Eco. Env. & Cons. 27 (1) : 2021; pp. (347-358)
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ISSN 0971–765X

Diversity, vegetation structure and C stocks of inundated riparian forest protected from conversion to oil palm in C. Kalimantan

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(Received 19 August, 2020; accepted 26 September, 2020)

ABSTRACT

Riparian zone of conservation forests that buffer stream flow by periodic inundation deserve to be protected from conversion to plantation crops. In this study, C storage and tree diversity was quantified for 5 pools (above-ground tree biomass, understorey, necromass, root and soils) in inundated and non-inundated parts of conservation forest set aside by PT AMR (Anugerah Menara Rahmat), Central Kalimantan. We estimated C stock in the forest using RaCSA (*Rapid Carbon Stock Appraisal*) method in inundated and non-inundated forest sites in 4 replicates in 3 locations. Tree biomass of mixed deciduous forest trees was calculated using *allometric* equation. A specific allometric equation was developed for *Pandanus sp*. $y= 0.002 x^{4.023}$ ($R^2= 0.903$). Total C stock in inundated forest was to be 325 ton ha^{-1}, considerably higher than that in non-inundated conditions: 144 ton ha^{-1}. Drainage of these riparian forests may thus cause substantial C emissions if it leads to a change in forest type. Trees with DBH > 30 cm were more frequent been found in the inundated ecosystem, but all C pools ecosystem (313 Mg C ha^{-1}) were 50% higher compare to those non-inundated plots (143 Mg C ha^{-1}). Bulk density in the inundated ecosystem was 0.5-0.8 g cm^{-3}, significantly lower than that in non-inundated plots (0.8-1.3 g cm^{-3}). The inundated forest was dominated by *Shorea balangeran, Callicarpa havilandii, Baccaurea edulis* and *Polyalthia xanthopetala*, while *Schima wallichii, Hevea brasiliensis* and *Macaranga gigantean* were frequently observed in non-inundated forest. In total 1017 species were recorded in the inundated forest and 1191 species in non-inundated forest. The diversity and similarity indices differed significantly ($p<0.05$) between inundated and non-inundated conditions, Indices Diversity H'<1.0 of inundated and 1.0<H'>3.0 of non-inundated. Thus, differences in carbon stocks were not matched directly by differences in tree diversity, and conservation is needed of both inundated and non-inundated forest types.

Key word *: Tree biomass, Biodiversity, Allometric equation, C emission and sequestration, Forest*

Introduction

In the world, Indonesia is one of the countries that has the largest tropical forest after Brazil and Congo. Indonesia's forest area reaches 121.11 million ha which is divided into 20.62 million ha of conservation forest, 33.92 million ha of protected forest, 35.32 million ha of permanent production forest, limited production area of 23.17 million ha, and converted production forests of 8.08 million ha (Suparna, 2005). Indonesia, which is located in the tropics rich in biodiversity, ranks fifth in the world with more than 38,000 plant species, of which 55% are endemic. More than 50% of the total timber producers with around 175 tree species in Indonesia have important economic value from the Dipterocarpaceae family (Bappenas, 2003). Nonetheless, the conversion of tropical forest land use in Indonesia increased until 2000. The rate of forest loss between 1980-1996 was estimated at around 2.7 million hectares per year and between 1996-2000 it reached around 2 million hectares per year (FWI / GFW, 2001). The existence of forest land use change can lead to reduced diversity and density of plant species so that the impact on ecosystem services can reduce hydrological functions, biodiversity levels, and C-stocks (Hairiah *et al.,* 2003). Indonesia as one of the agaris countries contributes 10% or around two billion tons per year of world CO_2 gas emissions which ranks third after the United States and China (Imiliyana *et al*., 2011). More than 75% of Indonesia's CO_2 gas emissions come from forest and peat land use conversion activities into other forms of use so that activities to reduce emissions need to be carried out (Hairiah *et al.,* 2011). One of the actions to reduce emissions and concentrations of CO_2 gas in the atmosphere is by implementing the management and conservation of forests and peatlands that have high value as carbon storage (Fajar, 2015).

The conservation forest area of PT Agro Menara Rachmat is an area that has a unique and rare diversity of structures and compositions. Some of these areas are in the lowest part of PT. Agro Menara Rahmat which caused conditions in the forest had been flooding during the rainy season. The inundated land conditions have diverse land biophysical conditions and specific plant species composition. This is influenced by the high inundation factor and the frequency of flooding. According to Hook (1984), plant tolerance to flooding can be seen from the ability of plants to adapt and survive in conditions without oxygen (anoxic). With specific types of plants, the biodiversity in forests is lower when compared to forests that are composed of complex plant species (Indriyanto, 2006). The conservation forest area owned by PT Agro Menara Rachmat (PT AMR) is an area that has the structure and diversity of unique and rare plants such as *Shorea balarengan*, *Eusideroxylon zwageri,* and others. Some of this forest area is in the lowlands which makes this forest has a characteristic flooded throughout the rainy season so that this area becomes a forest conservation area and is not suitable to be used as plantation land. According to Sugirahayu and Rusdiana (2011), C-stocks in flooded forests such as mangrove forests and swamp forests are larger than secondary forests. Some of the factors that affect the amount of carbon deposits in stagnant forests are the physical and chemical properties of soil and the process of decomposition of organic matter that lasts long with anaerobic conditions which make carbon stored for longer period (Hanafiah, 2012).

The importance of conserving forests means maintaining the biodiversity in it and try to find the best option to preserve the existing diversity to control C-emission. The activities carried out by PT AMR have many benefits, including safeguarding carbon stocks, the hydrological cycle and maintaining habitat for biodiversity (Chapin *et al*., 2000) and also the main key as mitigation efforts for the accumulation of greenhouse gases in the atmosphere (IPCC, 2000). FAO (2010), reports that as many as 233 countries, including Indonesia, do not have complete data on all five carbon pools. Further information about carbon stocks throughout the world is needed to monitor carbon stocks and their cycles (Ngo *et al.,* 2013). In addition to carbon stocks in mangrove forests, there has not been much research on carbon stocks in areas flooded with lowland tropical forests. Therefore, it is necessary to conduct a study of the potential of carbon contained in this conservation forest area so that the results of research on the potential of PT AMR's conservation forest as a store of carbon reserves can be studied and can help manage conservation forests in a good and sustainable manner. Previously, many researchs on biodiversity on inundated condition were focus on mangrove forests or peatland ecosystem (Sulistyowati, 2009) or wetland tropical forest (Pantanal) (Ferreiera-Junior 2016; Whitmann *et al.,* 2008), however research on inundated lowland tropical forests such as in riparian forest adjacent to oil palm plantation has not been done much. Thus it is necessary to conduct a biodiversity connected to C-stock that produces an inventory dataset of plant species to evaluate the stability of the forest so that it remains sustainable and their ability to storage C.

The purpose of this study is to evaluate the density and level of diversity of vegetation in various growth stages in various conservation forest ecosystems. The hypothesis of this study is: the condition of the forest inundated the level of vegetation diversity is lower than the condition of the forest that is not inundated.

Methods

The field survey, data collection and analysis was conducted in October 2014 - March 2017 on PT. Astra Agro Lestari which has a subsidiary company PT. GSIP-AMR, Kumai, Pangkalanbun, Central Kalimantan (Figure 1) and Soil Science Department, Faculty of Agriculture University of Brawijaya-Malang. The field was split into 2 categories : inundated and non inundated ecosystem in which each ecosystem were consisted of 4 plots with 3 replicate resulted in 24 experimental plot in total (Figure 2). For transect were selected, started from the highest ground to the lowest part. The highest part was recorded at 36 mabsl and the lowest was at 6 m. The determination of topographic condition were used DEM (Digital Elevation Model) developed from 5 m count our map. C stock and tree diversity was quantified for 5 pools (above-ground tree biomass, understorey, necromass, root and soils) in inundated and non-inundated parts of conservation forest set aside by PT AMR (Anugerah Menara Rahmat), Central Kalimantan adjacent to oil palm plantation production area. C stock in the forest were estimated using RaCSA (*Rapid Carbon Stock Appraisal*) method in inundated and non-inundated forest sites in 4 replicates in 3 locations. Tree biomass of mixed deciduous forest trees was calculated using *allometric* equation developed by Chave *et al.*, (2005), whereas : $(\text{Above Ground Biomass (AGB)})_{estimated} = \pi * \exp(-1.499 + 2.148 \ln(D) + 0.207(\ln(D))^2 - 0.0281 (\ln(D))^3)$. A specific allometric equation was developed for *Pandanus sp*. $Y = 0.002X^{4.023}$ ($R^2 = 0.903$) in which develop from destructive sampling.The method for estimating understorey is done by destructive methods. The total dry weight of understorey per quadrant is calculated by the following formula (Hairiah and Rahayu, 2007), while the measurement of root biomass can be estimated using the default value of the canopy ratio: root, which is 4: 1. (Hairiah *et al*., 2011). The necromasa component was separated between woody and non-woody necromasa which was then they were estimated by non destructive method before calculated using general equation (Hairiah *et al.,* 2011; Hairiah and Rahayu, 2007). Soil sampling were collected from each selected plot disturbed and un disturbed protocol to determine soil bulk density, soil C content, pH and soil texture. Soil samples are taken at three depths, namely 0-10 cm, 10-20 cm, and 20-30 cm.

Calculation of soil carbon reserves is calculated as soil layer (0 to 30 cm) using the following formula of : C soil (Mg ha^{-1}) = soil weight (Mg ha^{-1}) x soil C org (%). Observation and measurement of tree biodiversity was carried out on all plant growth stages: seedlings, saplings, pole, and trees within sampling plot at the size of 20 m x 100 m. Plot A with a size of 20 m x 20 m were carried out to measure "tree" at diameter > 10 cm (trees), plot B with a size of 10 m x 10 m to measure "pole" with a diameter of 5-10 cm, plot C with a size of 5 m x 5 m to measure "sapling" at diameter > 5 cm, and plot D

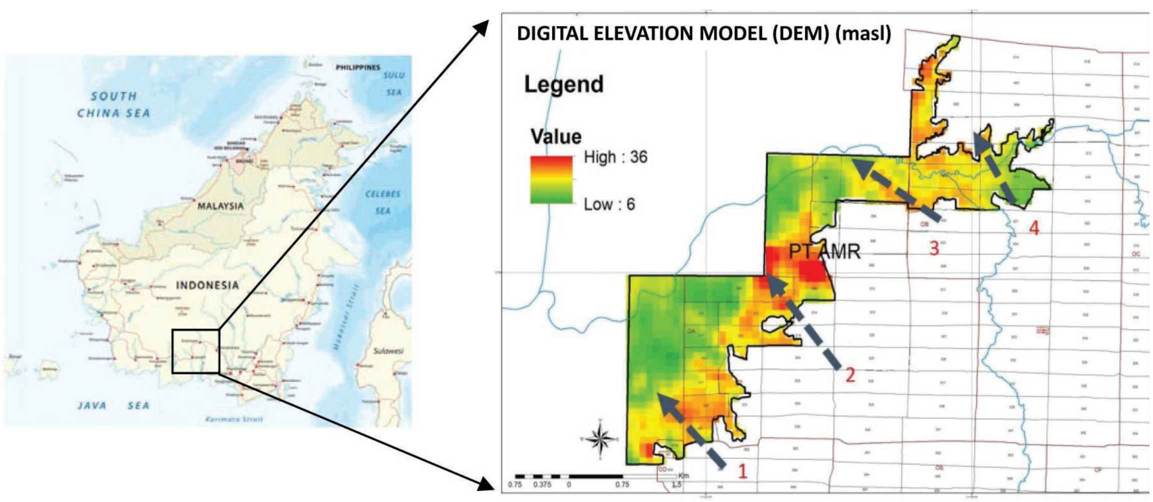

Fig. 1. Site location of study

with a size of 2 m x 2 m to measure seedlings / seedlings with a height of <2 m. Plots were placed on each of the found conservation forest ecosystems. Analysis of biodiversity vegetation includes several calculations including: (a) Calculation of plant density (RD, RF, and, TIV), (b) Species diversity index, (c) Species richness index, (d) Index of evenness types, (e) Similarity index. Data analysis of this study was obtained from variance analysis (ANOVA) using Genstat 18.1 if the results were significantly different followed by the DMRT test at the 5% level using similar software.

Results and Discussion

In general, vegetation in the riparian conservation forest of PT Agro Menara Rachmat (AMR) are dominated by tree belonging to the family *Dipterocarpaceae, Verbenaceae, Phyllanthaceae, Annonaceae, Euphorbiaceae*, and *Theaceae*. The richness of tree species in the conservation forest area was found as many as 10241 individuals tree ha^{-1} consisting of 333 species. For comparison, at Pantanal-Brazil wetland ecosystem comprises from 443 tree individuals belonged to 46 species were recorded which dominantly consisted of four species (*Inga vera*, *Ocotea suaveolens*, *Tabebuia heptaphylla* and *Cecropia pachystachya*) (Whitmann *et al*., 2008).

Distribution of tree diameter classes

Based on the distribution of existing stem diameter and individual tree density, the average density of tree with the diameter > 5 cm was to about 132 individuals ha^{-1} for inundated and it was lower significantly ($p<0.05$) almost 50% compare to non-inundated plot which had 238 individuals ha^{-1}. Also, from the figure 2 below, it was clearly showed that the numberof trees increases very much in trees with the diameter > 5 cm occupied 43% of the total population, followed by tree with the diameter of 20 - 39.9 cm, 40-59.9 cm, 60-79.9 cm, 80.9-99.9 cm and > 100 cm at about 33%, 10%, 2%, 3%, and 9% respectively (Figure 3). It can be concluded that under inundated plot bigger tree were still dominant, while in non-inundated ecosystem small tree were much easier to be found. This was due to difficult it's accessibility to reach those of inundated plot which then may protect the loss of bigger for being harvested, however this plot also had a problem on tree survival rate for long term period since population tree species at the small diameter were lower than those at non-inundated plots. The flooded condition effected tree seed opportunity for being germinated.

Tree wood density

Wood density is part of the physical properties of wood which is directly proportionaly to the strength of wood. PT AMR riparian conservation forest has an average wood density of 0.66 g cm^{-3} (medium wood density) for inundated ecosystems which was higher significantly ($p<0.95$) than those of non-inundated plot at the value to about 0.53 g cm^{-3} (light wood density) (Figure 4). Under the non-inundated ecosystems, basal cumulative area was found to be no more than 25 m^2 ha^{-1} with the density

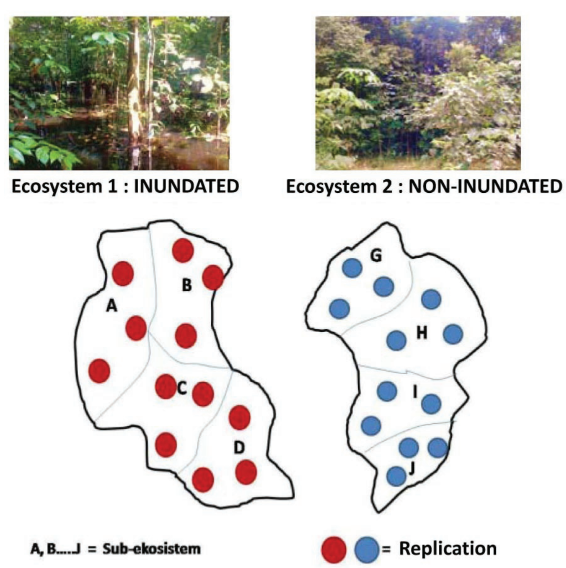

Fig. 2. Two different ecosystem at PT AMR-Central Kalimantan

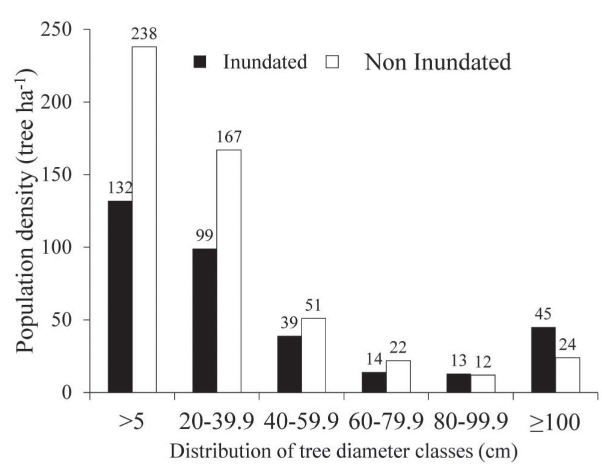

Fig. 3. Population density of inundated and non-inundated riparian forest

of wood ranging from 0.3-0.75 g cm^{-3}. The value was lower than those of cumulative basal area under inundated plot which was reached at about 40 m^2 ha^{-1}, indicate that some of tree had wood density between 0.7 to 0.9 g cm^{-3}. This was in accordance to the higher tree diameter at the size > 100 m. This fact shows under inundated plot beside consisted in greater tree diameter at the size < 100 cm was correspond to the higher value of cumulative basal area the tree wood density is not always large in diameter. The greater the density of wood in the stand, the greater the potential of the store in carbon.

Development of the Alometric Equation of *Pandanus* sp.

In the T1 sub-ecosystem many Pandanus species (*Pandanus sp*) were found. So to estimate the biomass value, specific allometric equations were needed. Based on the results of the correlation analysis and regression of the sample data of *Pandanus sp*, the dry mass of the tree period was more closely related to the stem diameter (R^2 = 0.90) than the stem length (R^2 = 0.55) (Figure 5). To improve the robustness of the relationship, then the wood density (WD) of *Pandanus sp* were enclose to the formula. Thus the estimation of *Pandanus sp* biomass is strong enough to be estimated based on plant DBH data and for further estimation of stand biomass of *Pandanus sp*. can be calculated by simply measuring the stem diameter without having to measure the stand height but considering their wood density as well, using allometric equations, as follow : Above Ground Biomass $(AGB)_{estimated} = WD \times 0.002\ D^{4.023}$, whereas AGB = estimated pandanus biomass (kg $tree^{-1}$), D = DBH pandanus (cm), measured at 1.3 m from soil surface. Later, the allometric equation were used to estimated to C-stock in all ecosystem where the *Pandanus sp* were exist.

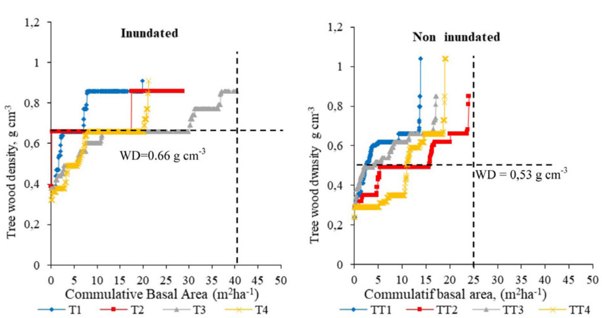

Fig. 4. The relationship between tree wood density and cumulative basal area in both ecosystem

C-stock

The results showed that the average carbon stock of conservation forest trees was 2 times greater in inundated ecosystems (313 Mg ha^{-1}) when compared to non-inundated ecosystems (143 Mg ha^{-1}) (Figure 5a). The results of the variance analysis (ANOVA) showed that there was a significantly different on tree C-stock between inundated and non-inundated plot ($p<0.05$). The largest carbon reserve is found in the T2 (inundated 2nd plot), while the smallest sub-ecosystem found in the TT3 non-inundated sub-ecosystem. Trees with a diameter of 5-30 cm dominate in both ecosystems, but for the number of trees with a diameter > 100 cm more often to be found in inundated ecosystems, even though under non-inundated ecosystems have greater trees at dimeter < 80 cm. This then affected overall total carbon stocks, where the big tree plays important role on sequestered C in large quantity compared to the small ones. This is in accordance with Suwardi *et al.*, (2013), stated that the number of individual trees is inversely proportional to carbon stocks.

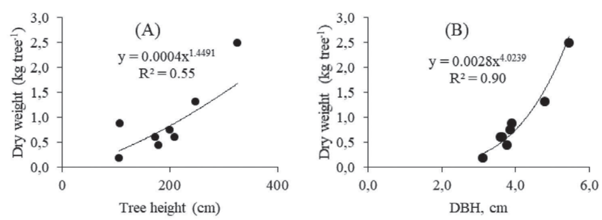

Fig. 5. Relationship between height and stem diameter of *Pandanus sp* to dry matter biomass (kg $tree^{-1}$)

Interestingly, the average understory carbon stock was in the opposite, whereas under non-inundated plot, it was significantly higher almost double (2 Mg ha^{-1}) compared to those value of inundated ecosystem (1 Mg ha^{-1}) ($p<0.05$). In all sub ecosystem T3 resulted the lowest understorey C-stock since this quite often under flooded condition particularly during rainy season, which is not allowing a new small seedling being survived and developed into mature tree (Figure 6).

Surprisingly, inundated ecosystem provided a unique condition in which, most of the necromass were not able to be decompose easily since most of year this plot is saturated with water, resulted in dead wood/branches necromass C-stock to about 22 Mg ha^{-1} which is almost three time significantly ($p<0.05$) higher than those value at non-inundated plot (8 Mg ha^{-1}), similar pattern has been observed to the litter necromass C-stock. Litter necromass C-stock polls contribute (60%) of the total nekromass C-stock, whlist the remaining dead wood/branches necromas C-stock only at about 40% in inundated plot. The proportions of this pools were slightly different under non-inundated ecosystem, whereas contribution of litter necromass C-stock are more dominant (70-80%) compared to dead wood/ branches (20-30%) (Figure 7).

In term of above-ground C-stock the proportion of carbon stocks from tree component were reached 39% which become the dominant pools, while for below ground C-stock, the major C-stock were derived from soil at about 44%. The proportion of understorey to above-ground C-stocks is relatively small (1%). This was supported by Krisnawati *et al.*, (2014), which mentioned that secondary forests generally have a small proportion of understorey biomass.

The high amount of C-stock in inundated ecosystem instead of contributed by the larger tree diameter >100 which is indicate that the tree is already mature, but it also derived from un-decomposed litter and dead woody branches, twigs and leaves remaining on the ground and covered upper soil layer. This limits the process of regeneration new young seedling emerge from the surface of the soil. According to Indriyani (2011), the higher the age of a tree stand, the more litter produce the surface of the soil. Moreover, Krisnawat *et al.*, (2014) reported that dead wood is a component of carbon pools that play a large role in forest types, especially secondary forests. The magnitude of the role of dead wood in storing carbon can range between 11-40% of the total carbon in the ecosystem. The presence of dead wood in secondary forests indicates that the forest has been disturbed. Disrupted forests will affect the potential of carbon stocks held, where carbon flows will occur from the pool of biomass carbon into the dead pool of carbon (necromass) after a disturbance

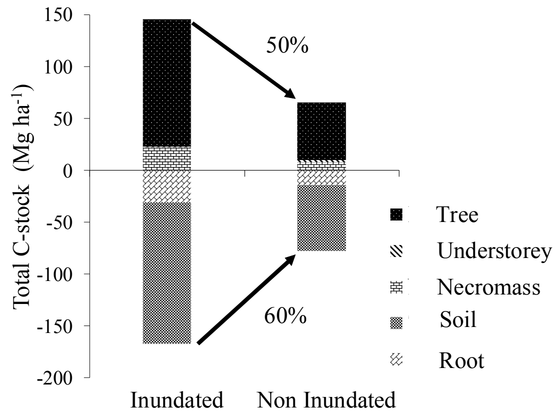

Fig. 7. Contribution of each C-pools to total C-stock across two ecosystem

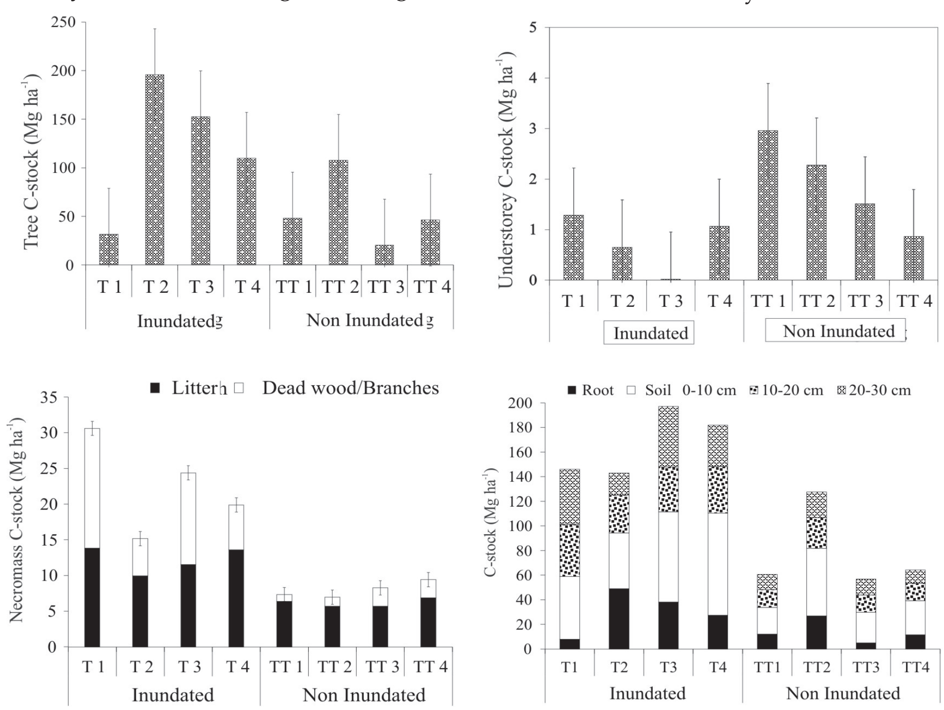

Fig. 6. C-Stock in various pools accross two different ecosystem

in the ecosystem.

The consequences of this, total C-stocks in roots and soil were 2 times significantly ($p<0.05$) greater than non-inundated ecosystems. This means under inundated ecosystem the transformation of organic material into soil organic C has been occurred for ages and deposit in all soil layer since the rate of decomposition was slower, while soil C-stock under non-inundated site were continuously being decomposed and sometime was cycled back to the atmosphere or being consume by soil microbe for energy and growth.

It can be seen that in general the higher contribution of soil C-stock were derived from soil C at a depth of 0-10 cm (40 %) which then decreases with the depth of the soil. These larger amount of carbon content in the depth of 0-10 cm is due to the large input of soil organic matter in the form of litter and dead wood C-stock (Figure). This is in line with the Siringoringo (2013), stated that the increasing level of organic carbon in the upper layer is due to the large amount of litter that accumulated in soil surface. In addition, the soil in the inundated ecosystem has more clay content. The increasing on soil clay content, created a slower organic matter decomposition process since some of soil organic matter were trapped between soil mineral and difficult for being accessed by soil microbe particularly the labile pools. Furthermore Jeyanny *et al.* (2014) and Siringoringo (2013) mentioned that greater soil C-stocks are not affected only by accumulation of soil organic in soil surface and clay content but also affected by those soil bulk density. Table 1 showed the comparison of soil bulk density of both ecosystems, whereas both soil organic content and soil bulk density are significantly different particularly in the soil layer at 0-10 cm depth (Table 1).

The average contribution of above ground C-stock was about 45% which was lower than those contribution from belowground C-stock (55%). Markum *et al.,* (2013), reported that the highest contribution of total C-stocks is determined by large trees at diameter > 60 cm with has high woody densities. Total reduction of total C-stock from inundated to non-inundated ecosystem were reached 50 to 60% (Figure 7). For those non-inundated C-stock, the values were comparable to the value of secondary forest in Papua or dryland forest and community forest in Aceh Province (Fauzi *et al.,* 2009). In this case, the area of riparian conservation forest occupied an area of 700 ha which has a potential of average carbon stock at 228 Mg ha^{-1}, providing total C-stock at about 159.600 Mg C or equivalent to 0.160 Mg ha^{-1}. Thus from the results, it can be seen that PT AMR's riparian conservation forest can play an important role in reducing global warming and reducing the accumulation of CO_2. Therefore, the monitoring of C-stocks changes needs to be done regularly to maintain the preservation and function of forests in maintaining the balance of the ecosystem. Previous studies by Adame *et al.,* (2015) confirmed that C stocks in mangroves and peat swamps in Mexico, represented inundated condition, were recorded to about 784.5 ± 73.5 and 722.2 ± 63.6 Mg C ha^{-1} , respectively) were much higher than those of marshes (336.5 ± 38.3 MgC ha^{-1}) or even to C-stock in inundated riparian forest this study (313 Mg ha^{-1}). It may due the higher soil C content which were reached 19.9% for peat swamps, 10.1 % for marsh and 14.6% for mangrove ecosystem (Adame *et al.*, 2015). On the other hand, potential carbon storage in *Melaleuca* wetland forests-Queensland-Australia (157.8 Mg C ha^{-1} to 363.0 Mg C ha^{-1}) (Tran, 2015), were comparable and falls within the ranges to the C-stock in this study. For comparison the soil C concentrations of Mexican wet forests reported to be about 0 to 7.8% at upper layer and reduced to 1.9% at the lower depth, whlist C concentration at lower depths in mangrove ecosystem were recorded at the level of 7.5–18.7% (Hughes *et al.*, 2000). In addition

Table 1. Soil C and bulk density in both ecosystems according to soil depth

Ecosystem		Soil depth (cm)	Soil bulk density (g cm^{-3})	Soil C-Org (%)
Inundated		0-10	13,58 c	13,58 c
		10-20	6,18 b	6,18 b
		20-30	6,11 b	6,11 b
	Average	0,64	8,62	
Non inundated		0-10	3,97 b	3,97 b
		10-20	1,69 a	1,69 a
		20-30	1,32 a	1,32 a
Average		0,99	2,33	

secondary forest in Central Kalimantan which dominated by *Hevea* species were accumulated C-stock at 217 Mg C ha^{-1} in average (Natalia *et al.*, 2017). This were confirmed that total C-stock were influenced such as: existing total soil C (%), diversity of tree species, and their geographical position. (Singh and Lal, 2005).

Vegetation density, no of tree species and family, diversity

The ANOVA of seedlings in inundated and non-inundated showed a significantly different on vegetation density ($p<0.05$), whereas density of seedling of inundated reach about 47 species m^{-2} which is lower 3 times than non-inundated plot (121 species m^{-2}). The opposite pattern was found for the vegetation density of pole, in which under inundated plot were significantly ($p<0.05$) higher to about 25% than those value of pole vegetation density in non-inundated ecosystem. Meanwhile, there were no significantly different of vegetation density on sapling and tree categories. In term of number of tree species and family, inundated ecosystem had lower of those value approximately 50% compared to non inundated plots in average. The PT AMR conservation forest with an area of 700 ha has two types of inundated and inundated forest land forms which are habitat for 333 plant species from 52 families on average were found.

At inundated plots total species at various tree stages were recorded from 10 to 143.3 species ha^{-1} which clustered into 10 to 76.7 family ha^{-1}, in which this was 3-6 times lower than non-inundated ecosystem in which reached to about 63.3 to 170 species ha^{-1} and it were consisted of 10 to 105 family ha^{-1}. For comparison, at least there were 2227 individuals from different location being observed in tropical forest in Northern Andra Pradesh-India, giving an average of 556 individuals ha^{-1}, in which they were consisted from 129 species and 44 family in total, with an average of species at about 62 to 72 ha^{-1} (Naidu and Kumar, 2016). This value was lower compere to the no of species and family in this study. Other tropical forests were reported to have a no of species between 88-94 ha^{-1}. The number of species and family found in this study confirmed that in conservation forests there is a high level of biodiversity and this is a forest where stability is maintained. Forest stand structure by rapid inventory assessment is important element to understand forest ecosystems and a stand biodiversity (Ozcelik, 2009), which give an opportunity maximizing our ability for maintaining biodiversity conservation (Naidu and Kumar, 2016).

Comparison of the level of plant species diversity at inundated and non inundated ecosystems from various growth stages was evaluated using the Shannon-Wiener (H') indices. The results showed that those value categorized from low to high. ANOVA of the species diversity index value (H') of all growth stages (seedling, sapling, pole and tree) showed that the value in the inundated ecosystem was significantly ($p<0,05$) higher than those in the non-inundated ecosystem (Figures 4a, 4b, 4c, 4d)., where the level of sustainability is rather safe. In term of tree management conservation and maintaining the diversity of tree inundated ecosystem can preserve those species under niches environment. The higher the level of diversity of a community, the community is more stable (Bratawinata,

Table 2. No of species and family across two ecosystem (ha^{-1})

Ecosystem	Σ Seedling spesies (ha^{-1})	Σ Seedling family (ha^{-1})	Σ Seedling spesies (ha^{-1})	Σ Seedling family (ha^{-1})	Σ Pole spesies (ha^{-1})	Σ Pole family (ha^{-1})	Σ Tree spesies (ha^{-1})	Σ Tree Family (ha^{-1})
Inundated								
T1	25 a	20 a	40 b	36.7 b	48.3 ab	36.7 ab	45 ab	35 ab
T2	10 a	10 a	11.7 a	11.7 a	16.7 a	16.7 a	10 a	10 a
T3	25 a	23.3 a	46.7 b	35 b	66.7 bcd	48.3 bc	123.3 cd	76.7 cd
T4	36.7 a	31.7 a	100 c	61.7 c	118.3 e	65 cd	143.3 de	73.3 cd
Non inundated								
TT1	116.7 b	70 b	91.7 c	61.7 c	91.7 cde	66.7 cd	170 e	105 e
TT2	113.3 b	63.3 b	81.7 c	55 c	63.3 bc	40 b	85 bc	60 bc
TT3	161.7 c	86.7 b	128.3 d	81.7 d	98.3 de	71.7 d	150 de	93.3 de
TT4	126.7 b	76.7 b	96.7 c	60 c	86.7 cde	53.3 bcd	111.7 cd	65 c

1998). From the results of this study indicate that the average level of species diversity in the medium class (H'= 2.5) in the conservation forest PT AMR is able to play a role in maintaining and preserving flora and fauna, and providing benefits to environmental services at the plot level (maintaining soil fertility (physical, chemical, biological), reducing pest explosions, and regulating microclimates), as well as at the landscape level in the form of hydrological functions, reducing carbon emissions, and maintaining biomass. In addition, Diversity indeks (H') of *Shorea robusta* of Sal forest in Nepal, at about 2.06 to 2.50 were falled within the range of diversity indeks of this study (Sapkota *et al.,* 2009).

In term of tree diversity it was shown that there was a significant difference of all stage of tree growth (seedling, sapling, pole and tree) between inundated and non-inundated ecosystem ($p<0.05$). Non-inundated provide more diver tree species compare to inundated plot which more suitable for selective species, survived under this condition. Saturated condition created a difficult environment for several seed to grow, but some of them will be adapt and creating a unique ecosystem. Some species that well adapted to this such as: *Shorea balangeran*, now became classified as one of endangered tree spesies. The lowest diversity index which was found at T2 inundated ecosystem, was due to the highest water level during flooding period (January to March), in which the maximum water level was recorded at 240 cm (Figure 9).

Vegetation Density, frequency and important value indeks of each tree stadia of growth: The dominant seedling species found under inundated ecosystem were dominated by *Shorea balangeran*, *Callicarpa havilandii*, *Baccaurea edulis*, and *Polyalthia xanthopetala* in which in accordance to the dominant species under sapling pole and tree categories. This can be conclude that the regenerating process is being achieved toward a sustainable of each stadium of tree categories. However, under noninundated ecosystem the vegetation type of seedling tree species were different to those species on the tree stages of sapling, pole or tree except for *Hevea braziliensis* whereas commonly observed in all tree stadium of growth. (Table 1). Sustainability of tree species of inundated plot was better than those non-inundated ecosystems as there were a continuoes similarity on tree species across different stadium of tree growth.

Base on RD, RF, IVI, no of population and tree density, a multivariate analysis were performed. Canonical Variate Analysis presented in Figure 9

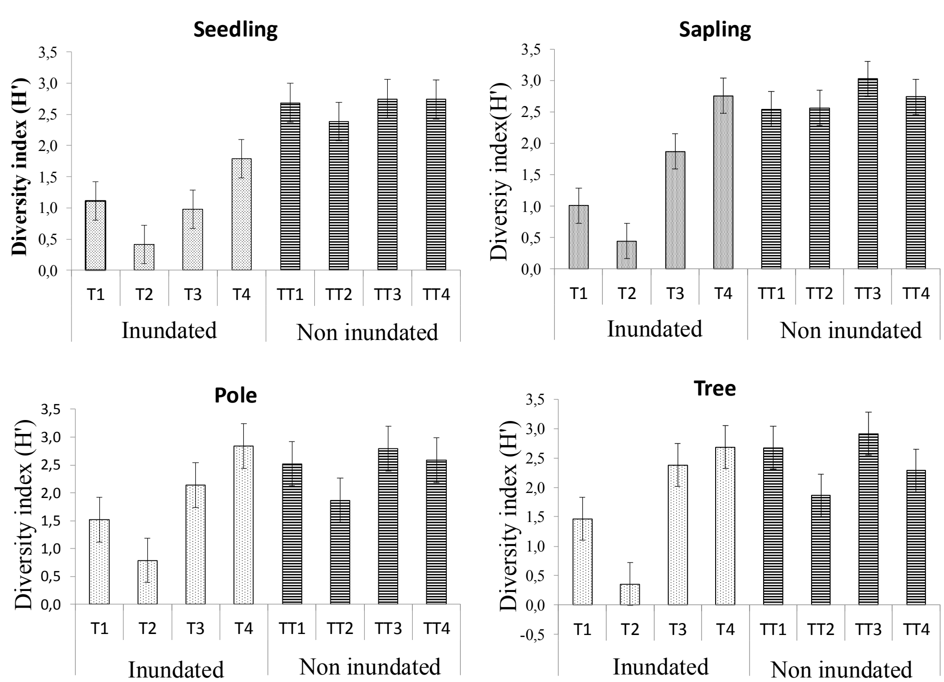

Fig. 8. Diversity indeks of different stage of tree growth (seedling, sapling, pole and tree) of two different ecosystem

shows that between inundated ecosystem (T) and non inundated (TT) plots were significantly different ($P<0.05$) which positioned separate to each other particularly along with axis (Canonical variate 1). This is indicated by a circle of confidence intervals (95%) that are intersecting or not intersecting. T and TT ecosystem had a positive correlation to the axis of Canonical Variate 1 with a percentage variation of 69.9% higher than the axis of Canonical Variate 2 which represent to about of 16.8% of the variation. Moreover, in term on inundated ecosystem (T), there were two plots which overlap to each other, means these two plots under inundated ecosystem (T1 & T3) were assumed to be similar. In addition to that, the plot of T2 and T4 were separated a bit far away one to each other. In term of non-inundated ecosystem (TT), the plot of TT1 and TT3 were significantly different one to each other and also to the plot of TT2 and TT4 which overlapped one to each other. The observation of the effect ecosystem was succesfully grouped by CVA multivariate analysis (Figure 5).

Table 1. Dominant species on their relationship with dominance relative value, frequency relative value and importance value indeks of each stadium of tree growth

Ecosystem	Sub ecosystem	Dominant spesies	RD (%)	RF (%)	IVI (%)
		Seedling			
Inundated	T1	*Shorea balangeran*	34.1	35.4	69,6
	T2	*Callicarpa havilandii*	65.2	77.4	142.6
	T3	*Baccaurea edulis*	63.1	31.0	94.1
	T4	*Polyalthia xanthopetala*	16.5	17.0	33.5
Non-inundated	TT1	*Syzygium lineatum*	17.2	12.0	29.2
	TT2	*Hevea brasiliensis*	25.5	9.2	34.7
	TT3	*Syzygium leucocladum*	15.5	5.0	20.5
	TT4	*Archidendron jiringa*	10.9	7.4	18.3
		Sapling			
Inundated	T1	*Shorea balangeran*	58.7	31.5	90.2
	T2	*Callicarpa havilandii*	63.6	52.2	115.8
	T3	*Vatica rassak*	20.0	19.3	39.3
	T4	*Popowia bancana*	6.9	8.0	14.9
Non-inundated	TT1	*Syzygium lineatum*	16.5	11.7	28.2
	TT2	*Hevea brasiliensis*	16.1	12.1	28.3
	TT3	*Barringtonia lanceolata*	9.5	3.0	12.5
	TT4	*Artabotrys hexapetalus*	13.7	7.3	21.1
		Pole			
Inundated	T1	*Shorea balangeran*	42.8	29.3	111.7
	T2	*Callicarpa havilandii*	65.0	46.6	177.8
	T3	*Baccaurea edulis*	23.4	13.9	61.5
	T4	*Polyalthia xanthopetala*	13.0	9.4	35.5
Non-inundated	TT1	*Dendrocalamus asper*	17.7	3.0	36.3
	TT2	*Hevea brasiliensis*	39.6	20.0	105.7
	TT3	*Hevea brasiliensis*	9.7	5.5	26.0
	TT4	*Artocarpus elasticus*	19.3	12.5	52.9
		Tree			
Inundated	T1	*Shorea balangeran*	52.4	32.0	147,7
	T2	*Callicarpa havilandii*	68.6	66.4	199.9
	T3	*Baccaurea edulis*	24.5	9.1	52.9
	T4	*Polyalthia xanthopetala*	15.8	9.8	39.7
Non-inundated	TT1	*Schima wallichii*	35.9	9.0	81.0
	TT2	*Hevea brasiliensis*	33.9	13.7	86.7
	TT3	*Schima wallichii*	15.2	10.6	40.7
	TT4	*Macaranga gigantea*	30.2	11.1	71.3

Note : RD=Relatif Density, RF=Relatif frekwensi, RD=Relatif dominance, IVI=Important Value Indeks

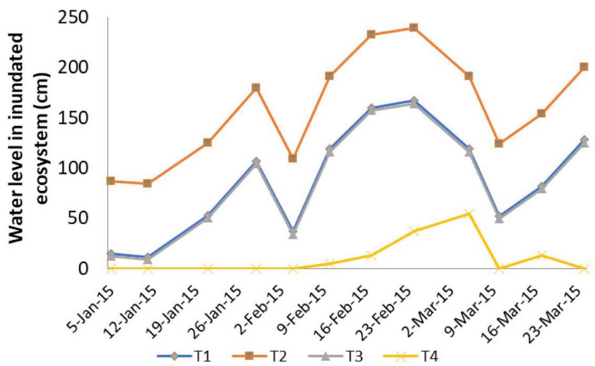

Fig. 9. Water level in inundated ecosystem over the period of flooding

Conclusions

The inundated riparian forest had lower tree population in lower tree diameter (5-60 cm) compare to adjacent non inundated ecosystem but had higher wood tree density (0.66 g cm^{-3}). A total system carbon stock of 313 Mg C ha^{-1} equivalent to inundated riparian forest in this ecoregion which more than twice than non inundated plot, reached only 142 Mg ha^{-1}. Tree biomass contributed 70-80 % to total carbon stocks and the soil between 0 and 30 cm depth approximately 80-90 % across all systems. Carbon stock in riparian conservation forest of PT AMR is about 228 Mg ha^{-1} giving a total accumulation of 159.600 Mg C ha^{-1}. The specific allometric equation has been developed to anticipate measuring *Pandanus sp* tree $y = 0.002\ x^{4.023}$ ($R^2 = 0.903$). These inundated can be recognized as part of an option to reduce emissions from deforestation and forest degradation along with maintaining tree biodiversity, as the condition of highest water level were reached 250 cm during flooded period. In total 333 plant species from 52 families on average were found. The Index of Species Diversity (H') was medium (mean H' values =2.5) at both areas, for all four age classes: trees, poles, sapling and seedlings. The diversity of all tree stadia under inundated ecosystem were much lower compared to non -inundated plots, eventhough it has higher wood density (0.66 g cm^{-3}), also the average DbH >100 are more dominant. The dominant seedling species found under inundated ecosystem were dominated by *Shorea balangeran*, *Callicarpa havilandii*, *Baccaurea edulis*, and *Polyalthia xanthopetala* in which in accordance to the dominant species under sapling pole and tree categories and *Hevea brasiliensis* are major species under non inundated ecosystem, means that human intervention had been used this region as one on productive soil for agriculture crop in the past were being confirmed, eventhough at present this plot has been neglected. CVA analysis revealed a grouping of inundated and non-inundated ecosystem based on various variable involved (CV1=70%) dan CV2(17 %).

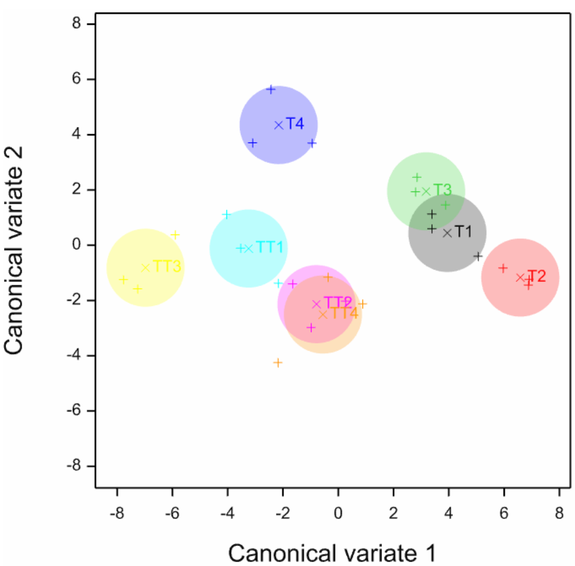

Figure 9. Canonical variate analysis of two ecosystem

Acknowledgement

The data presented in this paper were part of research collaboration between Faculty of Agriculture-University of Brawijaya-Malang and PT.Astra Agro Lestari TBK, located in Pandu Senjaya Village, Kec. Pangkalan Lada, Kab.Kotawaringin Barat, Central Kalimantan, which provide funding and facilities. Grateful thank to all field and laboratory staff for their great help and support and students who involving to this activities.

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