BIODIVERSITAS
Volume 17, Number 1, April 2016
Pages: 359-365

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d170148

The roles of community fruit garden (*tembawang*) on maintaining forest structure, diversity and standing biomass allocation: an alternative effort on reducing carbon emission

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Manuscript received: 12 February 2015. Revision accepted: 22 April 2016.

Abstract. *Astiani D, Ripin. 2016. The roles of community fruit garden (tembawang) on maintaining forest structure, diversity and standing biomass allocation: an alternative effort on reducing carbon emission. Biodiversitas 17: 359-365.* Fruit garden (*tembawang*) Cempedak Village in Sanggau West Kalimantan has been established by local community for their family mixed garden ~ >100 years. The families of 3rd generation were utilizing the tembawang for their needs of building materials, fire woods, rattan, vegetables, fruits, and traditionals medicine. It is important to study how this tembawang play their roles in maintaing forest structure, species diversity and stocking biomass. In 2014, we studied this area for exploring the vegetation composition and their ability to stock biomass of the tembawang. Stratified Random Sampling was applied to the 6.69 ha tembawang area, which devided into three major land cover patches (Mixed fruit garden, mixed rubber plants, and fruit garden mixed with *apik-Arenga undulatifolia* Becc palm). We surveyed and sampled vegetation using transect methods purposively chosen on each landcover patch, with sampling area consecutively for mixed fruit garden, mixed rubber plants, and mixed of fruit garden and *apik* were 1.52, 0.6, and 0.72 hectars. Results demonstrated that mixed fruit garden carried out higher tree diversity, density, basal area, and maintained the largest above ground biomass per hectar compared to the two other patches. From 97 vegetation spesies registered, it maintained 49 tree species of diameter >20cm and 51 tree species in the lower strature in the forest structure. Interestingly, *Durio zibethinus* Murr. was a dominant species on all landcover patches types and sinked the largest above ground living biomass. The choice of fruit species on tembawang determined the capability of the *tembawang* land to sequester and stock carbon in trees, because the trees were standing in tembawang for longer time compared to the one in production forest. This results show that, beside its multiple role for people community, tembawang provide other benefits to the nature in maintaining forest structure, diversity, and stocking large carbon in standing biomass.

Keywords: Above ground biomass, carbon stocks, lowland tropical forest, mixed fruit garden

INTRODUCTION

Rapid loss and degradation of humid tropical rain forests over recent years threatened the sustainability of forest in serving their functions to nature and surrounding people, which has direct need on forest for their daily life (Colfer et al. 1997). It had been long time ago, West Kalimantan dayak people established agricultural system that traditionally based on production of upland rice field. Upon the 2-3 times of growing rice, the land was planted with fruit trees, rubber, plant together with edible plant such as mushroom, fern, vegetables, medicinal herbs and other non timber forest products (Wulan et al. 2008; Potter 2012). Non timber forest product in the mixed fruit garden, so called *tembawang*, play an important role in rural livelihood strategies and contributes to sustained forested landscapes in various tropical areas (Jong, 2001). The mixed planted fruit trees and other then grown and maintain for many generation, and taken care of by communal families. The *tembawang* has also been used for their historical placed where their ancestors longhouse were built at the site.

Tembawang Cempedak Village is one sample of the mixed forest that was established in Tayan District Kabupaten Sanggau West Kalimantan. It was part of lowland tropical forest that has large range of species diversity. The alteration of natural forest to tembawang changed the natural species composition into mixed fruit garden and trees. Forest management should facilitate both the preservation of ecosystem function and the conservation of biodiversity, as well as supporting economic benefit (Lawrence et al. 2007; Potter et al. 2008). However, those mixed forest provide an array of benefits and goods for people communities such as supplying raw material for housing and building, fire woods, vegetables, fruits, traditional medicines and other uses. In fact, the forest is maintain for many years growing large trees especially fruit trees, bamboos, shrubs, and vegetables sustainably. The mixed vegetation demonstrated enhancing soil nutrition in tembawang (Lawrence et al. 2007).

Recent condition, on the other hand, these areas was also facing large pressures from other land uses which could destruct those valuable lands. Since there are large benefits for communities and the sustanable management they applied, it is urgent to maintain tembawang for local communities demonstrating their roles on preserving biodiversity, mitigating global warming, and protect them from the pressures. The study of the mixed forest species composition, structure, and their role in carbon allocation is important to describe this subsistent management practices in West Kalimantan rural communities.

MATERIALS AND METHODS

Study site

The area of research was in community fruit garden of Cempedak Village, Tayan Hilir, Sanggau District in West Kalimantan which located between 00º43’06”LU and 110º18,5’39’’ BT, and 24 -140 m above sea level (Figure 1). The site was about 200 km from Pontianak (West Kalimantan Capital City) and can be reach ~ 2 hours with land transportation. From 2000-2013, mean annual rainfall was 3025 mm ± 52 mm with 182 ± 5 rain days per year (compiled from local Climate station 2000-2013) with mean temperature 29^{0}C. The soil of area was dominated by 'Red-Yellow Podsolic' Ultisols, an acidic, leached, light color surface layer soil, with topography dominated by flat area mixed with some hilly terrains which reached 30% slope.

People community was native Dayak Tobak ethnicity. Shifting cultivation and tree-crop management have continously practiced for over 100 years by people community in this region. The community fruit gardens were formerly started as practices of cultivation of upland rice within scattered areas, and followed by establihment of relatively longtime mixed fruit-forest garden management. The fruit garden supplied community's basic needs of families for 3-4 generation.

Vegetation analysis

Survey technique. Vegetation analysis was done with survey and vegetation inventory. First, we used *stratified random sampling* to group landcovers variation within the tembawang by horizontally surveying overall the area and discover that the tembawang had 4 main different land covers (i.e., upland rice field, mixed fruit garden, mixed

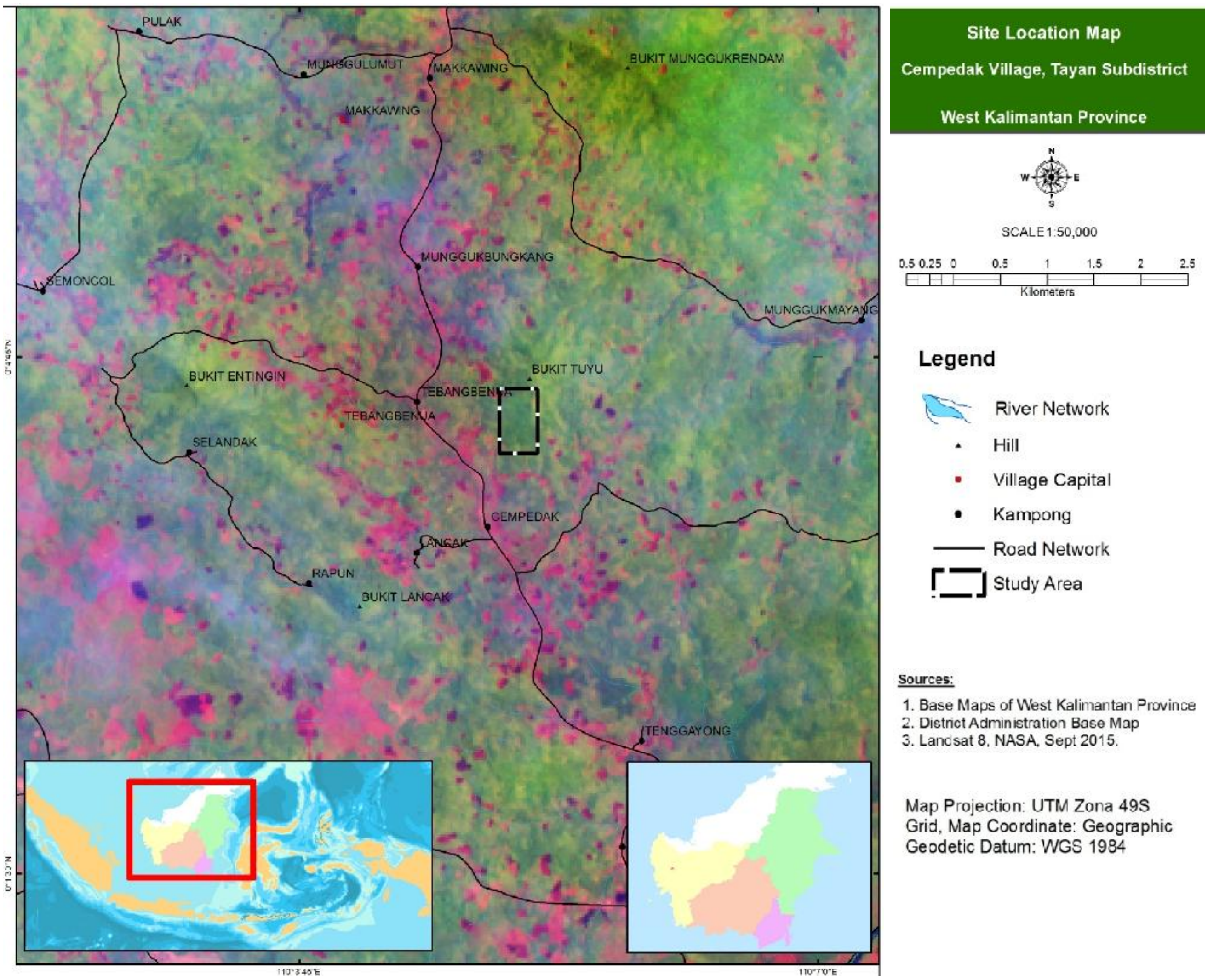

Figure 1. Research site in Cempedak Village, Sanggau District, West Kalimantan, Indonesia

rubber plants, and mixed of fruit garden and *apik* (*Arenga undulatifolia* Becc.). The *apik* was naturally growing plant on the hilly site which found abundant and grown among the fruit garden. The soil on this site was shallow and mixed with large rocks, with a dominant proportion of fruit trees, dominant rubber plant (*Hevea brasiliensis*) and *apik* plant (*Arenga undulatifolia*) as well as upland ricefield (this patch was not measured in this study).

Sampling technique. Since the area of each landcover patch varies, the sampling areas on each land cover type were also proportionally different. The sample area for mixed fruit garden, mixed rubber plants, and mixed of fruit garden and *apik* were 1.52, 0.6, and 0.72 hectars respectively. Based on our pre-survey the mixed fruit garden had higher vegetation variability and diversity, therefore, the sample transects were distributed wider and more than other 2 land covers, while mixed rubber plants and mixed *apik* forest were relatively more uniform. Transects in each landcover type were distributed sistematicaly within each area. Along each transect, 20m x 20m plots were established for tree diameter >20cm registration, and smaller nested plots were established to analyse smaller tree structure (10 m x 10 m for tree diameter 10-20cm, 5m x 5m for tree diameter 5-10cm, and 2m x 2m for seedlings, including groundstorey, small shrubs, and liana. Trees diameter >5 cm were assessed for their diameter, identified their species name, and collected their sample for scientific name. All tree diameters were assessed at breast height (DBH) using *phi band*. Smaller trees were disturbedly sampled with 1m x1m of 4-5 plots nested within their larger plots. The all species within the sample plots were harvested, weighted and sampled for water content and carbon analysis. All field works were executed by Tanjungpura University team and 4-5 local community workers

Data analysis

Within each landcover condition, data were separated based on tree/plant growing levels. Basal areas of trees on patches were calculated using the area of a circle formula (*Basal area of a tree* $= \pi / 4 \times DBH^2$). The cummulative basal area was presented in m^2 per hectar. Biomass of tree diameter >5cm biomass were estimated using Chave (2005) equation which involved tree wood-specific gravities. Each data was presented as total (species composition) or mean and standard error. The comparation among three each landcover was compared using multiple T Test.

RESULTS AND DISCUSSION

Vegetation structures

Each landcover patch demonstrate significantly in its own stature. More than 100 years old forest tree garden resulted an advance trees succession and growth compared to other two landcaover patches. More and larger trees standing resulted in higher basal area and higher persentage canopy cover which rated ~>80% yet lesser amount of trees in small trees compared to mixed rubber plants (Figure 2A and 2B). Figure 2C. demonstrate that mixed fruit garden with *apik* had less trees and the natural growth *apik* has relatively high density and dominated that stony, lesser topsoil land, while Figure 2D showed hilly rice field which hardly trees available. The ricefield patch was not measured in this study.

All three land cover patches demonstrated a balance composition in the forest stature shown by 'J-shape' in their logged graphics (Figure 3). However, mixed rubber plant and mixed fruit with *apik* land cover show much lower density. Seedling, sapling, pole, and tree density were respectively ranged between 40,000-50,000; 975-2,500; 234-300; and 131-176 trees per hectar. This structure represented the present of each forest stature. This results explained that the *tembawang* forest regeneration was distributed well in each landcover type, regardless what type was the landcover patch..

Based on tree basal area analysis, mixed fruit garden seems more eficient in accupying land per unit area. Observed basal area were 31.8, 14.1, and 13.2 m2 ha-1 respectively for mixed fruit garden, mixed rubber plants, and mixed fruit garden with *apik*. Figure 4. described how trees basal area per hectar of mixed fruit garden produced much higher (more than double) than the other land cover types, while mixed rubber and fruit mixed with *apik* showed relatively similar basal area. The basal arrea of mixed fruit garden was comparable to published value abd a bit higher than Chave et al. (2005) (26.35 m^2 ha^{-1}, Djulkono et al. (2010) (29.38 m^2 ha^{-1}), and Swamy et al. (2010) (29.42 m^2 ha^{-1}).

Species diversity on each land covers type

Mixed fruit garden tree species content showed significantly higher in tree species diversity, comparatively on each structural level (Figure 5). It maintain 49 tree species on diameter >20cm and 51 tree species in the lowest strature in the forest structure. Our previous analysis, there were 97 plant species from 37 family were found in the tembawang (Ripin et al. 2014). Our results indicated significant reduction of larger tree species diversity in mixed rubber (6 tree species) and mixed *apik* garden (7 tree species) compared to mixed fruit garden (49 tree species). The most prominent amount of species was showed in seedling and tree level of structure. The list of tree species is presented in Table 1. Mixed fruit garden was dominated with rambutan (*Nephelium lappaceum*), duku (*Lansium domesticum* var. duku), mahang (*Macaranga pruinosa* Muell. Arg), karet (*Hevea brasilliesis* Will ex A. Juss), durian (*Durio zibethinus* Murr). Mixed rubber plant was dominated by karet, duku, mahang, kepayang (*Scaphium macropodum* J. Beum), and durian while in Mixed Fruit Garden with *apik* was dominated with asam gandaria (*Bouea macrophylla* Griff.), asam kemantan (*Mangifera torquenda),* jengkol (*Pithecellobium jiringa* (Jack) Prain.), engkasai (*Pometia* sp.), and durian. Interestingly, each land cover type was dominated by almost similar species such as karet, mahang, and durian. This is indicated that those common species were significantly and economically important in fulfilling community daily needs.

Biomass allocation on landcover patches

Similar with tree basal area on each landcover patch, because more trees diameter >20 cm mean in mixed fruit garden patch, biomass allocation was also significantly different, however, the trend on mixed fruit garden with *apik* was lower than mixed rubber plants (Figure 6).

The biomass was estimated by using allometric equation that consider spesific wood density of each tree species. Aboveground standing biomass were 554.9 ±21.7, 200.8 ± 18.4, 97.7 ± 9.7 ton ha^{-1} respectively for mixed fruit garden, mixed rubber plant, and mixed fruit garden with *apik*. Mixed fruit garden biomass alocation reach This results show that eventhough the land accupation by vegetation was equal on mixed rubber and mixed fruit with *apik*, their biomass allocation was much depend on the vegetation species which was higher in mixed rubber plant.

Figure 2. The figures of (A) mixed fruit garden, (B) mixed rubber plants, (C) mixed fruit garden with *apik*, and (D) hilly rice-field

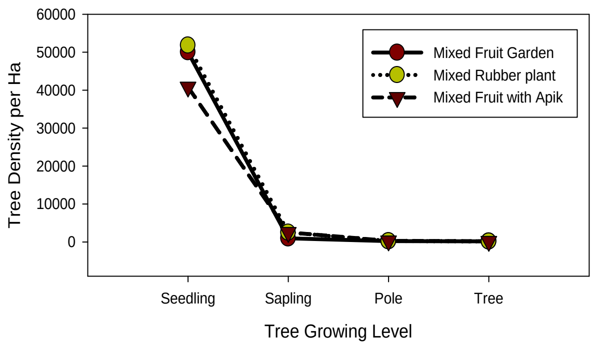

Figure 3. Tree structure distributions on each tembawang dominant land cover patches

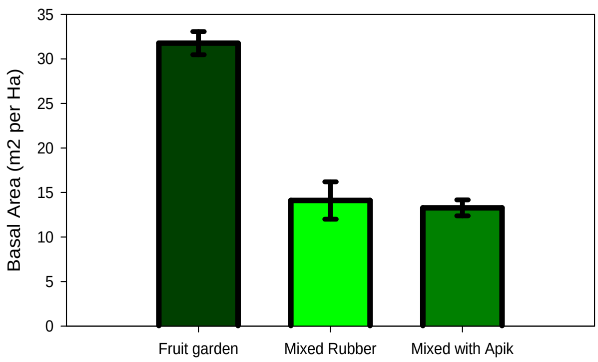

Figure 4. Basal Area distribution on each land cover patch

Table 1. Tree species diameter >20, basal area, and tree density found on each land cover patch of Tembawang Cempedak Village, Sanggau District, West Kalimantan, Indonesia

Nama jenis	Scientific names	LBD (m^2 ha^{-1})	Tree density (N ha^{-1})
Mixed fruit garden			
Asam gandaria	*Bouea macrophylla* Griff.	0,15	1
Asam kemantan	*Mangifera torquenda* Kosterm.	0,24	1
Asam mawang	*Xanthophyllum excelsum* Miq .	0,59	1
Belimbing darah	*Baccaurea angulata* Merr.	0,45	1
Benyalit/langer	*Xanthophyllum excelsum* Miq .	0,18	2
Cempedak	*Artocarpus teysmanni* Miq .	1,15	9
Ceriak	*Baccaurea sp* (Euphorbiaceae)	0,17	3
Dadap	*Erythrina variegata* L.	0,08	1
Duku	*Lansium domesticum var Aqueun* Corr	0,44	7
Durian	*Durio zibethinus* Murr.	14,49	44
Embacang	*Mangifera swintonioides*	0,19	1
Engkasai	*Pometia* glabra (Bl) Teijsm.	0,16	2
Entanak	*Pterocarpus* sp. (Fabaceae)	0,05	1
Jabon	*Antocephalus cadamba* Miq	0,12	1
Jengkol	*Pithecellobium jiringa* (Jack) Prain	0,84	1
Karet	*Hevea brasilliesis* Will ex A. Juss	0,73	13
Kayu Ara	*Ficus benyamina* Linn.	0,10	1
Kelampai	*Elateriospermum tapos* Bl.	0,17	1
Kelampai Tupai	*Blumeodendron tokbrai* Bl.	0,42	1
Kelawik/Teratung	*Durio oxleyanus* Griff.	0,79	1
Kemenyan	*Styrax benzoin* Dryand.	0,47	11
Kempas	*Koompassia malaccensis* Maing.	0,48	1
Ketup	*Lansium domesticum var. aquaeum*	0,19	7
Kubing	*Artocarpus* heterophyllus. Lam	0,21	3
Kumpang	*Gynnacranthera forbesii* Warb.	0,49	3
Lansat	*Lansium parasiticum* (Osbeck) K.C.Sahni & Bennet	0,05	9
Leban	*Vitex pubescens* Vahl.	0,03	1
Manggis	*Garcinia mangostana* L.	2,68	1
Mentawa	*Artocarpus anisopyllus* Miq	0,90	12
Meranti batu	*Shorea palembanica* Miq.	0,06	3
Meranti padi	*Shorea leprosula* Miq .	0,48	1
Nyatoh	*Palaquium pseudocuneatum* H.J.L	0,11	4
Panting	*Aporosa arborea* Muell. Arg.	0,36	1
Peluntan	*Artocarpus rigidus* Bl.	0,43	2
Petai	*Parkia speciosa* Hassk.	0,08	3
Petai hutan	*Leucaena leucocephala* (Lam) de Wit	0,09	1
Rambai	*Baccaurea motleyana* Mull.Arg.	0,08	1
Sibau	*Nephelium uncinatum* Radlk. ex Leenh.	0,78	6
Sotol	*Sandoricum koetjape* (Burm. f.) Merr.	0,30	3
Tampui	*Baccaurea grifithii* Hookf.	0,25	3
Tengkw. rambai	*Shorea splendida* (de Vriese) P. Ashton	0,02	1
Tengkw. tungkul	*Shorea stenoptera* Burck	0,45	1
Terap	*Artocarpus elasticus* Reinw.	0,93	6
Terentang	*Campnosperma auriculata* Hook. F.	0,11	1
Ubah sp.1	*Eugenia albidiramea* Merr.	0,10	1
Ubah sp.2	*Syzigium kunstleri* (King) Bahadur & R.C.Gaur	0,12	1
	Total	32,20	176
Mixed rubber plants			
Durian	*Durio zibethinus* Murr.	4,07	6
Karet	*Hevea brasilliesis* Will ex A. Juss	5,57	88
Kelangkik	*Blumeodendron tokbrai* Bl.	0,28	6
Ketup	*Koompassia malaccensis* Maing.	0,57	6
Lansat	*Gynnacranthera forbesii* Warb.	0,22	6
Peluntan	*Aporosa arborea* Muell. Arg.	2,76	6
Sotol	*Sandoricum koetjape* (Burm. f.) Merr.	0,28	6
Tampui	*Baccaurea grifithii* Hookf.	0,36	6
	Total	14,11	131
Mixed forest with *apik*			
Asam Mawang Bulan	*Xanthophyllum excelsum* Miq .	0,63	8
Cempedak	*Artocarpus teysmanni* Miq .	0,67	8
Durian	*Durio zibethinus* Murr.	3,95	33
Karet	*Hevea brasilliesis* Will ex A. Juss	2,51	33
Kemenyan	*Styrax benzoin* Dryand.	2,35	33
Kepayang	*Scapium macropodum* J.Beum	1,64	8
Terap	*Artocarpus elasticus* Reinw.	1,53	33
	Total	13,27	158

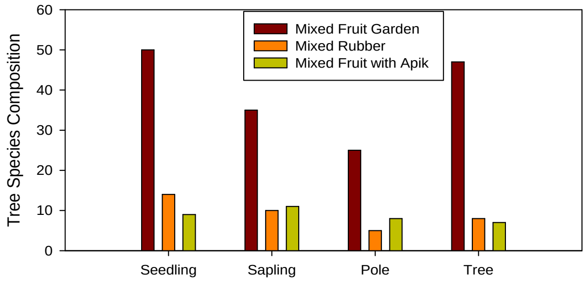

Figure 5. Tree species composition on each growing stage of three land cover in tembawang

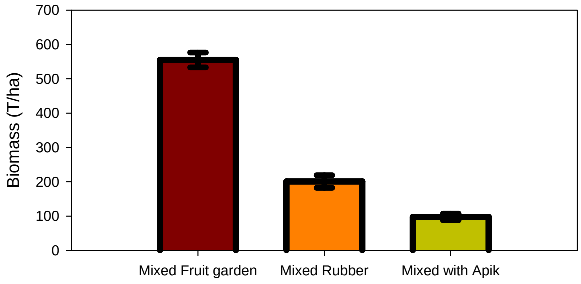

Figure 6. Biomass allocation of each land cover patch in tembawang

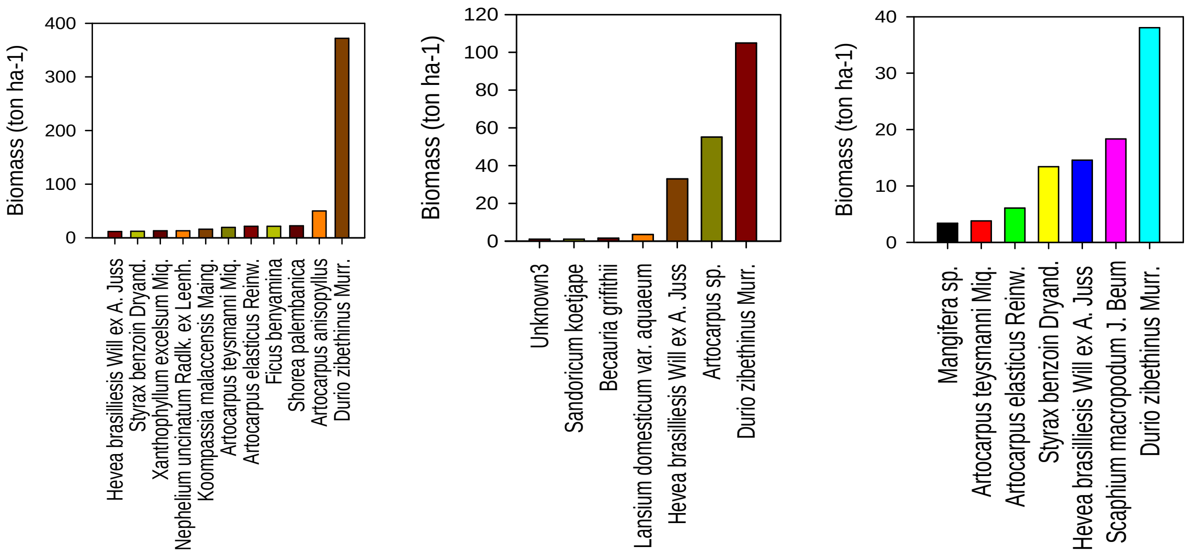

Figure 7. Tree species biomass allocation on three land cover patches: A. Mixed fruit garden, B. Mixed rubber plants, and C. Mixed fruit garden with *apik*

Each tree had their special ability in producing living biomass. Our further analysis on each tree biomas found that durian trees (*D. zibethinus* Murr.) allocated biomass significantly high in all land cover patches (Figure 7A, 7B, and 7C). This trend affected because most of durian trees in this area were old and mostly huge in tree diameter, which cause high total biomass allocation.

Discussion

We compared 3 land cover patches type of forest gardens, or *tembawang*, in Cempedak Village, Sanggau District, West Kalimantan, Indonesia, to to examine community forest in terms of diversity, structure, and biomass alocation. This information was acquired for 97 vegetation species inventoried in the *tembawang* forest gardens and its 3 varians of forest landcover-type patches. In particular tembawang with mixed fruit garden type were found to have higher species diversity, higher density, and higher biomass allocation compared to mixed rubber plant and mixed fruit garden with *apik*. mixed fruit garden also showed better successional stages and modes of dispersal as natural forests. Thus, this was emphasising the potentialof *tembawang* in conserving tree species.

Within two patches of land cover types (mixed rubber plant and mixed with *apik*), non-planted trees species of *tembawang* and natural forests also have practically been maintained, indicating that the management of these *tembawang* does not significantly discriminate between species with certain uses. However, we also identified two aspects that should be taken into account in considering the conservation role of *tembawang*. The species composition of the 3 patches showed significant difference, implying that efficient conservation in West Kalimantan ex-agricultural land areas. We found the reduction in species diversity of pathes in the tembawang were worse than the on impacted by forest degradation (Astiani 2016). We also found some species of the same ecological characteristics found in natural forests. Thus, even if *tembawang* are similar to natural forests in terms of numbers of species with different ecological characteristics, the composition of non-planted tree species in *tembawang* is not a random sample from natural forest, but over represents species that are useful and provided benefits for community daily needs.

Because the carbon stocks of tropical forest were uncertain (Houghton et al. 2001; Fearnside and Laurance 2003; Eva et al. 2010), this *tembawang* mixed fruit garden with the various kind of patches is important to refine and explain that the deforestation in tropical forest can not only explain the emission rate Houghton et al. (2005), yet on the other hand with tembawang management applied by rural communities in West Kalimantan also show how much carbon can be sinked for longer period of time. Viewed from *tembawang* ability to sink carbon, it is undoubtable that they sink large amount of above ground carbon especially within mixed fruit garden patches that reach ~300 ton/ha. The carbon maintained far larger than peatland forest that we assessed (Astiani et al. 2015). This results proof that tembawang at Cempedak Village provides an array of benefit, not only for local economic conservation, but also for biodiversity conservation and environment points.

In conclusions, West Kalimantan community fruit garden management was able on maintaining forest structure, diversity, and sinking a significant amount of carbon in forest biomass, fulfilling wide range of family needs to support their life as well as tending the sustainability of the forest for more than a hundred years. The choice of tree species determined the *tembawang* characteristics and their ability to sequestered and sink carbon. It is important to support this type of forest management since it demonstrated to benefit more for community life and forest conservation, especially in efforts on reducing carbon emission from forest degradation and deforestation activities. A scheme of financial award through carbon sequestration insentives program could be an alternative to enhance and maintain this type of forest management.

ACKNOWLEDGEMENTS

We thank people of Cempedak Village for their contribution in supporting us in vegetation survey. Our appreciation passes to Yadi and Dessy Ratnasari in LLI for training our Faculty of Forestry, Tanjungpura University, West Kalimantan, Indonesia students in field GPS measurement. Special thank to Darkono (GIS specialist) on his contribution producing site map for this paper.

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