ROLE OF AGROFORESTRY IN MITIGATION AND ADAPTATION OF CARBON EMISSION TO SUSTAINABLE DEVELOPMENT

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Abstract. The loss of forest cover due to the conversion of forests to settlements, plantations, agriculture and the need for development in other sectors, has caused changes in weather/climate patterns in various places. Climate change can be anticipated by mitigation and adaptation. Mitigation means prevention efforts that need to be done, whereas adaptation is the necessary adjustment activities to be able to live and survive and increase resilience, flexibility and lead to migration due to different climatic conditions. Agroforestry is expected to function as a mitigation and adaptation agent by comparing previously untreated sites with agroforestry to store carbon or to absorb carbon, so that the greenhouse gas effect will decrease. Several research results indicate that agroforestry systems have proven effective in absorbing carbon emissions into the air. Research conducted in East Kalimantan's forest area shows the ability of *Shorea leprosula* plants aged 1-6 years old with the diameter between 2.96 to 8.27 cm in absorbing CO_2 gas from an atmosphere of 0.54-10.17 ton ha^{-1} CO_2. Similarly, the research conducted in Sampang-Madura resulted in the results that carbon stocks in the highest tidal zone were 232.59 ton ha^{-1} on a stem, 0.4658 ton ha^{-1} on a root, 0.0049 ton ha^{-1} in a litter and 0 ton ha^{-1} on woody necromass. While the carbon stock in the lowest tide zone was 111.91 ton ha^{-1} in a stem, 0.21492 ton ha^{-1} at root, 0.0031 on litter and 48,521 on woody necromass. Rubber agroforestry activities in peatlands are capable of producing carbon uptake of 43.28 tons ha^{-1}.

Keywords: Agroforestry, mitigation, adaptation, carbon, emission

INTRODUCTION

Deforestation activities are increasingly common. Almost in all parts of the world the forests are converted into commercial establishments. As a result, the number of forests is dwindling and its role as the world's lungs, water storage, biodiversity conservation and as a means of carbon sequestration is declining. The loss of forest cover due to conversion of forests to settlements, plantations, agriculture and the need for development in other sectors, has caused changes in weather or climate patterns in various places. The impact of climate change is the prediction of the wet and dry months become difficult. However, according to (Santoso and Forner in Kurniatun *et. al.* 2008), information on the occurrence of an increase in extreme weather frequencies per year is far more important than just information on increasing the amount of annual rainfall. This is because the extreme weather conditions cause the occurrence of floods and landslides that occur at any time, so early warning to the community is needed to reduce the number of losses and the loss of life

The phenomenon of climate change seems can no longer be disputed. Various scientific studies illustrate that carbon dioxide (CO_2) in the atmosphere layer which is a consequence of combustion products from coal, forest wood, oil, and gas has risen almost 20% since the start of the industrial revolution. Industrial areas built almost across the continent of the world have produced "Greenhouse Gas" (GHG) waste, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which can cause "blanket effect". This effect then causes the rise in temperature in the earth's surface. As a comparison, the pre-industrial GHG concentration in the nineteenth century was 290 ppmv (CO_2), 700 ppbv

(CH_2), and 275 ppbv (N_2O). While at this time, the increase to be 360 ppmv (CO_2), 1.745 ppbv (CH_4), and 311 ppbv (N_2O). Thus, according to experts, GHGs for CO_2 by 2050 are expected to reach the 550 ppmv range (Gunningham *et. al.*, 2004).

Climate change can be anticipated by mitigation and adaptation. In order to deal with the problem of global warming that has indeed occurred, the current research direction in general is to manage land resources shifted to adaptation efforts to global climate change synergies with Greenhouse Gas mitigation efforts (Verchot *et. al.*., 2006). Mitigation means prevention efforts that need to be done, whereas adaptation is the necessary adjustment activities to be able to live and survive and increase resilience, flexibility and lead to migration due to different climatic conditions.

Agroforestry is expected to function as a mitigation agent by comparing previously untreated sites with agroforestry to store carbon or to absorb carbon, so that the greenhouse gas effect will decrease. Compared to forested vegetation, it will be different, but prevention here does not mean total prevention, but reduces greenhouse gas emissions by absorbing the carbon present. The agroforestry system is also expected to contribute to climate change through improved micro-climate and the achievement of food security (N'Klo, *et.al.* 2011). Ultimately, the agroforestry system is expected to help minimize greenhouse gases occurring today and in the foreseeable future.

Agroforestry System. According to Butarbutar (2011), agroforestry is a model of forest management that aims to increase the productivity of land in the form of forest products, agricultural products or livestock and fisheries so that people can obtain results in the short, medium and long term. Meanwhile, according to Kurniatun *et. al.* (2008), agroforestry simply means planting various types of trees on agricultural land that doubles as a source of farmer income and protection of the surrounding soil and water. Agroforestry is a forest structure managed by farmers to obtain various forestry and agricultural products cultivated on the same land. From this definition the emphasis is more emphasized for the preservation of forestry crops (De Foresta and Michon, 1996). Maness (2009) suggests that there are 3 (three) processes in which forest management can reduce greenhouse gas concentrations: 1) stock protection strategy (through conservation activities, harvest delays, fire prevention and pest and disease prevention b) carbon sequestration strategy through cultivation activities, enhancement of carbon stocks, use of preserved wood) and c) Renewable energy use strategies, through the production of renewable biomass to replace fossil energy. From some of the above definition can be seen that agroforestry is a system of forest management by planting various types of trees on agricultural land that serves for the preservation of crops both from forestry and agriculture to obtain optimal results both in the medium and long term. Forests play an important role in regulating the Earth's climate through the carbon cycle; absorb carbon from the atmosphere as it grows, and store carbon in foliage, woody tissue, roots, and organic matter in the soil. The world's forests absorb 2.4 billion tons of carbon dioxide annually, or about a third of the carbon dioxide released by burning fossil fuels. Forests are also the world's most important terrestrial carbon store, comprising about 77 percent of all the carbon stored in vegetation and 39 percent of all the carbon stored in the soil; twice the amount of carbon in the atmosphere (CIFOR, 2013).

Impact of CO_2 Increase and Climate Change on Agricultural Sector. Deforestation and forest degradation account for about 10 to 15 percent of the world's greenhouse gas (GHG) emissions caused by human activities and the burning of peatlands associated with deforestation causing the next 3 percent of emissions. This emission is larger than the global transportation sector. According to (Cifor, 2013) Eighty percent of these emissions come from only 10 countries, especially in developing countries. In some countries, such as

Indonesia, deforestation and forest degradation are the main sources of emissions. The loss of global forest cover also means the loss of the forest's natural ability to absorb carbon and its storage capacity, which means enlarging emissions from other sources.

Climate change can affect the sectors of life on earth, including the agricultural sector. Climate change will have a major impact on crop production (Bannayan *et. al.*., 2005). Climate change affects the global production of some major food crops. The growth and productivity of the plant is affected by increases in CO_2 concentration and temperature (Kim and You, 2010). Temperature rises that are one of the issues of climate change can lead to increased rates of transpiration and respiration and faster aging with low yields (Perdinan *et. al.*., 2008). In Kim and You (2010) study results explain that there is a high correlation between CO_2 increase and temperature to crop productivity. Increase in CO_2 concentration will increase total biomass. While the temperature will decrease lower total biomass. If these two factors are combined, it will negatively affect the productivity and physiological response of the plant because although CO_2 decreases the amount of chlorophyll and nitrogen. This will decrease the leaf response in the photosynthesis process.

Kobayashi *et. al.* (2011) studied the effects of summer 2007 on plant growth in Japan. The effects of such hot temperatures will thwart pollination, increase the number of empty seeds and lead to decreased yields. (Matthews *et. al.* 1997) showed that a rise in temperature of 10 C would decrease production by 5-7%. While the research results (Peng *et. al.* 2004) shows that every 10^0 C temperature increase will decrease production by about 10%. The three main factors associated with the increase of CO_2 in causing global climate change, affecting the agricultural sector are: 1) changes in rainfall patterns, 2) increased extreme climatic events such as floods (La Nina) and drought (El Nino), and 3) increased temperatures and sea levels (Salinger, 2005). One of the sectors most affected by climate change is the agricultural sector, especially the food crop sub-sector. This is because food crops are generally an annual crop that is relatively sensitive to stress, especially the advantages and disadvantages of water. Technically, vulnerability is closely related to land use systems and soil properties, cropping patterns, soil management technologies, water, and crops, as well as crop varieties (Las *et. al.*., 2009).

Carbon Mitigation Process. Mitigation is every effort made to control the causes of climate change, by absorbing CO_2 in the air and storing it in crops and soil in both forest and agricultural ecosystems for a long time. Mitigation activities are carried out as one of the efforts to reduce the greenhouse gas effect so that it can slow the rate of global warming. (Kurniatun, 2013). So, simply, mitigation can be defined as a process of reducing greenhouse gas emissions.

DISCUSSION AND CASE STUDY

Meranti Plant and Carbon Absorption. A study in the District of Penajam Paser Utara, East Kalimantan, focuses on the type of *Shorea leprosula* (Meranti) from the youngest to the oldest (1 - 6 years) in the forest management area. Potential *Shorea leprosula* plant is calculated through the manufacture of the widest plot 0.25 ha (50 x 50 m) were randomly plated at each tree age, then an inventory was performed on each plot of the sample of 6 plots. Potential reserves of tree biomass as a whole are known by the sum of the biomass content of each tree organ, which is the total organic material resulting from photosynthesis. Through the process of photosynthesis, CO_2 in the air is absorbed by plants with the help of sunlight and then converted into carbohydrates, then distributed throughout the body of plants and dumped in the form of leaves, stems, branches, fruits and flowers (Hairiah and Rahayu, 2007).

The ability of *Shorea leprosula* plants aged 1 - 6 years of diameter between 2.96 to 8.27 cm in absorb CO_2 gas from the atmosphere ranges from 0.54 to 10.17 tons ha^{-1} of CO_2 . These results are in line with the potential of plants in storing carbon stocks, where through the process of photosynthesis, CO_2 in the air is absorbed by plants with the help of sunlight and then converted into carbohydrates, then distributed to all plant organs are stockpiled in the form of biomass (Hairiah and Rahayu, 2007). Then when measurements for the average annual ability of *Shorea leprosula* plants to absorb CO_2 from the atmosphere are around 0.27 - 1.69 ton ha^{-1} $year^{-1}$. The average annual CO_2 absorption potential represents the average annual rate of plant capability in absorbing CO_2 from the atmosphere. In another study, (Siregar et. al 2010) reported that carbon biomass reserves and the ability to absorb CO_2 in *Shorea leprosula* plants between 5.5 and 35.3 cm in diameter with tree age between 3 to 23 years in Ngasuh, Bogor sequentially were 0.076 tons $tree^{-1}$ and 0.139 tons $tree^{-1}$. In this study it can be seen that the contribution of CO_2 absorption from the atmosphere by *Shorea leprosula* miq plants aged 1-6 years with a diameter range of 2.96-8.27 cm in the area of East Kalimantan is 0.54-10.17 ton ha^{-1} CO_2 with an average annual capability in absorbing CO_2 gas from the atmosphere ranging from 0.27 to 1.69 ton ha^{-1} $year^{-1}$.

Tree Stands (Rhizophora stylosa) and Carbon Absorption. In this research, the location of mangrove forest of Camplong beach, Sampang-Madura is divided into 2 zones based on the difference of environmental tone. The first zone is the highest tidal zone, which is the area of mangrove forest of Camplong beach which gets the seawater only at the highest tide or in other words the area of mangrove forest which is directly adjacent to the mainland. The second zone is the lowest tidal zone, which is the area of mangrove forest of Camplong beach which is directly adjacent to the beach, where the area gets puddle of sea water at high tide. The content of tree biomass is the sum of the biomass content of each tree organ which is the total picture of organic material resulting from photosynthesis. Through the process of photosynthesis, CO in the air is absorbed by plants with the help of sunlight and then converted into carbohydrates, then distributed throughout the body of plants and dumped in the form of leaves, stems, branches, fruits and flowers (Hairiah and Rahayu, 2007).

Based on the results of this study, we found that carbon stocks in the highest tidal zone were 232.59 ton ha^{-1} on stem, 0.4658 ton ha^{-1} root, 0.0049 ton ton ha^{-1} on litter and 0 ton ha^{-1} on woody necromassa. Necromassa woody is a dead tree that is still standing or falling, plant stumps, branches and twigs are still intact that diameter> 5cm and 0.5m long. While the carbon stock in the lowest tide zone was 111.91 ton ha^{-1} on the stem, 0.21492 ton ha^{-1} on root, 0.0031 ton ha^{-1} on litter and 48.521 ton ha^{-1} on woody necromassa. From the statistical test, there were significant carbon stocks of stem, roots and litter at the highest tidal zone while necromassa carbon stock was significant at lowest tidal zone Total carbon stock in both zones was 196.8549 ton ha^{-1} with average absorption of (CO_2) 721.5822 ton ha^{-1}.

Agroforestry Rubber and Carbon Absorption. Agroforestry is a forest structure managed by farmers to obtain various forestry and agricultural products cultivated on the same land (De Foresta and Michon, 1996). Rubber agroforestry activities with the planting of forest plant species aims to conserve forests that focus on ecological interests. Rubber plantation, which is a branching type of tree, is more focused on generating regular income. The combination of the two types of crops is an incentive for communities to conserve or conserve forests in state forest production forest areas by earning revenue during the forest maintenance period. Forests and rubber plants have permanence properties in absorbing carbon and can store carbon for a period of time. One cycle of silvicultural rotation of natural forest can be done two to three regeneration cycles or rejuvenation of rubber plants. From the results of the research as described previously, that carbon uptake and storage from the presence of tropical forests and rubber plantations can be known. Thus, in the agroforestry activities of degraded peat soils with some combination engineering, the carbon additions can be taken into account. An illustration of the magnitude of the uptake, release and storage of carbon dioxide as presented in the table below. Additional quantities of carbon uptake from various compositions of rubber agroforestry activities with a range that does not show significant differences.

Table 1.

Carbon uptake composition in rubber agroforestry

Composition	Land Area (% ha^{-1})		Carbon Uptake (CO_2 ton ha^{-1})		Carbon Protection (CO_2 ton ha^{-1})	Carbon Release (CO_2 ton ha^{-1})	Additional Carbon Uptake (CO_2 ton ha^{-1})
	Rubber	Forest Species	Rubber	Forest Species			
A	25	75	3,56	5.50	44.30	15.21	38.15
B	50	50	7,12	3.67	44.30	15.21	39.88
C	75	25	10.68	1.83	44.30	15.21	41.60
D	100	100	0	7.34	44.30	15.21	36.43
E	0	0	14.24	0	44.30	15.21	43.28

Source : (Asmani, 2012)

The highest absorption occurs if the land is entirely planted with rubber, and the lowest if only planted with forest plant species. Thus the greater the proportion of the rubber plant area the higher the carbon uptake. The high carbon uptake is due to rubber age of about 25 years, while in natural forest species reaches about 60 years. With high carbon uptake, the rubber plant can be an alternative substitution for forest plant species.

Agroforestry Mechanisms in Adapting Climate Change. From some of the above discussion it can be seen that the agroforestry system can mitigate carbon emissions in nature. The role of agroforestry on climate change adaptation can be seen from 3 (three) approaches, namely: 1) displacement/translocation of germaplasma; 2) local genetic adaptation and 3) the role of type plasticity.

1) Translocation of germaplasm. In 2007 the speed of species migration in natural forests due to anthropogenic climate change is estimated to be more than 1 (one) km per year or 10 (ten) times the rate of climate change in nature. This migration required trees to adapt physiological inadequacies and to maintain/adapt to changes in temperature and precipitation at the taxa level (Person, 2006 in Dawson 2011). How to adapt the types of forest trees or forest type groups will tend to move toward the northern hemisphere and rise to higher elevations. Global warming can add montane forests, grasslands, and arid forests. In the context of management, the agroforestry system is a translocation facilitator (which does not occur in natural forests). This facilitation includes human influences such as in the transport of seeds and seeds, microorganisms such as nitrogen-fixing bacteria and pollinating animals/insects. Some things to note in the germaplasm translocation are the suitability of the growing place and the variation of species, the exchange of germaplasma between countries and the farmers' access to suitable genetic resources.

2) Local genetic adaptation. Local genetic adaptation means developing a particular species of a certain amount externally (outside its habitat). The effective population number is an ideal population size with the same genetic properties as observed in populations in nature. The value of Ne of a particular kind is a reflection of: a) the number of individuals of a certain species within a community in nature or artificial plants; b) have high levels of

genetic diversity; c) having "natural out crossing" of the dominant type; d) produce a lot of seeds and e) pollen and seeds can spread long distances, so that pollination can occur over long distances. Such adaptation can be done by maintaining and increasing the effective population size.

3) Type plasticity individually. Plastic tree species are species that have morphology and physiology that are flexible and can grow well under minimum conditions without genetic alteration (Gienapp 2008 in Dawson, 2011). For example, *Pinus patula* and *P. tecunumanii* originating from Central America, this species grows better in wider environmental intervals than their natural requirements (Naver, 2010). Another type is like from Australia, now it can be cultivated at least in 25 countries with better conditions (Naver, 2010). The diversity of local and exotic tree species and agricultural crops can improve the resilience of agricultural systems to environmental changes if they have a different response to the disorder (Dawson, 2011).

2.5 The Role of Agroforestry in Carbon Mitigation. (Maness, 2009) suggests that there are 3 (three) processes in which forest management can reduce greenhouse gas concentrations: 1) stock protection strategy (through conservation activities, harvest delays, fire prevention and pest and disease prevention b) carbon sequestration strategy through cultivation activities, enhancement of carbon stocks, use of preserved wood) and c) Renewable energy use strategies, through the production of renewable biomass to replace fossil energy. The role of agroforestry in mitigation can be seen from the above three strategies, namely the first function as carbon sequestration, through mixed cultivation (wood carpentry, fodder, fruits and others). Secondly to stock protection function is seen in reducing fire hazard and pest attack by mixing crops and the third on the function of renewable energy utilization, with plant type of wood fuel.

The degree of carbon storage across land varies, depending on the species diversity and density of plant plants (Mutuo *et. al.*., 2005; Hairiah *et. al.*., 2011). Therefore, for extrapolation of C reserve on land use system Agroforestry to landscape level, it is necessary to measure the average C per plant life cycle (Time-averaged C stock = TAC) of each type of agroforestry. However, the available data is generally limited to reserve C in plant biomass only, for which the measurement of five reserve pool C is still needed. Dawson (2011) recommends reducing carbon emissions by applying agroforestry through mixed timber tree species, fodder and fruits. (Kaiser, 2000) mentions that agroforestry activities can increase carbon storage more than farmland, pasture, forest and grasslands of 390, 125, 240, 170 and 38 x 10 grams C per year (Tg C year^{-1}) respectively.

Mitigation of climate change through increasing the amount of CO_2 absorption from the air and storing it in the field (agroforestry) for a long time. Thus agroforestry is as important as the benefits of other vegetation in natural forests (Montagnini and Nair, 2004), while crop production continues. However, the amount of carbon stored in agroforestry is more limited than in natural forests, due to the harvesting and reduction of planted tree species that will reduce the content of soil organic matter (SOM), where SOM is also one component of carbon stock composition of a land (Mutuo *et. al.*, 2005). Soil treatment through the addition of organic materials is important to maintain the growth (biomass) of plants that ultimately increase the carbon stock in the land.

CONCLUSION

Agroforestry has many functions in adaptation and mitigation to climate change. The role of agroforestry on climate change adaptation can be seen from 3 (three) approaches, namely: 1) displacement / translocation of germaplasma; 2) local genetic adaptation and 3) the role of type plasticity. There are 3 (three) processes in which forest management can reduce greenhouse gas concentrations: 1) stock protection strategy (through conservation activities, harvest delays, fire prevention and pest and disease prevention b) carbon sequestration strategy (through planting activities, carbon stocks, use of preserved wood) and c) Renewable energy use strategies, through the production of renewable biomass to replace fossil energy.

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