutu on Ambon Island. Data were obtained through site survey based on vegetation conditions formed from farming patterns of monocultures, semi-monocultures, and mixed plants that make up the *dusung* agroforestry. The sample selection is determined based on the spatial distribution of the landscape according to the representative land samples' location. The Land classification is determined based on the weighted parameter values from the researches.. The data taken in each sample include length and width of the land, area covered by stands, inventory of vegetation types according to potential, the grouping of plant types based on *dusung* farming patterns, and the layout of the planting system representing a mosaic landscape of *dusung* at various heights, such as flat, hills and mountains. The analysis is limited to the stand measurement model due to resource sharing as well as the climatic and growth factors that affect plant productivity, thereby making its survival possible. Furthermore, based on the land sample surveyed, information classification was carried out regarding the landscape conditions of the *dusung* agroforestry pattern for each respondent, such as the land owner (farmer) in each sample village location. This model is related to the development of the vegetation constituent components on the landscape, therefore, the model stratification approach is based on the ratio of the area of land for effective cultivation of plants to a suitable growing place. The stratification is divided into 3 classes, namely lowland *dusung* pattern, hilly and mountainous plains. The approach to growing places and distribution of tree species is based on the total number of land productivity according to the potential for each harvest season divided by the area of land. A regression approach is used to determine the relationship between the dependent and independent variables in accordance with the model class. The independent variable that has the main effect on the dependent makes the agroforestry system's key information. This information makes it easy to design and manipulate the actions intended to manage the agroforestry system. Therefore, the *dusung* agroforestry pattern model's determination with the distribution of productive plant species is alternatively carried out using an alternative design. Furthermore, to facilitate further analysis of the landscape model of the *dusung* agroforestry pattern in the agroforestry system, the land sample was divided into 3 clusters based on land area and composition of monoculture, semi-monoculture, and mixed crop types. They are also based on the landscape where they grow from the coast to the mountains, namely:

- Cluster 1 is located on an area of land with a composition of monoculture types of agricultural crops that occupy a landscape characterized by lowlands.
- Cluster 2 is located on an area of land with a composition of semi-monoculture farming types that occupy a landscape characterized by low to hilly lands.

- Cluster 3 is located on an area of land with a composition of mixed types of farming, which occupies a landscape characterized by hilly to mountainous plains.

Until now, the production of types of plants in the *dusung* pattern is still contributing as a source of community income with several factors, namely (1) the potential for cultivated plants, (2) the production value of the harvest, (3) the area of *dusung* land ownership of the farmer and (4) the area of each village. The farming characteristics of the *dusung* pattern are used to carry out cluster analysis based on the division of the type of area and according to the potential of the *dusung* land by determining the variables as shown in **Table 2**.

Meanwhile, the Multidimensional Scaling (MDS) analysis was used to measure the sustainability index and sustainability level [7]. Furthermore, the MDS method can be used to determine the position of the point of sustainability, which is visualized through the horizontal and vertical axes. The point position can be visualized on the horizontal axis, in accordance with the value of the sustainability index using the rotation process. The sustainability index is the value of each dimension that describes its level [8], as shown in **Table 3**.

The value of each dimension's sustainability index can be visualized simultaneously in the form of a kite diagram. Similarly, the symmetrical diagrams of kites are determined by each dimension's sustainability index, namely economic, social, cultural, ecological, legal, institutional, infrastructure, and technology. The cluster approach can also be described through the spatial analysis of the *dusung* farming patterns formed in lowlands, hilly, and mountainous plains. Spatial descriptive research, with land units, are used for analysis or mapping. Furthermore, this research spatially and temporally describes land cover and its effects on small

Variable	Remarks
• Area of <i>dusung</i> land type in each sampling village	• The area of <i>dusung</i> land cover is obtained from the results of satellite image analysis (ha)
• The area of land owned by farmers	• Area of land that is privately owned by the family and leased (m ² or ha)
• Total annual crop commodity produced	• Production capacity of each type of crop during the harvest season (kg/ha/yr)
• Total production of monoculture crops	• Production capacity of each type of crop during the harvest season (kg/ha/yr)
• Total production of mixed crop commodities	• Production capacity of each type of crop during the harvest season (kg/ha/yr)
• <i>Dusung</i> farmers' income contribution	• Average <i>dusung</i> farm income (IDR / year)

Table 2.
Forms of cluster analysis variables.

Index Values (%)	Category	Remarks
0.00–25.00	Bad	Not sustainable
25.01–50.00	Less	Less sustainable
50.01–75.00	Sufficient	Sufficiently sustainable
75.01–100.00	Good	Good Sustainable

Table 3.
Assessment categories based on the index value of the sustainability status.

Figure 2.
Land suitability for agriculture and estate.

Figure 3.
Land cover in Leitimur Selatan District.

islands' protection function. Spatial analysis was processed using a Geographical Information System, with outputs including land cover maps and suitability maps for *dusung* agroforestry patterns as shown in **Figures 2 and 3**. Most of the villages studied were classified as good (score average 89.2) and moderate (mean score 69.7), with none in the poor and bad categories.

5. Agroforestry contributes to the mitigation and adaptation of greenhouse gases through carbon sequestration

Agroforestry contributes to climate change and GHG mitigation of various land-use models. Physically, agroforestry has a complex canopy arrangement with varying characteristics and root depths, thereby making it unique for the adaptation to global warming through its role in reducing landslides, surface runoff, erosion, and nutrient loss through leaching while maintaining the biodiversity of soil flora

and fauna [9]. This agroforestry model combines trees with seasonal crops to ensure that their existence resembles a secondary forest. Although it does not absorb significant CO₂ in the air as a primary forest, land management through agroforestry can increase the absorption of CO, thereby mitigating climate change. Generally, there is a decrease in the world's primary forests due to the conversion of areas to other uses such as urban expansion, agricultural land, livestock, plantations, *etc.* Therefore, this agroforestry becomes one of the safety valves for forest sustainability, where residents can take advantage of forest and agricultural products to meet their basic needs. Agroforestry practices are considered potential in mitigating greenhouse gases (GHG), especially CO in the atmosphere. Agroforestry farming communities usually used the same land to cultivate a mixture of perennials, consisting of agricultural or fruit crops. The economic motive is the main objective, which means that the harvest income can be enjoyed at all times [10].

Conversely, multi-stratified land use is able to extract CO for photosynthetic purposes, which are stored in plant biomass for a relatively long time. Agroforestry also plays a role in adapting to climate change through the following processes (1) increasing resilience by mixing species with different resistance to temperature. In this process, a rise in temperature increases the number of species that can grow, and those likely to decline in growth with an equal amount of absorbed carbon, (2) increased resistance, which means that a rise in temperature increases the total productivity or absorption of the system disturbed to CO₂. This is because there are various adjustments caused by mixed plants which have relatively different physiological characteristics, (3) migration, which means that to a certain extent, all elements or species in the agroforestry system are no longer tolerant to existing temperature changes, therefore, in some cases certain elements or types of the ecosystem moves to a more suitable place. This is directly or indirectly assisted by natural processes [2].

Therefore, biomass measurements are used to determine *Dusung's* ability to absorb carbon. Basically, there are two methods of measuring biomass, namely (1) the non-destructive method, which is used when the allometric formula and type of plant in the *dusung* pattern are known. Some examples of allometric equations that have been created in *dusung* are presented in **Table 4**, (2) a destructive method which aims to develop allometric formulas, especially for various tree

No	Tree species	Allometric formula	Source
1	<i>Coffea arabica</i>	(AGB) est. = 0.281 D ^{2.06}	Hairiah <i>et al</i> , 2011 [9]
2	<i>Musa paradisiaca</i>	(AGB) est. = 0.030 D ^{2.13}	Hairiah <i>et al</i> , 2011 [9]
3	<i>Myristica fragrans</i>	(AGB) est. = 134.353 D ^{2.424}	Mardiatmoko <i>et al</i> , 2018 [11]
4	<i>Theobroma cacao</i>	(AGB) est. = 0.1208 D ^{1.98}	Yuliasmara <i>et al</i> , 2009 [12]
5	<i>Bambusa sp</i>	(AGB) est. = 0.131 D ^{2.28}	Priyadarsini, 1999 [13]
6	<i>Acacia mangium</i>	(AGB) est. = 0.1999 D ^{2.148}	Pusat Litbang Konservasi dan Rehabilitasi, 2013 [14]
7	<i>Eucalyptus grandis</i>	(AGB) est. = 0.0678 D ^{2.5794}	Pusat Litbang Konservasi dan Rehabilitasi, 2013 [14]
8	<i>Paraserianthes falcataria</i>	(AGB) est. = 0.0199 (D ² H) ^{0.9296}	Mugiono, 2009 [15]
9	<i>Acacia auriculiformis</i>	(AGB) est. = 0.0775 (D ² H) ^{0.9018}	Mugiono, 2009 [15]

Table 4.
Allometric equation of several types of plants in dusung.

species with specific branching patterns whose allometric equations understory, seasonal plants and shrubs are generally unknown. In other words, the absence of allometric equations for the various types of plants in *dusung*, means that a destructive method of measuring biomass is necessary.

6. Conclusions

In conclusion, Maluku have long practiced traditional '*dusung*' agroforestry management patterns through local wisdom known as "*Sasi*" and "*Masohi*." The role of agroforestry can be seen from its contribution to the economic, ecological, socio-cultural functions of people, as well as the mitigation and adaptation of greenhouse gases through carbon sequestration. Land management through agroforestry, actually increases the absorption of CO in the air. According to studies, there is a possible decrease in primary forest in the world due to designation for other functions. Therefore, agroforestry is one of the safety valves for forest sustainability where people can take advantage of agricultural products to meet their basic needs and in handling climate change. Furthermore, based on a cluster determination study in accordance with the land area and composition, there are various types of monoculture, semi-monoculture and mixed farming crops grown from the coast to the mountains. These crops are used to analyze the cluster variables, with the villages on the small island of Maluku classified as good (the average score for the sustainability index was 89.2) and moderate (the average score for the sustainability index was 69.7), with none in the poor category.

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