Agro Forestry Could Enhance Soil Moisture and Fertility in Farmlands

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Abstracts

Since draught and fertility of farmland can be considered as main constraint for food productions, mitigation of these constraints has to be continuously performed. The important of this mitigation mainly due to various data reported which show that rainforest has been continuously decreased for other uses. This decrease could then inhibited the potential of local water cycles and enhance draught. In order to minimize the overwhelming draught during dry seasons and flooding during rain seasons, agro forest system might become an option that has to be improved, as well as inhibiting the reduction of rain forest. This agroforest system do not only varied income for smallholder farmer, but also increased the capability of rain forest to maintain fresh water supply. This system could therefore also increase soil moisture and fertility of farmland. Mechanism by which this system could mitigate agricultural constraint is relied on the ability of deep root system of trees to absorb mineral and water. Whereas water taken up by this root system then evaporated to enhance local water cycles, mineral taken up from deep soil will enrich top soil of farmland. Thus, agroforestry could become a promising method to sustain food productions.

Key word, agroforestry, freshwater, water cycle, soil fertility and moisture.

Introductions

Agroforest or agrosylviculture is a land use management system in which trees or shrub are grown around or among crops (Wikipedia). In this system, trees play an important role as shading, nutrient and hydrological cycling (Tiralla et al. 2013). Particularly for smallholder farmer, trees grown with economical plant could provide various harvest, such as wood for building and fuel wood, fruit and other sources (Tscharntke et al. 2011). The trees could also enhance soil porocity and soil moisture (Shaxson and Barber 2003). However, although the benefit of agroforestry has already been acknowledged, implementation of this system has not

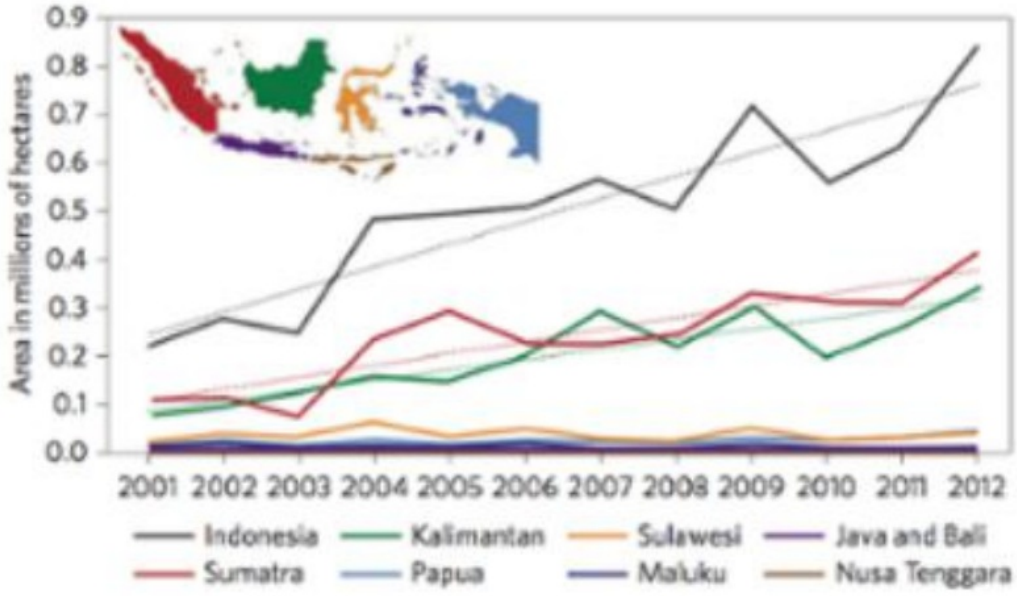
widely been employed. For example, in order to increase a short term high production, conversion from shaded to unshaded cacao plantation has been a common practice (Tscharntke et al 2011).

In theory, clearing natural tress for a short term high crop production would make a serious impact on long term food production. This impact is mainly attributed by the absent of mechanism that maintain a sustainable soil moisture and fertility. According to Shaxson and Barber (2003), conservation effect of the forest is mainly due to the litter of fallen leaves, twig and branches which slow rain water runoff and increase water infiltration. This imply that, monoculture system, in rainfed farmland, position the land at a high risk of nutrient scarcity and short water supply.

This system require more input such as fertilizer and pesticide which make increasing concern on health risk for soil organism and human being. In some study, this system is regarded as non sustainable since the high production could only occur for a relatively short period. This kind of production has been known as boom and burst (boss and). The other concern that is made by this monoculture system is that an overwhelming effect of global warming. It has widely been concerned that global warming has generated extreme climate change with main impact is drought or flooding. Without serious improvement in agricultural practice, food security could have been a real threat for global population. Thus, various effort need to be implemented to ensure the sustainability of food productions. One possible option that can be managed is optimation of agroforest in farmland in order to increase forest capacity in generating local water cycles.

Fresh water is one of the most basic needs for human being and other organism to live. It is not surprising that various techniques have been developed during the development of civilization to make this fresh water sufficiently available. Initially, this fresh water is mainly used for human consumption and agriculture, but after development of civilization, the use of fresh water has continuously to increase. However, the increasing requirement for fresh water does not adequately balance with information and practice on how this fresh water is available. Consequently, natural resources that make this fresh water available do not adequately maintain. A vast reports have been published which suggesting that fresh water resource has not adequately been managed. For example, tropical rain forest is continuously decreasing by logging and conversion into other land uses (Putri 2012), fresh water crisis because of inadequate

agricultural practices and tourism industry (Suriyani 2009) and potential social conflict because of inequity fresh water uses (Cole 2012). In most recent report, deforestation rate in Indonesia overtake Brazil (Guardian 2014).



Since water cycle is an ecological processes, maintaining sufficient fresh water available require the involvement of all level of society. This paper discussed the mechanism of fresh water cycles and the important role of agroforestry in maintaining fresh water supply.

Mechanism of fresh water cycles

Water is mostly stored in the sea, accounted for about 97% of total water in this planet (anonym). Evaporation of sea water into water vapor, by heat from the sun, purifies salt water to become fresh water (Wikipedia). This water vapor is then lifted up and drifted into land by low atmospheric pressure on land. Lower pressure on the land surface is attributed by a process where land surface is more easily warmed up by the sun rather than the sea.

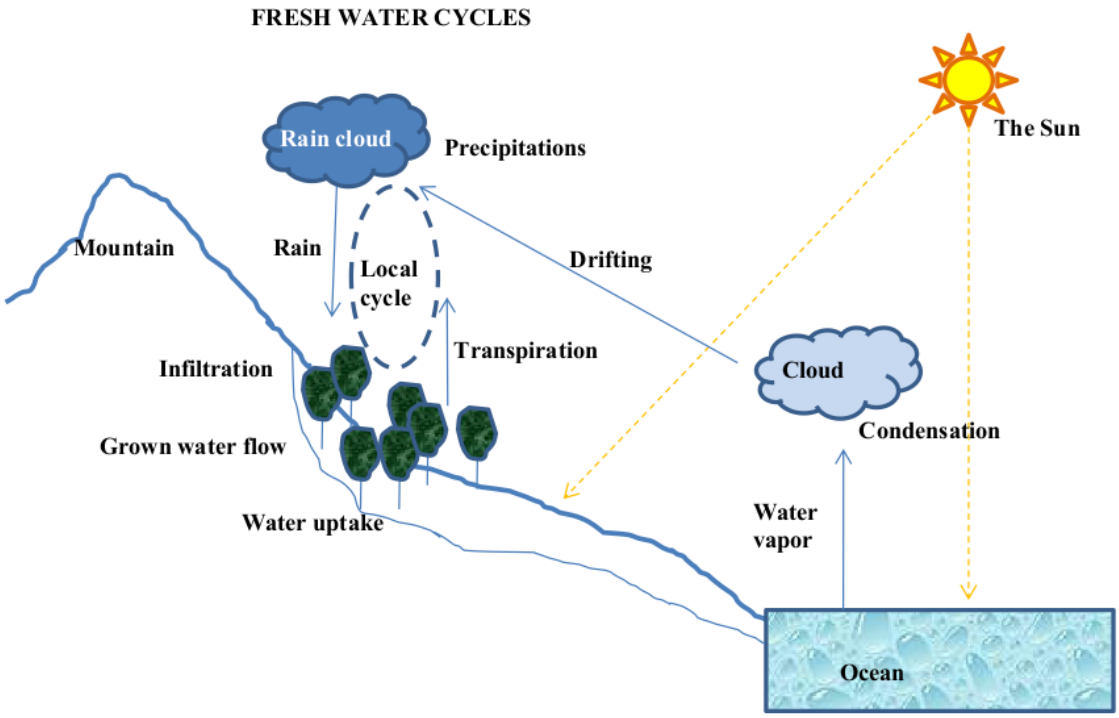


Fig.1. Fresh water cycles

The water vapor then condensed into small particle to produce cloud. One portion of this cloud can be drifted into mountain area and lifted up orrografically. Cooling system then make the small water particles to collide into larger particles via a precipitation process and eventually transformed into rainfalls. These processes make fresh water then available on upland area which then follows two main fates, i.e. flow into rivers (runoff) and infiltration into the lands. Grown water flow could then flow into spring or into the sea. Schematic mechanism of this process is provided in Fig. 1.

Local water cycle in the tropical rain forest

Tropical rain forest can make their own rain by water uptake via the root system and water transpiration via the leaves system. Bulk water transport from root system into the leaves system is pushed by hydrolic pressure which commonly known as root pressure. Mechanism by which

this high pressure occurs in the root has been a subject of study for a long period of times. One theory proposed that high root pressure occur because of continuous pumping of ion by ions pump in cell membrane of the root system. This pumping then enables various ions entering the root system and accumulates in endodermis of the roots. Accumulations of these ions resulting in the decrease of root water potential that make water influx into the root system. Influx of this water then increase hydrolic pressure in the root which drives upward transport of water via xylem in the stem into leaves systems. It is believed that this process occur during days and night time. Since a large area of big trees in the forest has to have a wide and deep root system, the amount of soil water can be taken up into the leaves system is therefore significantly high.

Leaves system of the trees, which is located in the atmosphere, enhance bulk water transport from the roots. With thin and relatively wide plate of the leaves, trees release water into atmosphere via stomata in a process known as transpiration. The rate of this water transpiration is depended on various factor such as, atmospheric moisture, wind and temperature. Generally, atmospheric humidity is lower than humidity in cell space of spongy tissues in the leaves. Gradient of humidity inside and outside of the leaves and also winds then resulted in the water release from the leaves. Similar to that in the root, capacity of trees in tropical rain forest to release water is substantially large. It was proposed that about 50 to 70% of rain water striking a dense rain forest then transpired into the atmosphere. According to Butler (2012), water release from forest trees into the atmosphere then forming cloud rain before precipitated into rain and fall back into the forest. Water cycle from forest to forest provides very important contribution to fresh water supply. This mechanism substantially reduces flood water flow into the river during rain seasons and delay water loss during dry seasons.

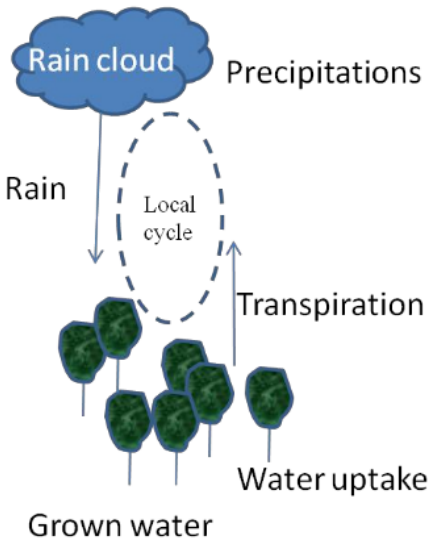


Fig.2. Water in the soil is taken via root system, transported in stem and transpirated into rain cloud in atmosphere. Water in the cloud then return back into the soil after precipitation to form rains.

Agroforestry support the capacity of rain forest to bring rain and maintain soil fertilities in plantations

Agroforestry is defined as agricultural practice which combined agricultural crop and trees (Fanish and Priya 2013). Crop plants were grown mainly for income purposes and trees were grown for building materials. In a certain crop plantations, like coffee and Vanilla, trees is also grown for canopy, stager or for the nutrient enrichment for the soil in the plantation. Naturally, trees grown in the plantation comprises a large total leaf area per plant and developed long deep roots. These large trees would enable more water to be taken up from deeper soil before evaporation into the atmosphere via stomata. So, the larger the trees, the higher rate of transpiration will be made. According to Fraser (2014), trees produce flow of water vapor 10 times greater than herbaceous. Therefore, transpirations of water via trees in agroforestry system potentially increased the capacity of forest to produce rain cloud that eventually transformed into rain falls. Water taken up from deep soil in the agroforest then cycled into the area as a rain falls. This recycled water is therefore could maintaining soil water content require by plant growth.

As an autotrophic organism, trees certainly also require nutrient for the synthesis of macromolecules for growth. Since these trees has a much deeper root, nutrient absorbed for growth is most likely originated from lower soil. From root system this nutrient is distributed into various plant parts and depending on the kind of compounds, some of the nutrient then underwent reduction into organic compounds. According to Adiputra and Anderson (1992, 1995) nutrient, such as nitrogen, sulphur and possibly also phosphorus, that redistributed into new developing leaves is incorporated into molecules and stay in the leaves. This compounds could then become nutrient for shallower rooted plants grown in the plantations. Therefore, Agroforest system could increase the capacity of rain forest to maintain soil moisture and soil fertilities.

Agricultural practice in plantations during development of modern economic era

Island of Bali is a mountainous area, so most agricultural activity is performed on hillside area. This type of area is characterized by a flooding water runoff that potential to result in landslide, particularly during rain seasons. Small farmer holder in rural area well aware of these possibilities, so various techniques had been developed. One of the most fascinating techniques that had been developed was terrace system for paddy field. This system could direct and distributes water in such a way which avoids flooding water runoff and landslide. In other land management, plantations on hillside were traditionally grown in mixed culture with trees. This land management is currently known as agroforestry. According to Rao et al. (2007), this traditional system is aimed to provide shade, a steady supply of food and income. In addition to that proposed by Rao et al (2007), Balinese peoples performed agroforestry very likely because of culture and religion which need various kinds of plants for offering and trees for traditional architecture. Cultural need to practice agroforestry is certainly favor the sustainability's of environment as has been described previously. In this section, development of agricultural practice for improvement of income in plantations is emphasized.

It is inevitably that increasing cost of living in modern economic development demanding the employment of agribusiness management. In this practice, agricultural activity is directed into the production of high yields in respect to profit. This practice is reasonable because farmers have to increase their income for daily spending and for longer education of their children as has been the case found in Peru (Johansson and Parsson 2012). However, this system

then brought some serious impact whether economically or environmentally. Conversion of traditional agroforestry into a high yield crop production has been experienced as not sustainable.

According to Clough et al. (2009) crops production is significantly high (booming) in the initial period after shade clearance. However, this production then decrease (bust) and it unable to be resumed. This kind of crops productions was reported in Brazil and Malaysia for cacao plantations (Fig.3). Other crops in different country are very likely also experienced the boom and bust crop yield. In my own experiences, Balinese people have also experienced this type of impact.

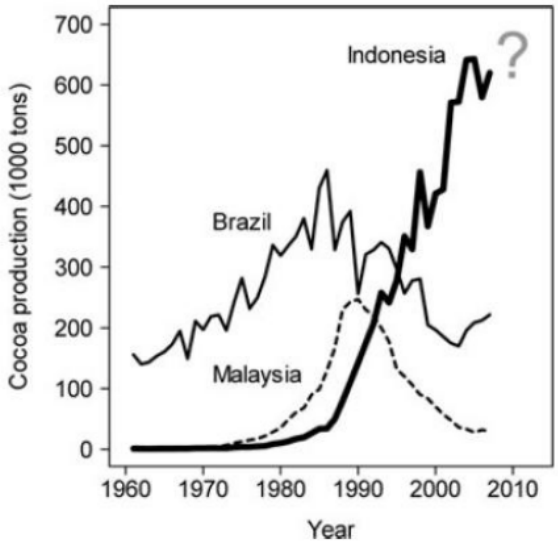


Fig. 3. Boom and bust of crop productions after shade trees removal (Clough et al. 2009).

For example, production of vanilla was booming for a periods of time but subsequently decreasing to almost zero production. Cacao plantation was also produce high yield in initial period, but subsequently decreased to a very low production. The main factor that viewed as the cause of this problem is diseases. Although various methods have been applied, crop yield was hardly to improve.

Studies which were aimed to resume crop production certainly have been conducted using various approaches, such as the use of diseases free vanilla seedlings, improvement of soil fertilities by addition of synthetic fertilizers. Adiputra et al. (2007, 2008) have also conducted

two year experiment in order to resumes vanilla productions. In these experiments, the growth of vanilla plants was monitored after application of various fertilizers. This experiment examined a hypothesis that slow vanilla growth is attributed by low amount of nutrient available for uptake by this plants. These experiments found that vanilla required fertilizers only in a particular dosage. After a prolonged observation, this vanilla plants then almost totally unable to continue growth. It is speculated that fertilizer supplement is not the main cause of growth inhibition. Accordingly, in order to examine more comprehensive study on the effect of fertilizer to the plants growth, further experiment was then conducted using orchid seedlings. This experiment concluded that synthetic fertilizer absorbed by plant could inhibit physiological mechanism in plants seriously (Adiputra 2014). Fertilizers taken up may squeeze water from physiological machinery attributed by water loss from the plants. These experiments suggesting that the growth of vanilla plant was inhibited by a severe water deficit during dry seasons. This example of difficulties in resuming crop yields after booming then has a significant effect on environment and farmer income.

In small holder farmer, decreasing crop productivity would enhance poverty particularly those people who most of their income depended on the crops. Therefore, in order to resume production, all possible method then applied, such as increasing the rate of synthetic pesticide applications and increasing dosages and rate of fertilizers applications. Without sufficient knowledge on soil and plant characteristic, application of synthetic compounds into plantations may be useless and endanger environment and human health. This practice has widely concern conservationist since these chemical compounds contain heavy metal that dangerous not only for human health but also soil biota and environment (Dias 2012, Zwieten 2004). By contrast, diseases outbreak is hardly controlled without the involvement of the synthetic fungicide.

In order to escape from a hot debate on safety agricultural practices, one of many possible options available is to look at other commodity to make farmland continuously profitable, such as introducing cacao plants after the cessation of previously grown vanilla. Introduction of this new commodity was employed a fairly robust methods during the initial establishment of plantations. It was suggested that before cacao seedling were transplanted into farmland, land cover has to be cleared such as big trees, bushes and grass (Litbang perkebunan 2010). This method has been employed in Sulawesi (Clough et al. 2009) and also in Bali. In the initial period of production, crop yield was booming, but then followed by bust, similar to that reported

in Brazil and Malaysia. After this bust, cacao plantations may then be abandoned or other commodity then introduced. For example, Malaysia replaced cacao plantations with palm oil and Indonesia become less and less interested in cacao production (Almeida and Valle 2007).

In Bali, some farmlands areas previously grown cacao then changed into trees plantations. This plantation very likely influenced by green movement, such as one billion trees programs (Simamora 2010). This program is really a good promise and support for the forest function in maintaining water cycles and coping global warming issues. However, there is a little worry since small holder farmer may undergo a scarifying income without crop plants. Unlike crop plants, where harvests are conducted more than twice a year, trees has to be grown for at less 10 years before harvest.

A compromise option and has already been practice traditionally is agroforestry. This system may not produce yield as high as that in shading clearance methods, but environmentally much more sustainable. For example, agroforest system has been known to have a capacity to maintain fresh water cycles and soil moisture (Shaxson and Barber 2003) and soil moisture is very important in maintaining plant growth (Coder 1999). Therefore, it is speculated that agroforestry which involving trees in production of crop is a suitable practice for sustainable environment and income for small holder farmer. Problems raised by this system should then become a priority for researcher in finding the solutions. For example, plant's disease is mostly fungi which prefer moist condition to grow. So, developing clones that resistant to diseases (Motamayor et al. 2013) is becoming more crucials. Other problem that also faced by plant grower is global climate changes which could threaten food security (Henry and Nevo 2014). According to these authors, climate change which reduce crop production urgently require varieties-resilient breedings.

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