Tree diversity and its use by local communities in Buol District, Indonesia

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Subekti Rahayu, Betha Lusiana, Sacha Amaruzaman,
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Abstract

We assessed plot-level, tree diversity and various tree-based systems in Buol District, Central Sulawesi Province, Indonesia: complex, clove, coconut and cacao agroforests; monoculture teak; and undisturbed and disturbed forests. The objectives were to assess the tree diversity of various land-use systems, to identify what tree species were used by the communities and to identify land-use systems that provided habitats for forest tree species. The indicators for tree diversity were tree species' richness and tree composition collected using a Quick Biodiversity Survey approach. The use of tree diversity by the communities was assessed though focus-group discussions in three clusters of villages: the upstream and midstream of the Buol watershed; and the coastal area. We found that tree species' richness in complex agroforests was 70% that of undisturbed forests. Only 5% of forest species regenerated in complex agroforestry systems, mostly represented by pioneer species. This condition indicated that although the complex agroforests species' richness in Buol was relatively high, complex agroforests could not provide refugee for forest tree species. Therefore, conserving forests was very important for maintaining forest tree diversity in Buol. The remaining small patch of disturbed forest in Buol District was in a developing stage, indicated by higher species' richness at sapling stage. The community in Buol had low dependency on forest species and were more interested in growing domesticated, commercial species. Not so long ago, farmers still harvested rattan from the forest but at the time of study the rattan population had diminished, most likely caused by over-harvesting.

Keywords

Agroforestry, Buol, Central Sulawesi, community forest use, tree diversity, tree species' richness

Acknowledgements

This working paper is the preliminary synthesis of research undertaken during the first year of the Climate-smart, Tree-based Co-investment in Adaptation and Mitigation in Asia (Smart Tree-Invest) project in Buol District, Central Sulawesi Province, Indonesia carried out by the World Agroforestry Centre with support from the International Fund for Agricultural Development and the CGIAR Research Program on Forests, Trees and Agroforestry. We also extend our gratitude to Harti Ningsih and Ni'matul Khasanah for their contributions during field work and data analysis.

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Introduction

Biodiversity directly affects human life. Beyond production of food, fibre, fuel and income, biodiversity plays an important role in nutrient cycling, control of microclimates, regulation of hydrological process and abundance of undesirable microorganisms and detoxification of noxious chemicals (Altieri 1999). Biodiversity not only contributes to material welfare and livelihoods but also contributes to security, resiliency, social relations, freedom of choice and actions (MEA 2005). At the landscape scale, patches of ecosystems with high biodiversity are important in providing environmental services, such as being sources of seeds for regeneration, habitat refuges for plants and animals and regulation of climate and hydrology. A sustainable landscape ideally contains diverse ecosystems that provide various services for communities, compared to monoculture or simple systems that focus only on providing economic benefits and food.
Converting forests to other systems, particularly, human-made systems, such as agriculture or settlements, has a direct impact on biodiversity across a range of taxonomic groups and population sizes, or both, causing taxonomies and populations of the majority of species to decline (MEA 2005).

Transmigration[1] settlements and oil-palm plantations started in 1990s have driven land-use change in Buol. The forest area has declined substantially since 2000, mostly converted into complex agroforests, cacao agroforests and oil-palm plantations. The oil-palm plantation area increased by 55% from 1995 to 2014, roughly covering 10% of Buol District (Wijaya et al 2015). A land-use and land-cover analysis of the district indicated that since 1996 more than 14% of undisturbed forest, which contained diverse tree species, was converted to other land use (Wijaya et al 2015). Besides the expansion of plantations, the development of transmigration settlements also potentially changed use of biodiversity by the community.

This study aimed to understand the condition of tree diversity in various land-use systems and the role of disturbed forests and complex agroforestry systems as habitat refuges for forest tree species. The specific objectives of the study were 1) to assess the tree diversity of various land-use systems in Buol District, including the use of trees by the communities; and 2) to identify land-use systems that provided habitat for tree diversity, both naturally grown and domesticated.
The hypotheses of the study were 1) complex agroforests and young secondary forests contained high tree diversity that allowed forest species to regenerate and play a role as habitat refuges; and 2) community dependency on naturally-grown species was low.

[1] Transmigration is Indonesia's program of moving people from the overcrowded islands of Java, Madura, Bali, and Lombok to the less crowded areas in other big islands of Sumatra, Kalimantan, Sulawesi, and Papua.

Methods

Tree-species' inventory

Field Survey

A tree-diversity survey was conducted in seven land-use systems in Buol District: 1) disturbed forests; 2) sago forests; 3) complex agroforests; 4) cacao agroforests; 5) coconut agroforests; 6) clove agroforests; and 7) monoculture teak. Undisturbed forests in the immediate vicinity were sampled as a reference. In each land-use system, we sampled two to four replications of 20 m x 100 m nested plots that were further divided into subplots of 1) 5 x 2 m x 2 m to observe seedlings with diameters less than 5 cm and heights less than 2 m; 2) 5 x 5 m x 5 m to observe saplings with diameters less than 5 cm and more than 2 m height; 3) 5 x 10 m x 10 m to observe poles 5–10 cm in diameter and above 2 m in height; and 4) 5 x 20 m x 20 m to observe trees with more than 10 cm diameter (Figure 1).

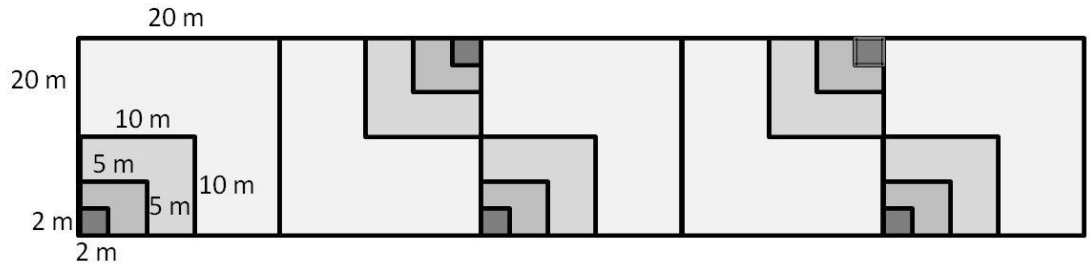

Figure 1. Plot sample scheme

The Herbarium Bogoriense in Bogor, West Java, Indonesia carried out a species' identification for all seedlings, saplings, poles and trees inside the plots using leaf specimens taken during a field survey. We measured the stem diameter at breast height (DBH ~ 1.3 m) for all trees and poles.

Data analysis

We used four indicators of tree diversity: 1) rarefaction or accumulation species' curve, representing the tree-species' richness in each land-use system, or alpha diversity; 2) Shannon-Wiener Diversity Index of species in each plot and in each land-use system; and 3) Bray-Curtis Distance representing dissimilarity of species across different land-use systems, or beta diversity. Bray Curtis Distance measured dissimilarity, therefore, the similarity index used the following equation:

$$1 - BC = 1 - \frac{\sum_{i=1}^{S} |(n_{1i} - n_{2i}|)}{\sum_{i=1}^{S} (n_{1i} + n_{2i})}$$

Where: BC = Bray-Curtis dissimilarity, S = total species number in land use 1 and land use 2, n_1 = number of individual species i in land use 1, n_2 = number of individual species i in land use 2.

We used the Shannon-Wiener Diversity Index to derive Species Diversity and Species Evenness values to represent how close (equal) in numbers were the species in various land-use systems.

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where: H' is Shannon-Wiener Diversity Index, while p_i is the proportion of species i relative to the total number of species (S). If H'<1 categorized low diversity, 1<H'<1 categorized medium diversity, H'>1 categorized high diversity.
Shannon Evenness was calculated by dividing H by H maximum (ln S):

$$E_H = \frac{H}{\ln S}$$

Evenness assumes a value between 0 to 1 with 1 being complete evenness.
In our study, rarefaction curves were derived from both sub-plot and plot data (Figure 1). Thus, the results can represent both alpha diversity (sub-plot data) and beta diversity (plot data). The species' diversity referred to tree species in vegetation stages: seedlings, saplings, poles and trees.
We also calculated the similarity within the early stages of trees (seedlings and saplings) in similar land-use systems to measure survival ability at the seedling, sapling, pole and tree stages. Using the similarity index, we identified forest species found in non-forest land uses as an indicator of the ability of the non-forest land use to function as habitat for forest species.

Local communities' perceptions of tree diversity and its functions

We applied the Capacity Strengthening Approach to Vulnerability Assessment framework developed by the World Agroforestry Centre (Dewi et al 2013) to gather information on local communities' use of trees in their daily activities. Focus-group discussions were conducted in three clusters of villages located in the upstream (Lomuli and Kokobuka villages) and midstream (Air Terang and Boilan villages) of Buol Watershed and the coastal area (Lokodidi, Matinan and Taat villages) of Buol District (Lusiana et al 2015). Those areas are the cluster sites of an action research project, Climate-Smart, Tree-Based, Co-investment in Adaptation and Mitigation in Asia, carried out by the World Agroforestry Centre (ICRAF) in Buol District, 2014–2017. The upstream and midstream clusters were dominated by migrants from other parts of Indonesia, while the coastal cluster was dominated by people indigenous t the area. In each cluster, the focus-group discussions were disaggregated by gender with each gender group (male and female) consisting of 5–7 participants.

Results and discussion

Current condition of tree-species' richness and diversity

Rarefaction curve

A rarefaction or species' accumulation curve represents an estimation of the number of species that would be found if sampling efforts were increased or reduced. The analysis was applied to sub-plot (Figure 2) and plot (Figure 3) data. At the seedling stage, cacao agroforests represented the lowest number of species. Weeding most likely had an impact on seedling establishment in cacao agroforests. The number of species found in cacao agroforests gradually increased at the sapling, pole and tree stages.

The highest species' richness of seedlings was found in clove agroforests but the number of species significantly declined by the sapling stage, with clove agroforests then representing the lowest richness (Figure 2A and B). Similar to cacao agroforests, in clove agroforests local people carried out weeding periodically, particularly before harvesting, which contributed to the dynamic of species' richness at seedling and sapling stages.

We found that complex agroforests, disturbed forests and undisturbed forests had consistently high species' richness at seedling, sapling, pole and tree stages, ranging 9–11 species in 20 sampling units. Adding sampling units would potentially increase the number of species. We found that species' richness in complex agroforests was dominated by domesticated species, such as durian (*Durio zibethinus*), rambutan (*Nephelium lappaceum*), cacao (*Theobroma cacao*) and coconut (*Cocos nucifera*).

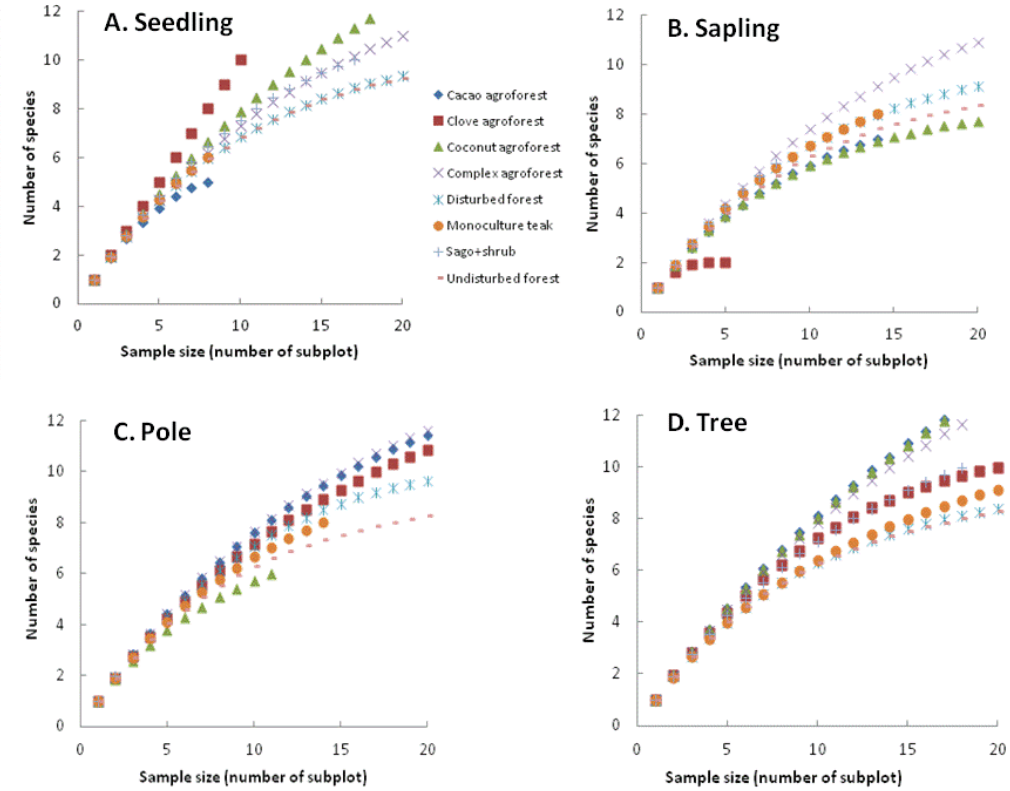

Figure 2. Species' accumulation curve of seedlings, saplings, poles and trees in each sub-plot of each land-use system in Buol District

A plot-level analysis showed similar results (Figure 3). Clove agroforests had relatively low species' richness of seedlings, saplings, poles and trees (Figure 3A, B, C, D), shown by the flat slope in the species' accumulation curve. This curve indicates that sampling more plots would not increase species' richness. Clove agroforests in Buol mostly consisted of monoculture species, representing only 2–3 tree species at seedling, and 3–4 at sapling, stages.

Low tree diversity, ranging 1–2 species, was also found in monoculture teak and sago forests. The species' richness in complex agroforests, disturbed forests and undisturbed forests was high, ranging 10–15 species in 20 sampling units. We found that the undisturbed forests had the highest species' richness at the seedling and pole stages and the disturbed forests had the highest at the sapling and tree stages. The high species' richness of all vegetation stages in the disturbed forests indicated that they are regenerating. The species' richness in complex agroforests decreased at pole and tree stages to less than nine species in each stage. Intensive weeding carried out in the complex agroforests mainly contributed to the loss of species, particularly, for naturally-regenerated tree species that were not being used. Farmers who managed perennial, crop-based agroforests only maintained domesticated tree species for the additional benefits of shade and fruit.

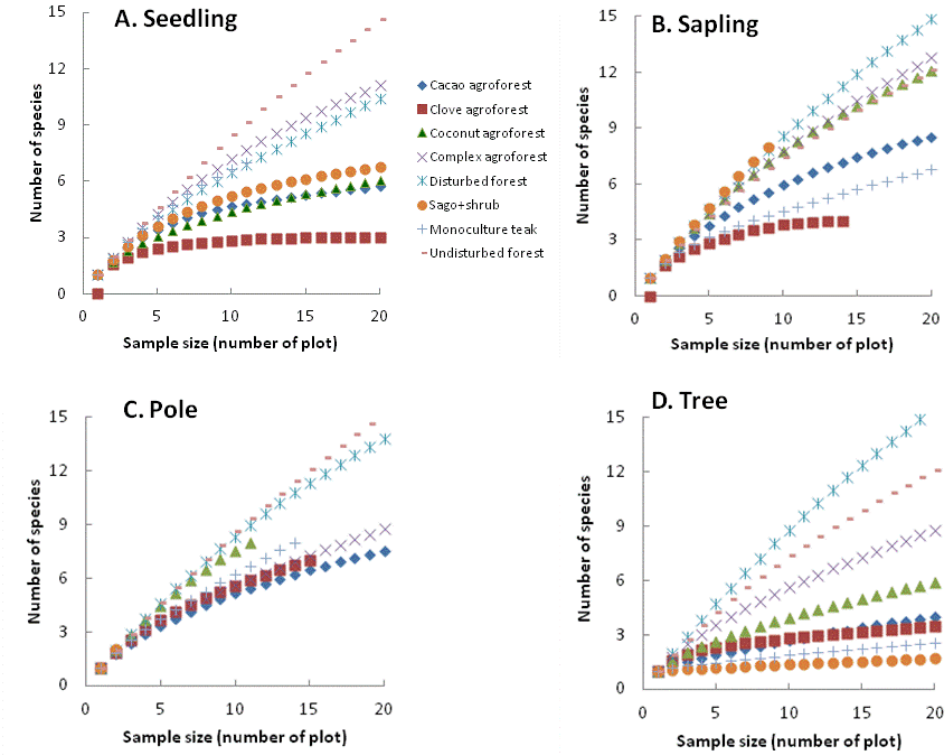

Figure 3. Species' accumulation curve of seedlings, saplings, poles and trees in each land-use system

Shannon-Wiener Index

The Shannon-Wiener Index (H') was used to quantify species' diversity both at plot and land-use levels. From a plot-level analysis, we found that tree-species' diversity was mostly in the medium range (1< H'< 3) value, except for the sapling stage in clove agroforests and pole stage in sago systems, which represented the low range value of H'<1 (Figure 4).

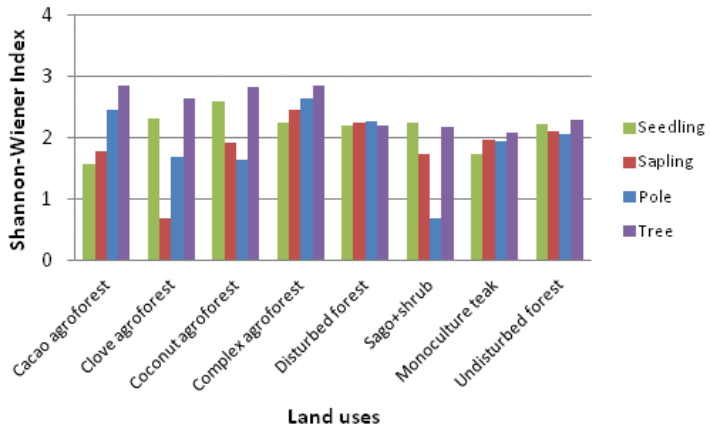

Figure 4. Plot-level Shannon-Wiener Diversity Index in each vegetation stage of various land-uses in Buol

Species' diversity was relatively similar between the disturbed and undisturbed forests and slightly higher in the cacao agroforests. Intensive weeding and species' selection by farmers resulted in low species' diversity of seedlings and saplings in the survey, consequently, we can predict that the diversity of poles and trees will decline in the future. Higher diversity in all vegetation stages can be found in complex agroforests and teak monoculture.

Farmers allowed other tree species to regenerate in teak plantations—which were commonly managed as monoculture—up to the tree stage. This interesting management resulted in higher tree diversity for teak plantations.

At the land-use level, high species' diversity of H'>3 was found in disturbed forests, particularly at the sapling and pole stages (Figure 5). This was influenced by the regeneration of several pioneer species when disturbance occurred about 5–10 years prior to the survey. As the forest cover increased, the number of seedlings of the pioneer species declined and were replaced by the seedlings of shade-tolerant species. Low species' diversity was mostly found at the tree stage of cacao agroforests, clove agroforests, sago forests and monoculture teak, and at the seedling stage of cacao agroforests. Complex agroforests and undisturbed forests had a similar pattern of species' diversity balance across all vegetation stages.

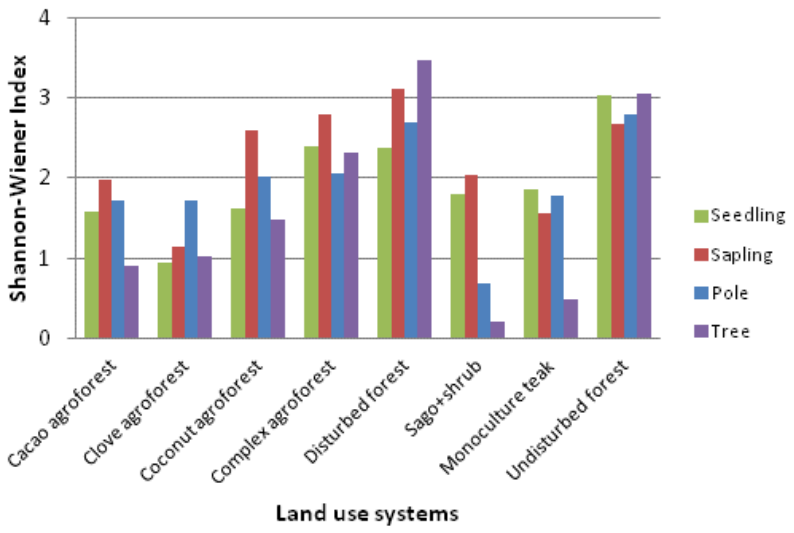

Figure 5. Land-use-level Shannon-Wiener Diversity Index in each vegetation stage of various land-uses in Buol

The Shannon Evenness Index (J) was used to quantify the evenness of species both at plot and land-use levels. From the plot-level calculation, we found a high evenness index of J > 0.9 for all vegetation stages in the various land uses (Figure 6). This result indicated that the number of tree species were evenly distributed in each sub-plot sample. A low evenness index at the pole stage of clove agroforests indicated that there were several found only at the specific sub-plot within the plot samples.

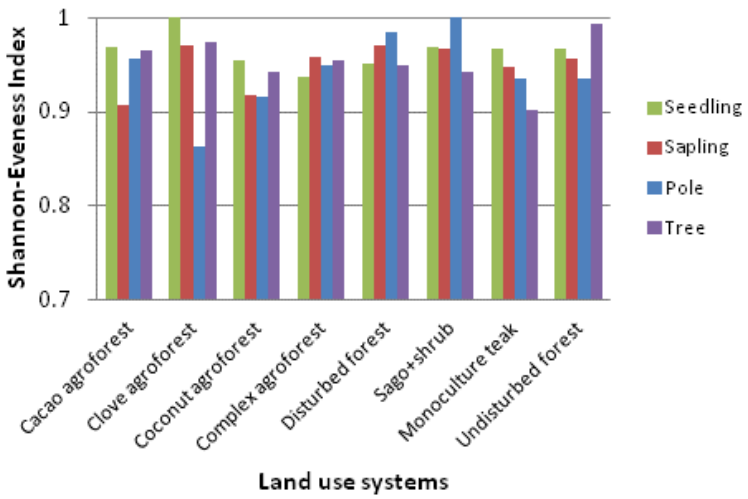

Figure 6. Plot-level Shannon Evenness Index in each vegetation stage of the various land uses in Buol

The evenness index decreased at land-use level (Figure 7). This was not surprising as it meant that some species tended to grow only in specific land uses. For example, sago will tend to be found in sago systems and nowhere else and teak can only be found in teak systems. We found low evenness ($J < 0.2$) for the tree stage in cacao agroforests, sago, and monoculture teak owing to low populations of species at the tree stage.

A higher evenness index was found in all vegetation stages in complex agroforests, disturbed forests and undisturbed forests. This indicated that all vegetation stages were distributed in more sample plots in those three land-use systems compared to other systems, such as cacao agroforests, sago and monoculture teak. We only found a sample of young teak that had just reached the pole stage, up to 9 years-old.

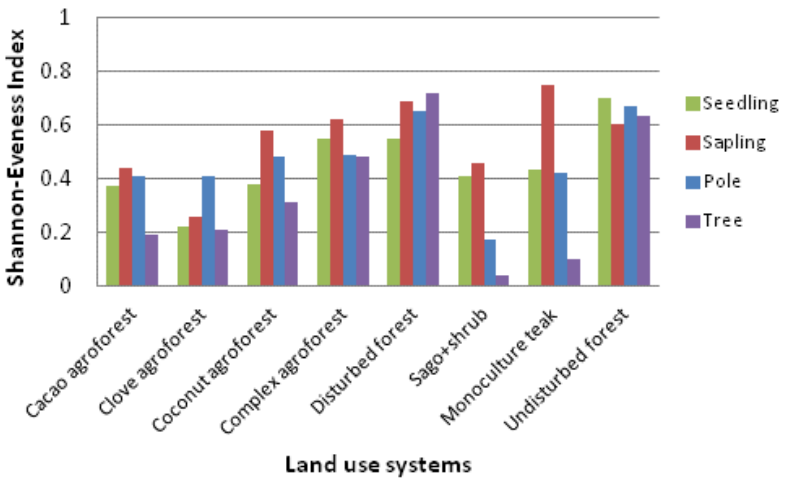

Figure 7. Land-use-level Shannon Evenness Index in each vegetation stage of the various land uses in Buol

Tree-species' similarity

At the seedling stage, the similarity of species between forests (disturbed and undisturbed) and other land-use systems was low. The complex agroforests and disturbed forests shared the highest similarity of 5% and the species *Tabernaemontana orientalis* and *Barringtonia tryscila*. This finding indicated that the opportunity of forest species to regenerate in agroforestry systems in Buol District was low. The highest similarity at the seedling stage was found between clove and coconut agroforests at 35% (Table 1), which shared guava (*Psidium guajava), Tabernaemontana orientalis,* clove (*Syzygium aromaticum*) and coconut (*Cocos nucifera*).

Table 1. Bray-Curtis similarity of seedlings across land-use systems

Land use	Cacao	Clove	Coconut	Complex	Disturbed	Sago	Teak	Un-disturbed
Cacao	1							
Clove	0.0	1						
Coconut	0.02	0.35	1					
Complex	0.07	0.30	0.21	1				
Disturbed	0.05	0.0	0.03	0.05	1			
Sago	0.0	0.10	0.0	0.0	0.0	1		
Teak	0.12	0.18	0.02	0.19	0.07	0.09	1	
Undisturbed	0.0	0.03	0.0	0.0	0.08	0.02	0.03	1

At the seedling stage, *Tabernaemontana orientalis* was the most common species in all plot samples. The species' similarity for the seedling stage between disturbed and undisturbed forest was 8%, with three species—*Ganua motleyana, Dracontomelon dao* and *Polyalthia lateriflora*—commonly found in both systems.

At the sapling stage, the species' similarity between the forests (disturbed and undisturbed) and other land-use systems in Buol was low, with the highest value of only 5% similarity with cacao agroforests. The highest species' similarity was found between monoculture teak and cacao agroforests, at 40% similarity (Table 2).

Monoculture teak and cacao agroforests shared *Piper aduncum* and *Saurauia tristyla* at the sapling stage. *P. aduncum* was a pioneer species commonly found in open and managed areas of most land-use systems in Indonesia. The species' similarity between disturbed and undisturbed forests at the sapling stage was 20%, higher than the seedling stage. The disturbed and undisturbed forests shared the similarity of *Aglaia odoratissima, Dracontomelon dao, Licuala spinosa, Macaranga gigantea* and *Spathiostemon javensis*.

Table 2. Similarity of sapling species across land-use systems

Land use	Cacao	Clove	Coconut	Complex	Disturbed	Sago	Teak	Undisturbed
Cacao	1							
Clove	0.09	1						
Coconut	0.21	0.08	1					
Complex	0.15	0.12	0.23	1				
Disturbed	0.05	0.0	0.02	0.04	1			
Sago	0.05	0.0	0.09	0.10	0.03	1		
Teak	**0.40**	0.1	0.13	0.13	0.05	0.0	1	
Undisturbed	0.0	0.0	0.02	0.02	0.20	0.0	0.0	1

At the pole stage, species' similarity between forests (disturbed and undisturbed) was 7%. This result was higher than the seedling and sapling stages. The highest similarity was found between complex and cacao agroforests at 39% (Table 3), with the domesticated species of rambutan (*Nephelium lappaceum*), durian (*Durio zibethinus*), cacao (*Theobroma cacao*) and *Ficus septica* being shared.

Table 3. Similarity of pole-stage species across land-use systems

Land use	Cacao	Clove	Coconut	Complex	Disturbed	Sago	Teak	Undisturbed
Cacao	1							
Clove	0.05	1						
Coconut	0.10	0.23	1					
Complex	**0.39**	0.09	0.03	1				
Disturbed	0.03	0.05	0.0	0.07	1			
Sago	0.0	0.0	0.0	0.04	0.0	1		
Teak	0.09	0.07	0.08	0.12	0.0	0.0	1	
Undisturbed	0.0	0.0	0.0	0.02	0.04	0.07	0.0	1

At the tree stage, the highest similarity of 53% could be found between the complex and cacao agroforests (Table 4). The species' similarity between forests (disturbed and undisturbed) and other land-use systems was low, with the highest similarity of 4% found between the disturbed forests and complex agroforests.

The complex and cacao agroforests shared domesticated species—such as *Artocarpus heterophyllus*, *Nephelium lappaceum*, *Durio zibethinus*, *Cocos nucifera*, *Mangifera indica*, *Theobroma cacao* and *Ceiba pentandra*—and naturally-grown species, such as *Aglaia* sp, *Kleinhova hospita* and *Artocarpus lanceifolius*. At this stage, the species' similarity between disturbed forests and undisturbed forests was low at 9%, with *Dracontomelon dao* as the shared species.

Table 4. Similarity of tree species across land-use systems

Land use	Cacao	Clove	Coconut	Complex	Disturbed	Sago	Teak	Undisturbed
Cacao	1							
Clove	0.09	1						
Coconut	0.10	0.30	1					
Complex	**0.53**	0.17	0.33	1				
Disturbed	0.02	0.0	0.01	0.04	1			
Sago	0.01	0.0	0.02	0.02	0.00	1		
Teak	0.06	0.01	0.09	0.07	0.03	0.0	1	
Undisturbed	0.01	0.0	0.0	0.03	0.09	0.00	0.00	1

Tree use by local communities

Migrant communities from Java and South Sulawesi (Bugis people), Bali and Lombok cultivated horticulture (annual crops), such as vegetables and pulses, in dry land converted from forests or shrubs. They also managed rice fields, converted from swamp sago forests, as their main source of income. Employees of oil-palm plantations were the potential market for horticultural products. Gender influence on perceptions of use of biodiversity can be seen in Table 5.

Table 5. Use of biodiversity by the upstream cluster in different land-use types, based on male and female perceptions

Land cover	Building material	Firewood	Fencing	Food	Income	Medicine	Others
Degraded forest			-				
Oil-palm plantation	-	-	-			-	-
Dry land	-	-	-				-
Rice field	-	-	-				
Cacao agroforest	-	-	-				-
Swamp	-	-	-		-	-	-
Shrub						-	-

Note: Others = bird food, rattan rug material;  = male perceptions;  = female perceptions

In Buol, long dry spells occurred in 1998 and 2009. The droughts drew pigs and monkeys from the forests to the villages, becoming pests in the agricultural systems. At those times, the farmers were not able to grow rice, vegetables, pulses and other annual crops for food or income.

Local migrants (Buol people) used forests as sources of timber, such as 'lingua' (*Pterocarpus indicus*), 'palapi' (*Heritiera* sp.), 'cempaga' (*Elmerillia* sp.), meranti (*Shorea* sp.), 'nantu' (*Palaquium* sp.), 'bayur' (*Pterospermum celebicum*), 'gaharu' (*Gyrinops versteghii*), dammar (*Agathis* sp.), rattan and 'aren' (*Arenga pinnata*). The biodiversity that the smallholders used during normal and extreme conditions was relatively similar, particularly for perennial plants, but slightly different for annual crops that were more vulnerable to disasters and pests (Table 6). The extreme conditions that had occurred in the cluster included droughts, floods, prolonged rains, pests and diseases.

Table 6. Use of tree diversity by the upstream cluster in various land covers during normal and extreme conditions

Land cover	Normal condition		Extreme condition	
				
Degraded forest	• Timber (building material) • Market items (income) • Fruit	• Timber (building material) • Market items (income) • Firewood	• Timber (building material) • Market items (income) • Fruit	• Timber (building material) • Market items (income) • Firewood
Oil-palm plantation	• Market items (income)	• Market items (income) • Fertilizer • Erosion prevention	• Market items (income)	• Market items (income) • Fertilizer • Erosion prevention
Dry land	-	• Fruit	-	-
Rice field	-	-	-	-
Cacao agroforest	• Fruit trees • Timber (building material) • Market items (income)	• Fruit trees • Market items (income) • Shade trees	• Fruit trees • Timber (building material) • Market items (income)	• Fruit trees • Market items (income) • Shade trees
Swamp	• Food • Fencing	-	• Food • Fencing	-
Shrub	• Timber • Firewood • Fruit	-	• Timber • Firewood	-

The community gathered timber, such as ‘kayu gempol’ (*Neonauclea* sp.), ‘kayu mas’ (*Anthocephalus chinensis*), ‘kayu kenanga’ (*Cananga odorata*), aren (*Arenga pinnata*) and firewood, such as ‘kayu tutup’ (*Mallotus* sp.), ‘kayu sirih’ (*Piper aduncum*) and ‘gamal’ (*Gliricidia sepium*) from swamp forests and shrub land. Migrants from Java, Madura, Bali and Lombok preferred to enrich their land with fruit trees, such as rambutan (*Nephelium lappaceum*), ‘langsat’ (*Lansium domesticum*), durian (*Durio zibethinus*), coconut (*Cocos nucifera*), rose apple (*Syzygium aqueum*), ‘jengkol’ (*Archidendron jiringa*), ‘petai’ (*Parkia speciosa*); timber tree species, such as teak (*Tectona grandis*), nantu (*Palaquium* sp.), cempaga (*Elmerilliia* sp.) and shade tree species, such as gamal (*Gliricidia sepium*) and ‘dadap’ (*Erythrina* sp.), in cacao agroforests. Women used tubers that they collected from dry land as a source of food.

The establishment of oil-palm plantations in the upstream cluster had provided other livelihoods’ options for both local migrants (Buol people) and transmigrants from Java, Sulawesi, Bali, Madura and Lombok. They were employed as day-labourers and as food suppliers.

Migrant communities in the midstream cluster were highly dependent on agricultural products from rice fields because forest products, particularly, high-value timber, were no longer available. However, the communities mentioned that they still used trees and other products from forests and other land-use systems (Table 7).

Table 7. Use of biodiversity by the midstream cluster in various land-use types, based on male and female perceptions

Land cover	Building material	Firewood	Food	Income	Erosion prevention	Medicine	Others
Forest		-			-		
Shrub					-	-	-
Seasonal crops		-			-		-
Rice field		-		-	-		
Oil-palm plantation	-	-				-	-
Swamp	-	-			-	-	-

Note: Others = decorative plants, bird food and fodder;  = male perceptions;  = female perceptions

The use of biodiversity by men and women in the midstream cluster was relatively similar during normal and extreme conditions, as shown in Table 8.

Table 8. Use of tree diversity by the midstream cluster from various land covers during normal and extreme conditions

Land cover	Normal condition		Extreme condition	
				
Degraded forest	• Timber (building material) • Market items (income) • Fruits	• Timber (building material) • Market items (income) • Firewood • Fruits	• Timber (building material) • Market items (income) • Fruits	• Timber (building material) • Market items (income) • Firewood • Fruits
Oil-palm plantation	• Market items (income)	• Market items (income)	• Market items (income)	• Market items (income)
Dry land	• Timber (building material) • Firewood • Fruit trees	• Fruit trees	• Timber (building material) • Firewood • Fruit trees	• Fruit trees
Rice field	• Food	-	• Food	-
Cacao agroforest	• Fruit trees • Timber (building material) • Market items (income)	• Fruit trees • Market items (income)	• Fruit trees • Timber (building material) • Market items (income)	• Fruit trees • Market items (income)
Swamp	• Timber (building material) • Market items (income) • Food	-	• Timber (building material) • Food	-
Shrub	• Food • Fruit trees	• Timber (building material)	• Food • Fruit trees	• Timber (building material)

Land cover	Normal condition		Extreme condition	
				
	• Timber (building material)	• Shade trees • Fruit • Market items (income)	• Timber (building material)	• Shading trees • Fruit • Market items (income)

The community in the midstream cluster used trees from secondary forests in the immediate vicinity for building materials, such as *Neonauclea* sp., *Anthocephalus chinensis* and *Alstonia scholaris*. From around 2010, the communities gradually abandoned their cacao agroforests owing to the seemingly unsolvable problem of pests and diseases.

The local people of the coastal area depended on agricultural products, both from rice fields and perennial crops. They managed agroforestry systems, such as clove, coconut and cacao. The mangrove systems along the coast were perceived to provide protection from waves. The mangroves, however, have suffered from deforestation, their area is diminishing and coastal abrasion increasing. The community also perceived other benefits from mangroves, such as habitat for fish and shrimps, which provided food and income (Table 9).

Table 9. Use of biodiversity by the coastal cluster in various land-cover types, based on female and male perceptions

Land cover	Building material	Firewood	Food	Income	Medicine	Coastal protection	Others
Forest		-			-	-	
Mangrove					-		-
Clove	-	-	-		-	-	-
Mixed garden				-		-	-
Coconut	-		-	-	-	-	-
Rice field	-	-			-	-	-

Note: Others = handicrafts, ladders for picking cloves;  = male perceptions;  = female perceptions

Compared to the upstream and midstream clusters, the coastal communities had different strategies for using tree diversity under extreme conditions (Table 10). Coastal people changed their livelihoods' strategies from land-based to marine-based.

Table 10. Use of tree diversity by the coastal cluster in various land-cover types during normal and extreme conditions

Land cover	Normal condition		Extreme condition	
				
Degraded forest	• Timber (building material) • Market items (income) • Fruits • Others	• Timber (building material) • Food • Market items (income)	• Timber (building material) • Rattan • Market items (income) • Fruits • Others	• Timber (building material) • Food • Market items (income)
Mangrove	• Timber (building material) • Others	• Timber (building material)	• Timber (building material) • Others	• Timber (building material)
Mixed garden	• Timber (building material) • Fruit • Market items (income)	• Timber (building material) • Fruits • Market items (income)	• Timber (building material) • Fruits • Market items (income)	• Timber (building material) • Fruit • Market items (income)
Rice field	-	-	-	-
Coconut	• Market items (income) • Fruit • Firewood	-	• Market items (income) • Fruit • Firewood	-
Clove	• Market items (income)	-	• Market items (income)	-

Extreme conditions of frequent occurrence in the upstream cluster provoked the communities to differing responses. Migrants from Java, Madura, Bali and Lombok, in particular, enriched their agricultural land with more species, particularly for domestic consumption. Local Buol migrants used the remaining forests to collect aren, rattan and timber and used sago as a food source.

In the midstream cluster, where agricultural production was the main livelihood, pests and diseases had a heavy impact on the production of rice, cacao and cloves. Unfortunately, the farmers had not developed any satisfactory measures for controlling pests and diseases, except for wealthier farmers, who could afford pesticides. Most farmers would instead replant with other crops if they had the financial capital or could borrow (money, seedlings, production inputs) from friends, loan agents and store owners. Farmers without access to capital or loans would fallow their rice fields, labour for wealthier farmers or sell banana and cassava chips as their livelihoods' alternatives.

In the coastal area, rice, cloves and fisheries were the main livelihoods during normal years. During extreme conditions, the main option was to work as labour in urban settlements, such as the district capital.

The communities in all clusters were aware that availability of timber in their immediate forests had significantly decreased in recent years. Activities to conserve or plant forest timber species on their managed land, however, were not yet an option since they had no capacity for domesticating such species.

Conclusions

Tree diversity in Buol District, Central Sulawesi in all land-use systems was dominated by domesticated species with high economic value, with the exception of disturbed forests. The communities had low dependency on trees, particularly on naturally-grown trees. Both the migrant communities from Java, Madura, Bali and Lombok and the people of Buol origin showed an interest in managing agro-biodiversity that consisted of annual and perennial crops, mainly as sources of income. Dependency on naturally-grown tree species as a source of income was low, as timber and rattan were no longer found in the immediate forests owing to over-harvesting in the past. Sago and *Arenga pinata* systems were potential land uses with high tree diversity, also for food provisioning and sources of income. However, these species had not been optimally used.

Tree-species' richness in disturbed forests in Buol was similar to undisturbed forests but the species' composition differed significantly. Only 20% of pole-stage species in disturbed forests was similar to those in undisturbed forests. Disturbed forests consisted of pioneer species, indicating that the forests are regenerating. Complex agroforests and disturbed forests could potentially provide habitat for forest tree species.

Farmer-managed systems of cacao, clove and coconut agroforests and teak in Buol cannot function as refuges for forest tree species. They are, unsurprisingly, dominated by domesticated economic species. Complex agroforests and disturbed forests can potentially provide habitat for tree species.

References

Altieri MA. 1999. The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment* 74:19–31.

[BPS] Biro Pusat Statistik. 2014. *Kabupaten Buol Dalam Angka 2014*. Buol District in figures 2014. Buol, Indonesia: Biro Pusat Statistik.

Dewi S, Khasanah N, Widayati A. 2013. Capacity Strengthening Approach to Vulnerability Assessment (CaSAVA). In: van Noordwijk M, Lusiana B, Leimona B, Dewi S, Wulandari D, eds. 2013. *Negotiation-support toolkit for learning landscapes*. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

Lusiana et al. 2015. *Potential and challenges in implementing the co-investment of ecosystem services scheme in Buol District, Indonesia*. Working Paper 211. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program.

[MEA] Millennium Ecosystem Assessment. 2005. *Ecosystems and human well-being: biodiversity synthesis*. Washington DC: World Resources Institute.

Saaty TL. 1980. The analytic hierarchy process: planning, priority setting, resource allocation. New York, USA: McGraw-Hill International.

Villamor G, Desrianti F, Akiefnawati R, Amaruzaman S, van Noordwijk M. 2013. Gender influences decisions to change land-use practices in the tropical forest margins of Jambi, Indonesia. Journal of Mitigation and Adaptation Strategies for Global Change 19(6):735–775.

Wijaya C, Rahayu S, Prasetyo A, Dwiyanti E. 2015. Dynamics of land use/cover change and carbon emission in Buol District, Central Sulawesi. Working Paper 214. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Regional Program. DOI: http://dx.doi.org/10.5716/WP15725.PDF.

Appendix

Table A. Tree and other biodiversity utilization by the local community in the upstream cluster during normal and extreme conditions

Land cover	Normal condition	Extreme condition
Disturbed forest	• **Timber (building material):** *Lingua* (*Pterocarpus indicus*) *Cempaga* (*Dysoxylum* sp.) *Meranti* (*Shorea* sp.) *Nyatoh* (*Palaquium obtusifolium*) *Palapi/kamper* (*Heritiera* sp.) *Manggis hutan* (*B. javanica*) *Mas* (*Dysoxylum* sp.) *Dara-dara* (*Ganua motleyana*) *Kembang,* (*Dalbergia* sp.) *Sengon* (*Albizia chinensis*) *Bayur* (*Pterospermum celebicum*) etc. • **Market items (income):** *Gaharu* (several species) Rattan (several species) Orchids (several species) Dammar resin (*Agathis* sp.) • **Fruit (income and consumption):** *Cempedak* (*Artocarpus integer*) Rambutan (*Nephelium lappaceum*) Langsat (*Lansium domesticum*) *Aren* (*Arenga pinnata*) *Kedau* (*Cryptocoryne* sp.) • **Medicinal plants and animals:** *Ciplukan* (*Physalis* sp.) *Sirih* (*Piper betel*) *Akar kuning* (*Eurycoma* sp.) Hornbill (*Penelopides exarhatus*) • **Firewood:** *Biluat* (*Diospyros maritima*) • **Food:** Mushrooms (several species) Animals: anoa (*Bubalus depressicornis*), pig (*Sus* sp.), deer (*Cervus* sp.) , chicken (*Gallus gallus*), parrot (several species), cockatoo (Cacatua sp.), maleo (*Macrocephalon maleo*), snake (several species),	• **Timber (building material):** *Lingua* (*Pterocarpus indicus*) *Cempaga* (*Dysoxylum* sp.) *Meranti* (*Shorea* sp.) *Nyatoh* (*Palaquium obtusifolium*) *Palapi/kamper* (*Heritiera* sp.) *Manggis hutan* (*B. javanica*) *Mas* (*Dysoxylum* sp.) *Dara-dara* (*Ganua motleyana*) *Kembang,* (*Dalbergia* sp.) *Sengon* (*Albizia chinensis*) *Bayur* (*Pterospermum celebicum*) etc. • **Market items (income):** Gaharu (several species) Rattan (several species) Orchids (several species) Dammar resin (*Agathis* sp.) • **Fruit (income and consumption):** *Cempedak* (*Artocarpus integer*) Rambutan (*Nephelium lappaceum*) Langsat (*Lansium domesticum*) *Aren* (*Arenga pinnata*) *Kedau* (*Cryptocoryne* sp.) • **Medicinal plants and animals:** *Ciplukan* (*Physalis* sp.) *Sirih* (*Piper betel*) *Akar kuning* (*Eurycoma* sp.) Hornbill (*Penelopides exarhatus*) • **Firewood:** *Biluat* (*Diospyros maritima*) • **Food:** Mushrooms (several species) • Animals: : anoa (*Bubalus depressicornis*), pig (*Sus* sp.), deer (*Cervus* sp.) , chicken (*Gallus gallus*), parrot (several species), cockatoo (Cacatua sp.), maleo (*Macrocephalon maleo*), snake (several species)
Oil-palm plantation	• **Market items (income):** Oil palm (*Elaeis guineensis*)	• **Market items (income):** Oil palm (*Elaeis guineensis*)

Land cover	Normal condition	Extreme condition
	• **Others (legume cover crop as fertilizer, erosion prevention):** Legume (several species: *Mucuna* sp., *Callopogonium* sp.)	• **Others (legume cover crop as fertilizer, erosion prevention):** Legume (several species: *Mucuna* sp., *Callopogonium* sp.)
Dry land	• **Food and/or market items (income):** Sugarcane (*Sacharrum officinarum*) Maize (*Zea mays*) Upland rice (*Oryza sativa* several verieties) Vegetables (onion, spinach, chilli, *kangkung* (*Ipomoea aquatica*), cabbage, pumpkin, patchouli*, pare* (*Momordica* sp.), lemongrass, celery, eggplant, cucumber, tomato) Pulses (string bean, green bean, soybean, long bean, peanut) Tubers (for example, *gadung* (*Dioscorea hispida*), ginger, potato, sweet potato) • **Fruits (consumption and income):** Orange (*Citrus* sp.) Langsat (*Lansium domesticum*) Mango (*Mangifera indica*) Coconut (*Cocos nucifera*) Rose apple (*Syzygium aqueum*) Guava (*Psidium guajava*) *Kedondong* (*Spondias dulcis*) *Petai* (*Parkia speciosa*) *Jengkol* (*Archidendron pauciflorum*) *Ganemo*(*Gnetum gnemon*) Snakefruit (*Salacca zalacca*) • **Fodder:** King grass	• **Food:** Tubers (for example, *gadung* (*Dioscorea hispida*), ginger, potato, sweet potato)
Rice field	• **Food:** Wet rice (*Oryza sativa*), Poultry Fish (mozambique tilapia (*Oreochromis mossambicus*), nile tilapia (*Oreochromis niloticus*), catfish (*Clarias* sp.), carp (*Cyprinus carpio*)) Plants (*genjer* (*Limnocharis flava*)*, kangkung* (*Ipomoea aquatica*)*, mendong* (*Fimbristylis umbellaris*), clover (*Marsilea* sp.))	• **Food:** Wet rice (*Oryza sativa*), Poultry Fish (mozambique tilapia (*Oreochromis mossambicus*), nile tilapia (*Oreochromis niloticus*), catfish (*Clarias* sp.), carp (*Cyprinus carpio*)) Plants (*genjer* (*Limnocharis flava*)*, kangkung* (*Ipomoea aquatica*)*, mendong* (*Fimbristylis umbellaris*), clover (*Marsilea* sp.))
Cacao agroforest	• **Market items (income):** Cacao (*Theobroma cacao*) Coffee (*Coffea* sp.) • **Fruits (consumption and income):** Durian (*Durio zibethinus*) Langsat (*Lansium domesticum*) Rambutan (*Nephelium lappaceum*) Coconut (*Cocos nucifera*) Banana (*Musa xparadisiaca*)	• **Market items (income):** Cacao (*Theobroma cacao*) Coffee (*Coffea* sp.) • **Fruits (consumption and income):** Durian (*Durio zibethinus*) Langsat (*Lansium domesticum*) Rambutan (*Nephelium lappaceum*) Coconut (*Cocos nucifera*) Banana (*Musa xparadisiaca*)

Land cover	Normal condition	Extreme condition
	Petai (*Parkia speciosa*) Rose apple (*Syzigium aqueum*) *Jengkol* (*Archidendron pauciflorum*) Soursop (*Annona muricata*) • **Timber (building material):** *Cempaga* (*Dysoxylum* sp.) Teak (*Tectona grandis*) *Nyatoh* (*Palaquium obtusifolium*) • **Annual crops:** Patchouli (*Pogostemon cablin*) Chilli (*Capsicum* sp.) • **Shade trees:** *Gliricidia sepium* *Erithryna* sp. • **Medicine:** *Physalis* sp.	*Petai* (*Parkia speciosa*) Rose apple (*Syzigium aqueum*) *Jengkol* (*Archidendron pauciflorum*) Soursop (*Annona muricata*) • **Timber (building material):** *Cempaga* (*Dysoxylum* sp.) Teak (*Tectona grandis*) *Nyatoh* (*Palaquium obtusifolium*) • **Shade trees:** *Gliricidia sepium* *Erithryna* sp. • **Medicine:** *Physalis* sp.
Swamp	• **Food:** Sago (*Metroxylon sagu)* • **Fencing:** *Ketapang (Terminalia catappa)*	• **Food:** Sago (*Metroxylon sagu)* • **Fencing:** *Ketapang (Terminalia catappa)*
Shrub	• **Timber (building material):** *Nyatoh* (*Palaquium obtusifolium*) Cananga (*Cananga odorata*) *Jabon (Anthocephalus chinensis)* *Gempol (Neonauclea* sp.) • **Firewood:** Manggis hutan (*Baccaurea javanica*) • **Fruits (consumption and income):** *Cempedak* (*Artocarpus integer*) Rambutan (*Nephelium lappaceum*) Langsat (*Lansium domesticum*) Mango (*Mangifera indica*) • **Building material (and/or income):** Bamboo • **Animals (food or income):** Snake, chicken, pig, deer	• **Timber (building material):** *Nyatoh* (*Palaquium obtusifolium*) Cananga (*Cananga odorata*) *Jabon (Anthocephalus chinensis)* *Gempol (Neonauclea* sp.) • **Firewood:** Manggis hutan (*Baccaurea javanica*) • **Fruits (consumption and income):** *Cempedak* (*Artocarpus integer*) Rambutan (*Nephelium lappaceum*) Langsat (*Lansium domesticum*) Mango (*Mangifera indica*)

* Local name mentioned by the communities during the discussion, need further survey to clarify the species

Table B. Tree and other biodiversity utilization by the local community in the midstream cluster during normal and extreme conditions

Land cover	Normal condition	Extreme condition
Degraded forest	• **Timber (building material):** *Lingua* (*Pterocarpus indicus*) *Palapi/kamper* (*Heritiera* sp.) White *meranti* (*Shorea* sp.) Red *meranti* (*Shorea* sp.) *Malapanga* * *Dao* (*Dracontomelon dao*) *Kapas* (*Sterculia stipulata*) Red *jabon* (*Anthocephalus macrophyllus*) *Binuang* (*Octomeles sumatrana*) *Kenanga* (*Cananga odorata*) *Lita-lita* (*Alstonia scholaris*) *Marbengi** *Nantu* (*Palaquium* sp.) *Kumat** *Sampan** *Bunga-bunga** *Bugis* (*Garcinia celebica*) *Cempaga* (*Dysoxylum* sp.) *Cina* (*Podocarpus* sp.) Teak (*Tectona grandis*) *Buaya darat* (*Cryptocarya tomentosa*) • **Market items (income):** *Gaharu* (several species) Rattan (several species) Dammar resin (*Agathis* sp.) Bamboo Orchids (several species) • **Fruits (consumption and income)** *Cempedak* (*Artocarpus integer*) Rambutan (*Nephelium lappaceum*) Langsat (*Lansium domesticum*) *Aren* (*Arenga pinnata*) Durian (*Durio zibethinus*) Banana (*Musa* x *paradisiaca*) Mangosteen (*Garcinia mangostana*) Mango (*Mangifera indica*) *Kluwek* (*Pangium edule*) Betel nut (*Areca catechu*) *Melinjo* or *ganemo* (*Gnetum gnemon)* • **Firewood:** *Biluat* (*Diospyros maritima*) • **Food:** Ferns	• **Timber (building material):** *Lingua* (*Pterocarpus indicus*) *Palapi/kamper* (*Heritiera* sp.) White *meranti* (*Shorea* sp.) Red *meranti* (*Shorea* sp.) *Malapanga* * *Dao* (*Dracontomelon dao*) *Kapas* (*Sterculia stipulata*) Red *jabon* (*Anthocephalus macrophyllus*) *Binuang* (*Octomeles sumatrana*) *Kenanga* (*Cananga odorata*) *Lita-lita* (*Alstonia scholaris*) *Marbengi** *Nantu* (*Palaquium* sp.) *Kumat** *Sampan** *Bunga-bunga** *Bugis* (*Garcinia celebica*) *Cempaga* (*Dysoxylum* sp.) *Cina* (*Podocarpus* sp.) Teak (*Tectona grandis*) *Buaya darat* (*Cryptocarya tomentosa*) • **Market items (income):** *Gaharu* (several species) Rattan (several species) Dammar resin (*Agathis* sp.) Bamboo Orchids (several species) • **Fruits (consumption and income)** *Cempedak* (*Artocarpus integer*) Rambutan (*Nephelium lappaceum*) Langsat (*Lansium domesticum*) *Aren* (*Arenga pinnata*) Durian (*Durio zibethinus*) Banana (*Musa* x *paradisiaca*) Mangosteen (*Garcinia mangostana*) Mango (*Mangifera indica*) *Kluwek* (*Pangium edule*) Betel nut (*Areca catechu*) *Melinjo* or *ganemo* (*Gnetum gnemon)* • **Firewood:** *Biluat* (*Diospyros maritima*) • **Food:** Ferns

Land cover	Normal condition	Extreme condition
	Honey Animals (anoa, chicken, hornbill, deer, fish, pig, snake)	Honey Animals (anoa, chicken, hornbill, deer, fish, pig, snake)
Oil-palm plantation	• **Market items (income):** Oil palm (*Elaeis guineensis*)	• **Market items (income):** Oil palm (*Elaeis guineensis*)
Dry land	• **Food:** Maize (*Zea mays*) Upland rice (*Oryza sativa*, several varieties) Vegetables (onion, spinach, chilli, leek, cabbage, pumpkin, patchouli, *pare* (*Momordica* sp.), pepper, mustard cabbage, lemongrass, eggplant, tomato) Pulses (green bean, soy bean, string bean, long bean, peanuts) Tubers (cassava, sweet potato) Spices (ginger, *kencur* (*Kaempferia galanga*), turmeric) • **Timbers (building material):** *Jabon* (*Anthocephalus chinensis*) *Acacia* sp. • **Building material:** Bamboo • **Fruits (consumption and income):** Rambutan (*Nephelium lappaceum*) *Cempedak* (*Artocarpus integer*) Durian (*Durio zibethinus*) *Aren* (*Arenga pinnata*) Coconut (*Cocos nucifera*) Langsat (*Lansium domesticum*) Cashew (*Anacardium occidentale*) *Petai* (*Parkia speciosa*) *Jengkol* (*Archidendron pauciflorum*) Jackfruit (*Artocarpus heterophyllus*) • **Others:** Fertilizer (*Leucaena* sp.)	• **Food:** Upland rice (*Oryza sativa*, several varieties) • **Timbers (building material):** *Jabon* (*Anthocephalus chinensis*) *Acacia* sp. • **Building material:** Bamboo • **Fruits (consumption and income):** Rambutan (*Nephelium lappaceum*) *Cempedak* (*Artocarpus integer*) Durian (*Durio zibethinus*) *Aren* (*Arenga pinnata*) Coconut (*Cocos nucifera*) Langsat (*Lansium domesticum*) Cashew (*Anacardium occidentale*) *Petai* (*Parkia speciosa*) *Jengkol* (*Archidendron pauciflorum*) Jackfruit (*Artocarpus heterophyllus*) • **Others:** Fertilizer (*Leucaena* sp.)
Rice field	• **Food:** Wet rice (*Oryza sativa)* Sago (*Metroxylon sagu)* • **Vegetables:** *Genjer* (*Limnocharis flava*) Kangkung (*Ipomoea aquatica*) • **Fish:** Snakehead fish (*Channa* sp.) *Sepat* (*Trichogaster trichopterus*) Catfish (*Clarias* sp.) *Segili** Mozambique tilapia (*Oreochromis mossambicus*)	• **Food:** Sago (*Metroxylon sagu)*

Land cover	Normal condition	Extreme condition
	• **Water birds (as food):** Waterhen (*Amaurornis phoenicurus*) *Rails** • **Handicraft :** *Mendong* grass (*Fimbristylis umbellaris*)	
Cacao agroforest	• **Fruits (consumption and income):** Durian (*Durio zibethinus*) Langsat (*Lansium domesticum*) Rambutan (*Nephelium lappaceum*) Coconut (*Cocos nucifera*) Banana (*Musa* x *paradisiaca*) *Petai* (*Parkia speciosa*) Rose apple (*Syzigium aqueum*) Guava (*Psidium guajava*) Mango (*Mangifera indica*) Lemon (*Citrus* sp.) Snakefruit (*Salacca zalacca*) *Kapok* (*Ceiba pentandra*) Papaya (*Carica papaya*) Betel nut (*Areca catechu*) • **Timber (building material):** *Jabon/kayu mas* (*Anthocephalus chinensis*) Gmelina (*Gmelina arborea*) • **Market items (income):** Coffee (*Coffea* spp.) Cacao *(Theobroma cacao*) Clove (*Syzygium aromaticum*)	• **Fruits (consumption and income):** Durian (*Durio zibethinus*) Langsat (*Lansium domesticum*) Rambutan (*Nephelium lappaceum*) Coconut (*Cocos nucifera*) Banana (*Musa* x *paradisiaca*) *Petai* (*Parkia speciosa*) Rose apple (*Syzigium aqueum*) Guava (*Psidium guajava*) Mango (*Mangifera indica*) Lemon (*Citrus* sp.) Snakefruit (*Salacca zalacca*) *Kapok* (*Ceiba pentandra*) Papaya (*Carica papaya*) Betel nut (*Areca catechu*) • **Timber (building material):** *Jabon/kayu mas* (*Anthocephalus chinensis*) Gmelina (*Gmelina arborea*) • **Market items (income):** Coffee (*Coffea* spp.) Cacao *(Theobroma cacao*) Clove (*Syzygium aromaticum*)
Swamp	• **Timber (building material):** *Ketapang* (*Terminalia catappa*) *Palapi/kamper* (Heritiera sp.) *Nantu* (Endiandra sp.) *Jabon/kayu mas* (*Anthocephalus chinensis*) *Buaya darat* (*Cryptocarya tomentosa*) • **Food:** Sago *(Metroxylon sagu)*	• **Timber (building material):** *Ketapang* (*Terminalia catappa*) *Palapi/kamper* (Heritiera sp.) *Nantu* (Endiandra sp.) *Jabon/kayu mas* (*Anthocephalus chinensis*) *Buaya darat* (*Cryptocarya tomentosa*) • **Food:** Sago *(Metroxylon sagu)*
Shrub	• **Food:** Sago *(Metroxylon sagu)* • **Fruits (consumption and income):** Durian (*Durio zibethinus*) Langsat (*Lansium domesticum*) Rambutan (*Nephelium lappaceum*) Coconut (*Cocos nucifera*) Banana (*Musa* x *paradisiaca*) *Petai* (*Parkia speciosa*) Rose apple (*Syzigium aqueum*) *Jengkol* (*Archidendron pauciflorum*)	• **Food:** Sago *(Metroxylon sagu)* • **Fruits (consumption and income):** Durian (*Durio zibethinus*) Langsat (*Lansium domesticum*) Rambutan (*Nephelium lappaceum*) Coconut (*Cocos nucifera*) Banana (*Musa* x *paradisiaca*) *Petai* (*Parkia speciosa*) Rose apple (*Syzigium aqueum*) *Jengkol* (*Archidendron pauciflorum*)

Land cover	Normal condition	Extreme condition
	• **Timber (building material):** Teak (*Tectona grandis*) *Kayu tutup/gempol* (*Neonauclea* sp.) *Jabon* (*Anthocephalus chinensis*) *Sirih* (*Piper aduncum*) *Tinta* (*Melastoma* sp.) *Pulai* (*Alstonia scholaris*) • **Animals (as food):** Water monitor (*Varanus salvator*) Waterhen (*Amaurornis phoenicurus*) Birds Rodents Deer Wild pig • **Building material:** Bamboo • **Shade tree:** *Gamal* (*Gliricidia sepium*) • **Market items (income):** Coffee (*Coffea* spp.) Cacao *(Theobroma cacao*) Clove (*Syzygium aromaticum*) • **Fodder:** Grass (for example, *Eleusine indica*)	• **Timber (building material):** Teak (*Tectona grandis*) *Kayu tutup/gempol* (*Neonauclea* sp.) *Jabon* (*Anthocephalus chinensis*) *Sirih* (*Piper aduncum*) *Tinta* (*Melastoma* sp.) *Pulai* (*Alstonia scholaris*) • **Animals (as food):** Water monitor (*Varanus salvator*) Waterhen (*Amaurornis phoenicurus*) Birds Rodents Deer Wild pig • **Building material:** Bamboo • **Shade tree:** *Gamal* (*Gliricidia sepium*) • **Market items (income):** Coffee (*Coffea* spp.) Cacao *(Theobroma cacao*) Clove (*Syzygium aromaticum*) • **Fodder:** • Grass (for example, *Eleusine indica*)

* Local name mentioned by the communities during the discussion, need further survey to clarify the species

Table C. Tree and other biodiversity utilization by the local community in the coastal cluster during normal and extreme conditions

Land cover	Normal condition	Extreme condition
Disturbed forest	• **Timber (building material):** *Palapi/kamper* (*Heritiera* sp.) *Meranti* (*Shorea* sp.) *Lingua* (*Pterocarpus indicus*) *Kayu merah** Ironwood (*Instia bijuga*) • **Food:** Sago (*Metroxylon sagu*) • **Market items (income):** Rattan (several species) *Nibung* (*Oncosperma* sp.) Dammar Bamboo • **Fruits:** Durian (*Durio zibethinus*) Rambutan (*Nephelium lappaceum*) *Kapok* (*Ceiba pentandra*) *Aren* (*Arenga pinnata*) • **Animals (as food):** Anoa (*Bubalus depressicornis*), pig (*Sus* sp.), deer (*Cervus* sp.) , chicken (*Gallus gallus*), parrot (several species), cockatoo	• **Timber (building material):** *Palapi/kamper* (*Heritiera* sp.) *Meranti* (*Shorea* sp.) *Lingua* (*Pterocarpus indicus*) *Kayu merah** Ironwood (*Instia bijuga*) • **Food:** Sago (*Metroxylon sagu*) • **Market items (income):** Rattan (several species) *Nibung* (*Oncosperma* sp.) Dammar Bamboo • **Fruits:** Durian (*Durio zibethinus*) Rambutan (*Nephelium lappaceum*) *Kapok* (*Ceiba pentandra*) *Aren* (*Arenga pinnata*) • **Animals (as food):** Anoa (*Bubalus depressicornis*), pig (*Sus* sp.), deer (*Cervus* sp.) , chicken (*Gallus gallus*), parrot (several species), cockatoo (Cacatua sp.), maleo

	(Cacatua sp.), maleo (*Macrocephalon maleo*) • **Animals (as medicine):** Hornbill (*Penelopides exarhatus*)	(*Macrocephalon maleo*) • **Animals (as medicine):** Hornbill (*Penelopides exarhatus*)
Mangrove	• **Timber (building material):** *Sonneratia* sp. *Rhizophora* sp. *Bruguiera* sp. *Mandoti** *Xylocarpus* sp. *Nypa fruticans* • **Food:** Fish (*ikan buronan, ikan tagogo, ikan bibitan, ikan sako, ikan tabobogug, ikan tagut*)* Crab, shrimp, sea cucumber, clam, sea eel, squid, octopus Birds	• **Timber (building material):** *Sonneratia* sp. *Rhizophora* sp. *Bruguiera* sp. *Mandoti** *Xylocarpus* sp. *Nypa fruticans* • **Food:** Fish (*ikan buronan, ikan tagogo, ikan bibitan, ikan sako, ikan tabobogug, ikan tagut*)* Crab, shrimp, sea cucumber, clam, sea eel, squid, octopus Birds
Complex agroforest	• **Timber (building material):** *Nyatoh* (*Palaquium obtusifolium*) Teak (*Tectona grandis*) *Sengon* (*Falcataria moluccana*) *Rikak** *Yokinak** *Kayu sumbai** • **Fruits:** Coconut (*Cocos nucifera*) Nutmeg (*Myristica fragrans*) Papaya (*Carica papaya*) Langsat (*Lansium domesticum*) Durian (*Durio zibethinus*) *Kedondong* (*Spondias dulcis*) • **Market items (income):** Coffee (*Coffea* spp.) Cacao *(Theobroma cacao*) Clove (*Syzygium aromaticum*) • **Food:** Maize (*Zea mays*) Cassava (*Manihot esculenta*) • **Vegetables:** Leek (*Allium* sp.) Pepper (*Piper* sp.) • **Pulses:** Green bean, long bean, peanut • **Medicine:** Turmeric (*Curcuma domestica*) *Temulawak* (*Curcuma xanthorizha)* *Kumis kucing* (*Ortosiphon grandiflorus*), *Bole bute** *Tonggu yapung** *Putik manuk** *Ramayana* (*Cassia* sp.) • **Firewood:** *Kayu sumbai** • **Animals:** Poultry, sheep, cattle, quail, other birds	• **Timber (building material):** *Nyatoh* (*Palaquium obtusifolium*) Teak (*Tectona grandis*) *Sengon* (*Falcataria moluccana*) *Rikak** *Yokinak** *Kayu sumbai** • **Fruits:** Coconut (*Cocos nucifera*) Nutmeg (*Myristica fragrans*) Papaya (*Carica papaya*) Langsat (*Lansium domesticum*) Durian (*Durio zibethinus*) *Kedondong* (*Spondias dulcis*) • **Market items (income):** Coffee (*Coffea* spp.) Cacao *(Theobroma cacao*) Clove (*Syzygium aromaticum*) • **Food:** Maize (*Zea mays*) Cassava (*Manihot esculenta*) • **Vegetables:** Leek (*Allium* sp.) Pepper (*Piper* sp.) • **Pulses:** Green bean, long bean, peanut • **Medicine:** Turmeric (*Curcuma domestica*) *Temulawak* (*Curcuma xanthorizha)* *Kumis kucing* (*Ortosiphon grandiflorus*), *Bole bute** *Tonggu yapung** *Putik manuk** *Ramayana* (*Cassia* sp.) • **Firewood:** *Kayu sumbai** • **Animals:** • Poultry, sheep, cattle, quail, other birds
Rice field	• **Food:** Wet rice (*Oryza sativa*) • **Animals:** Birds Snakehead fish (*Canna* sp.)	• **Food:** Wet rice (*Oryza sativa*) • **Animals:** Birds Snakehead fish (*Canna* sp.)
Coconut	• **Market items (income):** Coconut (*Cocos nucifera*)	• **Market items (income):** Coconut (*Cocos nucifera*)

	• **Fruits (consumption and income):** Jackfruit (*Artocarpus heterophyllus*) Nutmeg (*Myristica fragrans*) Langsat (*Lansium domesticum*) Mango (*Mangifera indica*) Pineapple (*Ananas comosus*) Banana (*Musa* x *paradisiaca*) Guava (*Psidium guajava*) • **Firewood:** *Kayu sirih* (*Piper aduncum*) *Lamtoro* (*Leucaena leucocephala*)	• **Fruits (consumption and income):** Jackfruit (*Artocarpus heterophyllus*) Nutmeg (*Myristica fragrans*) Langsat (*Lansium domesticum*) Mango (*Mangifera indica*) Pineapple (*Ananas comosus*) Banana (*Musa* x *paradisiaca*) Guava (*Psidium guajava*) • **Firewood:** *Kayu sirih* (*Piper aduncum*) • *Lamtoro* (*Leucaena leucocephala*)
Clove	• **Market items (income):** Clove (*Syzygium aromaticum*)	• **Market items (income):** Clove (*Syzygium aromaticum*)

* Local name mentioned by the communities during the discussion, need further survey to clarify the species

Table D. List of tree species found on various land-use in Buol district

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
Cacao agroforest	*Aglaia* sp.				2
	Artocarpus altilis				1
	Artocarpus heterophyllus				2
	Artocarpus integer				1
	Artocarpus lanceifolius				1
	Cananga odorata				1
	Ceiba pentandra				2
	Cocos nucifera				18
	Coffea canephora	6			
	Dillenia ochreata				1
	Durio zibethinus			1	16
	Ficus septica		1	3	
	Gliricidia sepium	6		4	
	Kleinhovia hospita			3	3
	Leucaena leucocephala	1	3		4
	Macaranga hispida	1			
	Mangifera indica				3
	Melastoma malabathricum		1		
	Nephelium lappaceum	6	1	1	7
	Piper aduncum		10		
	Planchonia valida				1
	Psidium guajava			1	
	Pycnarrhena cauliflora				1
	Saurauia tristyla		2		
	Syzygium aqueum		4		
	Syzygium jambos	3			1

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Theobroma cacao		2	13	284
	Trema orientalis			1	
	Unidentified 22		4		
	Villebrunea rubescens		1	1	
	Vitex quinata				1
Clove agroforest	*Barringtonia apiculata*	3			
	Carica papaya			5	
	Cocos nucifera				40
	Gliricidia sepium		2		
	Gliricidia sp.				3
	Mallotus moluccanus				1
	Musa sp.		2	2	
	Osmoxylon sp.			4	
	Piper aduncum		2		
	Psidium guajava	13			1
	Spondias pinnata			1	
	Syzygium aromaticum				58
	Tabernaemontana orientalis	6		1	
	Theobroma cacao			1	3
	Unidentified 1				1
	Unidentified 6		8	1	
Coconut agroforest	*Aglaia* sp.			2	17
	Alstonia scholaris	1			
	Artocarpus elasticus				1
	Barringtonia apiculata			1	
	Cananga odorata	4			
	Carica papaya			2	
	Carmona retusa	1			
	Citrus aurantifolia			1	1
	Clausena excavata	2			
	Clerodendrum paniculatum		1		
	Cocos nucifera		3	1	124
	Crescentia cujete	2			
	Durio zibethinus				5
	Elatostema polioneurum	2			
	Ficus septica		5		
	Ficus variegata		1		

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Ganua motleyana				1
	Gliricidia sepium			2	1
	Gliricidia sp.				8
	Macaranga gigantea		2		
	Mallotus moluccanus		3		1
	Mangifera indica				2
	Melastoma malabathricum	15	4		
	Metroxylon sagu				5
	Microcos paniculata		4		
	Musa sp.			1	
	Nephelium lappaceum				1
	Osmoxylon sp.				1
	Parinari oblongifolia		1		
	Piper aduncum		4		1
	Polyscias nodosa				1
	Pometia pinnata		1		
	Premna oblongifolia		1		
	Psidium guajava	14	2		
	Syzygium jambos	1			
	Syzygium malaccense	1		1	
	Tabernaemontana orientalis	41	2		
	Tectona grandis				20
	Theobroma cacao		1		
	Trema orientalis	1			
	Unidentified 1				2
	Unidentified 15		1		
	Unidentified 5				3
	Unidentified 7				1
Complex agroforest	*Acalypha caturus*				8
	Aglaia sp.	1	4		7
	Annona muricata				1
	Arenga pinnata				6
	Artocarpus heterophyllus				10
	Artocarpus lanceifolius		10	12	24
	Averrhoa bilimbi				2
	Bridelia insulana				1
	Cananga odorata				4

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Ceiba pentandra				7
	Citrus aurantifolia				4
	Citrus grandis				1
	Citrus microcarpa	4			2
	Citrus sp.		2	3	3
	Citrus x limon	1			
	Cocos nucifera		1		76
	Codiaeum variegatum		2		
	Crescentia cujete		2		4
	Dillenia ochreata			2	
	Dracontomelon dao				1
	Durio zibethinus	1	6	2	5
	Dysoxylum parasiticum	4			
	Elaeis guineensis		1		
	Euodia latifolia	2			
	Evodia latifolia		1	1	
	Ficus septica		4	1	6
	Ficus variegata				1
	Flacourtia rukam	2	1		11
	Ganua motleyana				1
	Gliricidia sepium		1		4
	Glochidion philippicum		1		1
	Jatropha curcas			2	
	Kleinhovia hospita				7
	Leea aequata		1		
	Litsea mappacea		1	1	12
	Macaranga gigantea				1
	Mallotus floribundus		1		
	Mangifera indica		2	2	6
	Melastoma malabathricum	3			
	Musa sp.		1	2	
	Nephelium lappaceum	2	1	1	11
	Osmoxylon sp.				1
	Piper aduncum		4	1	
	Piper betle		1		
	Polyscias nodosa				2
	Premna foetida				1

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Psidium guajava	7	1		
	Spondias dulcis				1
	Sterculia stipulata			2	2
	Syzygium aqueum	1			
	Syzygium malaccense	1	1		
	Tabernaemontana orientalis	1			
	Terminalia bellirica	1			
	Theobroma cacao			20	152
	Unidentified 641			1	
Disturbed forest	*Aglaia argentea*				4
	Aglaia edulis	1	2	1	7
	Aglaia malaccensis			1	
	Aglaia odoratissima		1		1
	Artocarpus elasticus	1			
	Artocarpus reticulatus		3	1	
	Atuna excelsa		1		
	Baccaurea javanica				3
	Cantleya corniculata	1			
	Carallia brachiata	2			
	Crypteronia paniculata		1		
	Cryptocarya cf. tomentosa				1
	Cynometra ramiflora				1
	Cyrtandra sp.	1			
	Dillenia ochreata	2	2	2	8
	Diospyros sp.				1
	Diospyros species 1				1
	Dracontomelon dao	13	7	4	6
	Dysoxylum sp.				4
	Elatostema polioneurum	12	1		
	Elattostachys verrucosa		1		
	Endiandra sp.				3
	Ficus benjamina	1			
	Ficus lepicarpa				2
	Ficus septica				3
	Ganua motleyana	1	2	1	3
	Garcinia celebica	1			
	Gnetum latifolium				3

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Gonystylus macrophyllus		1		
	Gyrinops versteegii				1
	Harpullia arborea			1	
	Ixora species 1				2
	Lepiniopsis ternatensis	1	1		1
	Licuala spinosa		1		
	Litsea mappacea				2
	Macaranga gigantea		1	3	9
	Mallotus floribundus		4	3	2
	Neonauclea calycina		1		
	Nephelium lappaceum	2	2	2	3
	Octomeles sumatrana				1
	Osmoxylon sp.			1	
	Palaquium obovatum				2
	Phaleria cf. capitata			1	
	Piper aduncum	1			
	Planchonia valida	2			
	Polyalthia lateriflora	4	1	2	3
	Pterocarpus indicus	1			1
	Pterospermum celebicum				1
	Saurauia tristyla		1		
	Schima wallichii		1		
	Shorea leprosula				1
	Shorea parvifolia				1
	Spathiostemon javensis		4		
	Terminalia bellirica				2
	Uncaria cf. gambir		1		
	Unidentified 10			1	2
	Unidentified 12				1
	Unidentified 13				1
	Unidentified 14				2
	Unidentified 16	1	4		
	Unidentified 17		1		
	Unidentified 18		2		
	Unidentified 19				1
	Unidentified 20			2	
	Unidentified 21			1	

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Unidentified 23		2		
	Unidentified 24	1	1		
	Unidentified 25		1	1	6
	Unidentified 26				1
	Unidentified 3				1
	Unidentified 4				1
	Unidentified 8				3
	Unidentified 9				1
Sago and shrub	*Artocarpus lanceifolius*				1
	Barringtonia apiculata	11			
	Crescentia cujete		1	1	
	Dillenia ochreata				1
	Ficus obscura		1		
	Ficus septica	2	2		
	Ficus variegata				1
	Glochidion macrocarpum	7			
	Kleinhovia hospita	6	1		6
	Leea angulata		1		
	Metroxylon sagu				396
	Microcos paniculata				1
	Morinda sp.	5			
	Neonauclea calycina		1		
	Saurauia tristyla	2			
	Spatholobus littoralis	1	1		
	Sterculia stipulata		1	1	
	Unidentified 7	1			5
Teak monoculture	*Averrhoa bilimbi*			1	1
	Barringtonia apiculata	2	2	2	
	Ceiba pentandra				1
	Durio zibethinus	1			1
	Ficus septica			1	
	Flacourtia rukam				1
	Gliricidia sepium				2
	Glochidion philippicum				1
	Leea aequata		1		
	Macaranga gigantea				6
	Mangifera indica	1		1	1

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Microcos paniculata			1	
	Nephelium lappaceum	2			
	Piper aduncum		10	1	
	Psidium guajava	1			
	Saurauia tristyla		1		
	Tectona grandis	3	9	6	269
	Theobroma cacao			1	16
	Unidentified 16		1		
	Unidentified 608	1	1		
	Unidentified 643		1		
Undisturbed forest	*Aglaia argentea*				12
	Aglaia leucophylla	1	4	1	2
	Aglaia odoratissima	1	1	1	1
	Anthocephalus chinensis				1
	Artocarpus elasticus				3
	Atuna excelsa				1
	Barringtonia apiculata	1			
	Bombax ceiba				2
	Bridelia insulana			1	
	Calophyllum soulatri	5	3	1	
	Calophyllum species 1	1	2		2
	Cananga odorata		2		5
	Carallia brachiata		1		3
	Celtis philippensis		2		
	Crypteronia griffithii				8
	Cyrtandra sp.				1
	Dimocarpus longan	1			
	Diospyros cf. maritima				4
	Diospyros maritima	5	1	4	17
	Diospyros sp.	1			
	Diospyros species 1				2
	Dracontomelon dao	1	1	1	1
	Durio carinatus	1			
	Evodia latifolia	2			3
	Ficus fistulosa		1		
	Ficus sp.			1	
	Ficus subulata				2

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Ganua motleyana	1			
	Heritiera javanica	1			
	Heritiera littoralis				1
	Hymenodictyon horsfieldii		1		1
	Kleinhovia hospita				2
	Leea aequata			1	
	Leea angulata				2
	Licuala spinosa		1		38
	Macaranga gigantea		1		1
	Macaranga tanarius				1
	Maesa cf. latifolia			1	
	Mallotus floribundus		1		
	Mangifera laurina				2
	Octomeles sumatrana				1
	Palaquium obtusifolium				1
	Planchonella cf. nitida	1			
	Planchonella nitida	1	1		
	Plectronia sp.	2			
	Dracaena angustifolia		3	1	2
	Polyalthia lateriflora	2	1		3
	Prainea limpato	1			
	Pterocarpus indicus			1	
	Salacia oblongifolia	5			
	Santiria oblongifolia		2	1	1
	Shorea acuminata	3			
	Shorea parvifolia				2
	Spathiostemon javensis	3	10	3	27
	Spondias pinnata				1
	Sterculia oblongata	1		1	
	Sterculia stipulata			1	2
	Strichnos sp.	1			1
	Syzygium malaccense				1
	Syzygium species 1				1
	Unidentified 11			1	
	Unidentified 24				1
	Unidentified 607		1		
	Unidentified 609				1

Land-use	Tree species	Number of individuals at each growth stage			
		Seedling	Sapling	Pole	Tree
	Unidentified 610	1	8		7
	Unidentified 614				1
	Unidentified 621			3	1
	Unidentified 624				1
	Unidentified 625			1	
	Unidentified 628				1
	Unidentified 642	1			
	Unidentified 644				1
	Unidentified 645				1
	Unidentified 646				1
	Unidentified 651				1
	Xylopia malayana			1	
	Ziziphus javanensis	1			

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10. La biodiversité des espèces ligneuses: Diversité arborée et unités de gestion du terroir dans le Cercle de Ségou, au Mali

2006

11. Bird diversity and land use on the slopes of Mt. Kilimanjaro and the adjacent plains, Tanzania
12. Water, women and local social organization in the Western Kenya Highlands
13. Highlights of ongoing research of the World Agroforestry Centre in Indonesia
14. Prospects of adoption of tree-based systems in a rural landscape and its likely impacts on carbon stocks and farmers' welfare: The FALLOW Model Application in Muara Sungkai, Lampung, Sumatra, in a 'Clean Development Mechanism' context
15. Equipping integrated natural resource managers for healthy Agroforestry landscapes.
17. Agro-biodiversity and CGIAR tree and forest science: approaches and examples from Sumatra.
18. Improving land management in eastern and southern Africa: A review of policies.
19. Farm and household economic study of Kecamatan Nanggung, Kabupaten Bogor, Indonesia: A socio-economic base line study of Agroforestry innovations and livelihood enhancement.
20. Lessons from eastern Africa's unsustainable charcoal business.
21. Evolution of RELMA's approaches to land management: Lessons from two decades of research and development in eastern and southern Africa
22. Participatory watershed management: Lessons from RELMA's work with farmers in eastern Africa.
23. Strengthening farmers' organizations: The experience of RELMA and ULAMP.
24. Promoting rainwater harvesting in eastern and southern Africa.
25. The role of livestock in integrated land management.
26. Status of carbon sequestration projects in Africa: Potential benefits and challenges to scaling up.
27. Social and Environmental Trade-Offs in Tree Species Selection: A Methodology for Identifying Niche Incompatibilities in Agroforestry *[Appears as AHI Working Paper no. 9]*
28. Managing tradeoffs in agroforestry: From conflict to collaboration in natural resource management. *[Appears as AHI Working Paper no. 10]*
29. Essai d'analyse de la prise en compte des systemes agroforestiers pa les legislations forestieres au Sahel: Cas du Burkina Faso, du Mali, du Niger et du Senegal.
30. Etat de la recherche agroforestière au Rwanda etude bibliographique, période 1987-2003

2007

31. Science and technological innovations for improving soil fertility and management in Africa: A report for NEPAD's Science and Technology Forum.
32. Compensation and rewards for environmental services.
33. Latin American regional workshop report compensation.
34. Asia regional workshop on compensation ecosystem services.
35. Report of African regional workshop on compensation ecosystem services.
36. Exploring the inter-linkages among and between compensation and rewards for ecosystem services CRES and human well-being
37. Criteria and indicators for environmental service compensation and reward mechanisms: realistic, voluntary, conditional and pro-poor
38. The conditions for effective mechanisms of compensation and rewards for environmental services.
39. Organization and governance for fostering Pro-Poor Compensation for Environmental Services.
40. How important are different types of compensation and reward mechanisms shaping poverty and ecosystem services across Africa, Asia & Latin America over the Next two decades?
41. Risk mitigation in contract farming: The case of poultry, cotton, woodfuel and cereals in East Africa.
42. The RELMA savings and credit experiences: Sowing the seed of sustainability
43. Yatich J., Policy and institutional context for NRM in Kenya: Challenges and opportunities for Landcare.
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45. Is Hutan Tanaman Rakyat a new paradigm in community based tree planting in Indonesia?
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53. Biofuels in China: An Analysis of the Opportunities and Challenges of Jatropha curcas in Southwest China.
54. Jatropha curcas biodiesel production in Kenya: Economics and potential value chain development for smallholder farmers
55. Livelihoods and Forest Resources in Aceh and Nias for a Sustainable Forest Resource Management and Economic Progress
56. Agroforestry on the interface of Orangutan Conservation and Sustainable Livelihoods in Batang Toru, North Sumatra.

2008

57. Assessing Hydrological Situation of Kapuas Hulu Basin, Kapuas Hulu Regency, West Kalimantan.
58. Assessing the Hydrological Situation of Talau Watershed, Belu Regency, East Nusa Tenggara.
59. Kajian Kondisi Hidrologis DAS Talau, Kabupaten Belu, Nusa Tenggara Timur.
60. Kajian Kondisi Hidrologis DAS Kapuas Hulu, Kabupaten Kapuas Hulu, Kalimantan Barat.
61. Lessons learned from community capacity building activities to support agroforest as sustainable economic alternatives in Batang Toru orang utan habitat conservation program (Martini, Endri et al.)
62. Mainstreaming Climate Change in the Philippines.
63. A Conjoint Analysis of Farmer Preferences for Community Forestry Contracts in the Sumber Jaya Watershed, Indonesia.
64. The highlands: a shared water tower in a changing climate and changing Asia
65. Eco-Certification: Can It Deliver Conservation and Development in the Tropics.
66. Designing ecological and biodiversity sampling strategies. Towards mainstreaming climate change in grassland management.
67. Towards mainstreaming climate change in grassland management policies and practices on the Tibetan Plateau
68. An Assessment of the Potential for Carbon Finance in Rangelands

69 ECA Trade-offs Among Ecosystem Services in the Lake Victoria Basin.

69. The last remnants of mega biodiversity in West Java and Banten: an in-depth exploration of RaTA (Rapid Land Tenure Assessment) in Mount Halimun-Salak National Park Indonesia
70. Le business plan d'une petite entreprise rurale de production et de commercialisation des plants des arbres locaux. Cas de quatre pépinières rurales au Cameroun.
71. Les unités de transformation des produits forestiers non ligneux alimentaires au Cameroun. Diagnostic technique et stratégie de développement Honoré Tabuna et Ingratia Kayitavu.
72. Les exportateurs camerounais de safou (Dacryodes edulis) sur le marché sous régional et international. Profil, fonctionnement et stratégies de développement.
73. Impact of the Southeast Asian Network for Agroforestry Education (SEANAFE) on agroforestry education capacity.
74. Setting landscape conservation targets and promoting them through compatible land use in the Philippines.
75. Review of methods for researching multistrata systems.
76. Study on economical viability of *Jatropha curcas* L. plantations in Northern Tanzania assessing farmers' prospects via cost-benefit analysis
77. Cooperation in Agroforestry between Ministry of Forestry of Indonesia and International Center for Research in Agroforestry
78. "China's bioenergy future. an analysis through the Lens if Yunnan Province
79. Land tenure and agricultural productivity in Africa: A comparative analysis of the economics literature and recent policy strategies and reforms
80. Boundary organizations, objects and agents: linking knowledge with action in Agroforestry watersheds
81. Reducing emissions from deforestation and forest degradation (REDD) in Indonesia: options and challenges for fair and efficient payment distribution mechanisms

2009

82. Mainstreaming climate change into agricultural education: challenges and perspectives
83. Challenging conventional mindsets and disconnects in conservation: the emerging role of eco-agriculture in Kenya's landscape mosaics
84. Lesson learned RATA garut dan bengkunat: suatu upaya membedah kebijakan pelepasan kawasan hutan dan redistribusi tanah bekas kawasan hutan
85. The emergence of forest land redistribution in Indonesia
86. Commercial opportunities for fruit in Malawi
87. Status of fruit production processing and marketing in Malawi
88. Fraud in tree science
89. Trees on farm: analysis of global extent and geographical patterns of agroforestry
90. The springs of Nyando: water, social organization and livelihoods in Western Kenya
91. Building capacity toward region-wide curriculum and teaching materials development in agroforestry education in Southeast Asia
92. Overview of biomass energy technology in rural Yunnan (Chinese – English abstract)
93. A pro-growth pathway for reducing net GHG emissions in China
94. Analysis of local livelihoods from past to present in the central Kalimantan Ex-Mega Rice Project area
95. Constraints and options to enhancing production of high quality feeds in dairy production in Kenya, Uganda and Rwanda

2010

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97. Economic viability of Jatropha curcas L. plantations in Northern Tanzania- assessing farmers' prospects via cost-benefit analysis.
98. Hot spot of emission and confusion: land tenure insecurity, contested policies and competing claims in the central Kalimantan Ex-Mega Rice Project area
99. Agroforestry competences and human resources needs in the Philippines
100. CES/COS/CIS paradigms for compensation and rewards to enhance environmental Services
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105. Improving smallholders' rubber quality in Lubuk Beringin, Bungo district, Jambi province, Indonesia: an initial analysis of the financial and social benefits
106. Rapid Carbon Stock Appraisal (RACSA) in Kalahan, Nueva Vizcaya, Philippines
107. Tree domestication by ICRAF and partners in the Peruvian Amazon: lessons learned and future prospects in the domain of the Amazon Initiative eco-regional program
108. Memorias del Taller Nacional: "Iniciativas para Reducir la Deforestación en la region Andino - Amazónica", 09 de Abril del 2010. Proyecto REALU Peru
109. Percepciones sobre la Equidad y Eficiencia en la cadena de valor de REDD en Perú –Reporte de Talleres en Ucayali, San Martín y Loreto, 2009. Proyecto REALU-Perú.

110. Reducción de emisiones de todos los Usos del Suelo. Reporte del Proyecto REALU Perú Fase 1
111. Programa Alternativas a la Tumba-y-Quema (ASB) en el Perú. Informe Resumen y Síntesis de la Fase II. 2da. versión revisada
112. Estudio de las cadenas de abastecimiento de germoplasma forestal en la amazonía Boliviana
113. Biodiesel in the Amazon
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116. How can systems thinking, social capital and social network analysis help programs achieve impact at scale?
117. Energy policies, forests and local communities in the Ucayali Region, Peruvian Amazon
118. NTFPs as a Source of Livelihood Diversification for Local Communities in the Batang Toru Orangutan Conservation Program
119. Studi Biodiversitas: Apakah agroforestry mampu mengkonservasi keanekaragaman hayati di DAS Konto?
120. Estimasi Karbon Tersimpan di Lahan-lahan Pertanian di DAS Konto, Jawa Timur
121. Implementasi Kaji Cepat Hidrologi (RHA) di Hulu DAS Brantas, Jawa Timur. http://dx.doi.org/10.5716/WP10338.PDF
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123. A Study of Rapid Hydrological Appraisal in the Krueng Peusangan Watershed, NAD, Sumatra. http://dx.doi.org/10.5716/WP10339.PDF

2011

124. An Assessment of farm timber value chains in Mt Kenya area, Kenya
125. A Comparative financial analysis of current land use systems and implications for the adoption of improved agroforestry in the East Usambaras, Tanzania
126. Agricultural monitoring and evaluation systems
127. Challenges and opportunities for collaborative landscape governance in the East Usambara Mountains, Tanzania
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2012

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The World Agroforestry Centre is an autonomous, non-profit research organization whose vision is a rural transformation in the developing world as smallholder households increase their use of trees in agricultural landscapes to improve food security, nutrition, income, health, shelter, social cohesion, energy resources and environmental sustainability. The Centre generates science-based knowledge about the diverse roles that trees play in agricultural landscapes, and uses its research to advance policies and practices, and their implementation that benefit the poor and the environment. It aims to ensure that all this is achieved by enhancing the quality of its science work, increasing operational efficiency, building and maintaining strong partnerships, accelerating the use and impact of its research, and promoting greater cohesion, interdependence and alignment within the organization.

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