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Full Length Review Paper

Shade tree and coffee production agroforesty system

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Coffee is one of the most expensive types of crop in the world. Due to the high stimulant value, Coffee is highly desirable crops in all areas. Growing coffee under shade trees is one of the fundamental principles in traditional organic coffee growing systems. Shade tree in coffee production is used to reduce excessive sun light from coffee and shades suffer the coffee from stress and have high biochemical and physiological potential for carbon sequestration both in the biomass and soil. Shade grown coffee plants also produce larger and heavier beans with a better coffee taste than coffee grown in the direct sun light. Also using of shade trees in coffee production provides additional income like fruits, fuel wood and timber. Shade trees assist in maintaining coffee yields in the long term by reducing periodic over-bearing and subsequent die-back of coffee branches. In addition, shading delays the maturation of coffee berries resulting in a better bean filling and larger bean size resulting in better coffee quality. Shade tree based coffee production system is also one of the agroforestry system which uses tree as a major components for the provision of shade. Agroforestry system which is adapting agriculture to climate change have been shown to increase on-farm production resilience to climate variability by buffering crops from the effects of temperature and precipitation variation as well as strong winds. In addition to this due huge carbon sequestration potential of trees and soils under the tree this system opens new financial income in the area of carbon trade. Because of the above mentioned reasons using of shade in coffee production is socially acceptable, economically more viable and environmentally sustainable.

Key words: Carbon, Climate change, Coffee Quality, Shade tree, Temperature

INTRODUCTION

Based on the interest and capacity, farmers practice different types of farming system. From those systems Agro forestry is one of the farming systems which are practiced on the farmers' field. According to shows based on the level of technological development, the main tree system, and their contribution to the agricultural structure of the area, we classify agro forestry in to perennial tree-based agro forestry system, annual crop based agro forestry system and agro forestry system with livestock. Based on the above classification shade tree and coffee production system is one of the agro forestry systems which are classified under perennial agro forestry systems [1].

Agro forestry is an integrated approach to solving land use problems by allowing farmers to produce food, fiber, fodder and fuel wood simultaneously from the same unit of land. In Agro forestry system there are both ecological and environmental interactions between different components.

The resulting biological interaction of agro forestry components provide multiple benefits, including diversified income sources increased biological production, better water quality, and improved habitat for both human and wild life. Farmers adopt agro forestry practices for two reasons. They want to increase their economic stability and they want to improve the management of natural resources under their care [2]. During this time due to the high income source coffee based agro forestry systems are strongly developed and cultivated by many farmers. Because of the reduction of land and the need to increase income from coffee monoculture system, the introduction of multi-purpose timbers in to this system is a good system to get different benefits simultaneously. As Travis and Adel (2010) said many small coffee farms around the world incorporate trees as part of the production system, as wind breaks, for landscaping around the home and to protect the coffee plants from excessive sun and high temperature [3].

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LITERATURE REVIEW

Concepts of perennial type agroforestry system

Based on World Agro forestry Center (ICRAF) definition "Agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos etc.) are deliberately used on the same land management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence''.

According to Nair (1993) shows that agroforestry can be classified based on different basis. These are;

- Structure of the system (nature and arrangement of components).
- Function of the system (role and output of components).
- Agro ecological zones where the system exists or is adoptable.
- Socioeconomic scales and management levels of the system.

Since there are only three basic sets of components that are managed by the land user in all agro forestry systems (woody perennials, herbaceous plants, and animals), a logical first step in classifying agroforestry should be based on the nature of these components.

Therefore according to their components, their lay out, or purposes agroforestry can be classified in to three groups;

- Agrisilvicultural/Tree with crops.
- Silvopastoral/Trees with pasture and livestock.
- Agrosilvopastoral/Tree with crops and pasture and livestock.

There fore based on the above classification perennial type of agro forestry is one of the agro forestry types which are categorized under agrisiviultural system.

Shade tree planting-agro-forestry system

Integrating tree growing with crop production in agroforestry system helps to increase agricultural production, minimize environmental degradation, increase the availability of firewood and improve the availability of fodder for animals. In addition to this planting shade tree contributes to the conservation of biodiversity.

But when we select seedlings to plant for shade it is important to plant shade trees species that do not compute with the coffee trees for nutrients. According to different studies conducted by various scientists shows that planting of shade trees in association with other crops has its own advantage and disadvantage [5].

Advantages of including shade trees with perennial crops

Planting shade tree in association with perennial crops has different uses for the environment and plant it self. Those are;

Consequences which facilitate crop management

- Prevention of overbearing results in less variable annual yields which, over a long-term, permits a more efficient utilization of labor and machinery during harvesting and processing.
- Suppression of weed growth.
- Product diversification, e.g. fruits, timber.
- Shade may improve the quality of the crop, e.g. coffee.
- Control of crop phenology, e.g. fruit setting and maturation, by manipulating the environmental conditions through the careful timing of shade tree pruning or the use of an appropriate deciduous tree species [4].

Beneficial influences on the hydrological cycle

- Reduction of evapo transpiration of the shaded crop.
- Removal of excess soil moisture by transpiration of a heavy shade tree cover.
- Increased moisture input through horizontal interception of mist or clouds.

Protection of the crop from pathogens, insects and adverse climatic conditions

- Extension of the productive life of the crop.
- Reduction of air, soil and crop leaf temperature extremes, and in some cases improvements of the microclimate for the crop, e.g. higher humidity.
- Reduction of damage caused by hail and heavy rain.
- Reduction of some diseases, pests and parasitic plant infestations.
- Reduction of wind velocities in the crop strata.

Improvement of soil fertility and soil protection

- The growth of the shade tree root system can improve soil drainage and aeration.
- The provision of a soil mulch (which helps retain soil moisture during the dry season) and an increase in the soil organic material from natural leaf fall and pruning residues.
- Reduction of erosion on slopes.
- Reduction of the decomposition rate of soil organic material (because of reduced soil temperatures).
- Recycling of nutrients which are not accessible to the crop.
- Nitrogen fixation by shade tree root nodules.
- Increased soil organic matter due to shade.

Disadvantages of including shade trees with perennial crops

Consequences which hinder crop management:

- Natural fall of branches and trees, or the harvest of mature trees, will damage the understory crop.
- Sudden defoliation of the shade trees, by insects or disease, could cause severe shock to a shade adapted crop and consequent die back.

- Additional manual labor is necessary for combinations where the trees are regularly pruned.
- Mechanization of the underlying crop is hampered.
- Establishment of erosion control structures (e.g. terracing) is hampered once the trees are established.
- New crop varieties are invariably bred for monocultural condition and may not be suitable under shade.
- Heavy shading can reduce the quality of a crop.

Detrimental influences on the hydrological cycle:

- Shade tree root competition for moisture during the dry season and oxygen during the wet season.

Promotion of adverse influences such as pathogens, insects and detrimental environmental conditions:

- Reduced air movement and increased humidity may favour fungal diseases.
- Insect attack may be greater when the crop is shaded.
- Allelopathic effects.
- Shade trees can act as alternative hosts for pests and diseases.
- In addition to reducing the quantity of available light and hence yields on fertile soils, shade trees reduce the quality of transmitted radiation since there is a preferential absorption of photosynthetically useful radiation.

Reduction in soil fertility (with respect to the associated crop) and increased erosion:

- Shade tree root competition for nutrients.
- Stem flow, and the drip of rain drops which coalesce on shade leaves, can adversely redistribute rainfall thus increasing erosion, crop damage, and reducing moisture absorption by the soil.
- Harvesting of fruit and/or wood from the shade tree constitutes an additional drain of nutrients from the site.

Desirable characteristics for perennial crop shade trees:

As we discussed in above topic planting of shade trees in association with crops proved different benefit for the environment, crop and the shade tree it self. To get all the necessary benefit from that shade tree appropriate selection of shade tree must important. According to Beer (1987) study tree which are selected for shade must be fulfilled the following criteria's. Those are;

- Compatibility with the crop, which means minimal competition for water, nutrients and growing space, e.g. does not produce suckers; the crown branches above the crop; deep rooting; minimum overlapping of under story and over story species root zones.
- Strong rooting systems (not susceptible to wind throw). Shade trees are more exposed to adverse climatic conditions than are trees in a forest or a plantation and should be capable of adaptation to open-grown conditions.
- Rooting ability of stakes to permit rapid shade establishment by vegetative propagation.
- Ability to extract soil nutrients which are not trapped by the crop.
- Ability to fix nitrogen.
- A light crown that provides a regular mottled shade pattern rather than uniform shadow of photo synthetically poor quality light.
- In the case of (timber producing species). A small diameter light crown to: a) reduce the wind resistance of the foliage and hence the risk of wind throw, b) permit relatively high shade tree densities without reducing light levels below critical values for the crop; and c) minimize crop damage when individual trees (continuous timber yield system) are harvested.
- Non-brittle branches and stem.
- Thorn less stem and branches to facilitate management.
- Rapid apical growth.
- Self-pruning and the ability to form a straight un forked stem in open-grown conditions.
- Tolerance of repeated heavy pruning or pollarding.
- High biomass productivity of material that is recycled, through leaf-fall and/or pruning.
- Readily decomposed leaves and woody material.
- If deciduous, rapid flushing of new leaves to regenerate the shade cover.
- Absence of major disease or insect susceptibility which could lead to sudden defoliation.
- Small leaves to minimize rain drop coalescence and subsequent drip damage.
- No allelopathic properties.
- Smooth bark that does not harbor epiphytes.
- Valuable wood, fruit or other product.
- Not an alternative host for insects and pathogens which are major enemies of the crop.

Shade tree and coffee production

Coffee is one of the most expensive types of crop in the world. Due to the high stimulant value, Coffee is highly desirable crops in all areas. Growing coffee under shade trees is one of the fundamental principles in traditional organic coffee growing systems. Shade trees reduce excessive light, mulch the soil with their litter, create hostile conditions for pests and diseases, and harbor a variety of predatory animals. According to Jordan in world coffee prices increment and an increase in '' green consumerism '' promote the role of shade trees in coffee production. Certification which is given for shade grown coffee (organic coffee) is initiate farmers to expand shade grown coffee than conventional (non-shaded) coffee plantation. Organic coffee is one of several types of specialty coffees selling at a premium over main steam coffees because of distinct origin and flavor, environment friendly production or socioeconomic concerns for the small holder coffee growers.

Basically there are two ways of producing coffee, the industrial coffee grown under the sun and traditional coffee grown under the shade. The first refers to a virtual monoculture of coffee that may include moderate to sparse shade cover of single species or in some cases no shade at all. The second system refers to a canopy covered coffee farm with a mixed plant community in the over story [6].

Due to the high structural complexity of the shaded coffee plantation offers living and nesting sites for a variety of organism. In addition to increasing primary structural diversity of foliage layers, the canopy of plantation can support secondary structures comprised of epiphytes parasites, moss, and lichens which in form support a community of arthropods, amphibians', and other creatures. Also shade tree in coffee plantations used as a source of food for the fruit and seed eating bird species. Shade trees assist in maintaining coffee yields in the long term by reducing periodic over-bearing and subsequent die-back of coffee branches. In addition, shading delays the maturation of coffee berries resulting in a better bean filling and larger bean size resulting in better coffee quality.

In our country Ethiopia, coffee was cultivated in this traditional way following the principles that lammerts and struik (2004) called 'the concept of naturalness'. In this system Soils were amended by applying compost, farm yard manure and green manure, while no chemical fertilizers, herbicides or fungicides were used. However, as demands for coffee production expanded, many coffee growers abandoned their traditional coffee growing system and started to grow coffee without shade trees. This new coffee production system was accompanied with intensive use of chemical fertilizers, insecticides, herbicides and fungicides resulting in blended and inferior coffee quality. Coffee plants in direct sunlight also showed a higher incidence of premature death.

Generally providing of shade in coffee production is important because:

- It reduces moisture loss from the soil.
- It reduces the temperature and air flow around the coffee trees and as a result reduces transpiration from the leaves.
- It improves the quality of the coffee through a slower ripening process.
- Shade trees provide natural mulching material when the leaves fall to the ground.
- Nutrients are returned back to the soil when the fallen leaves decompose.
- It can provide additional benefits to the farmers such as fruit for consumption, fodder for animals, timber, firewood, etc.

Environmental uses of shaded coffee

According to different research result shows soil temperature and light intensity of shaded coffee plants were significantly lower than those of coffee plants grown in direct sun light, whereas the relative humidity of the air of the shaded plants was significantly higher than that of plants grown in full sun light. Air temperature did not differ significantly [7].

Impacts of shade in plant variables

Coffee plants grown in the shade had higher values for SLA, LAI and leaf nitrogen content. Shaded leaves were also darker in leaf color than leaves from plants grown in direct sun light.

Impacts of shade in quality and yield

Bean weight and size assessment made on harvested coffee beans indicated that beans developed under shaded condition were heavier and larger in size and had better liquor taste than those developed on plants grown in direct sun light. No treatment difference was observed with respect to raw coffee quality. However, greater yields were obtained from un-shaded coffee plants but this is statistically not significant.

Organic coffee

Organic coffee is coffee which is grown naturally under shade without addition of artificial fertilizer, pesticides, herbicide and any other industrial chemical. This species is classified under rubiaceae family. Coffee is the most important raw material traded throughout the world behind crude oil, and has become the most important export commodity for the nations that grow it. Coffee is the second drunk beverage, the second highest commodity in demand and the third most chemically treated product. So, whenever 'organic' coffee is mentioned, the first thing that comes to our mind is the absence of harmful chemicals found in conventional coffee as a result of chemical fertilizers and pesticides used in cultivation of coffee. While this is true, it is not the only aspect of organic coffee. It involves how the coffee beans are cultivated, the production standards and the methods of roasting coffee beans. The difference between organic coffee and regular coffee is in the process of coffee cultivation [8].

According to van Der Vossen, H.A.M. (2005) Organic coffee is one of several types of specialty coffees selling at a premium over mainstream coffees because of distinct origin and flavor characteristics, environment-friendlier production systems (certified organic, shade-grown, bird-friendly) and socio-economic concerns for the smallholder coffee growers [9].

In our world organically produced foods started to gain popularity some 30 years ago, especially with urban consumers in Northwest Europe, North America and Japan, out of concern for the perceived negative effects of conventional (high-input) crop production on the environment and human health. Organic agriculture is claimed to combine superior ecological sustainability with lower health risks and sound economic viability based on the following principles [10].

- Composted organic matter to improve soil quality (no inorganic fertilizers).
- Soil conservation (contour planting, terracing, cover crops, mulch, shade trees).

- Disease, pest and weed control by 'natural' methods only (no synthetic pesticides).
- Minimum use of fossil fuels in the production system.
- Low environmental pollution during post-harvest handling.

Organic coffee production has to follow these practices, such as the regular application of composted organic matter, 'natural' methods of disease and pest control, and (leguminous) shade trees [11].

Effects of shade trees on coffee plantation

The reduction in soil temperature, observed under shade, was mainly caused by the ability of shaded soil by plants to stabilize the local thermal balances and also to reduce the heat flux caused by the accumulated plant based biomass. also clarify that shading reduces, modify and stabilizes the soil temperature by reducing the radiant flux reaching the soil and modifying the temperature amplitude at the soil surface. Reduced air temperature was mainly due to the reduced direct incidence of solar radiation on the coffee canopy. Shading buffers the extreme temperature variations and provides a microclimate which attenuates extreme temperatures of air and soil and preserves surface soil humidity [12].

According to cited in there is high biochemical and physiological potential for a high carbon fixation capacity. To increase their carbon fixing potential, shaded plants undertake certain modifications such as developing thinner and larger leaves with more thylakoids per granum and more grana per chloroplast. These modifications allow them to efficiently capture and utilize the available light energy in order to increase their dry matter production. Plants having higher SLA exhibit higher productivity and have higher potential relative growth rate than those having lower SLA.

The darker green color of coffee leaves developed in the shade was most likely associated with the larger amount of nitrogen accumulated in them. Leaves which have dark green color absorb more light, have chloroplasts with improved light capturing capability and increase their photosynthetic rate. According to Van Der Vossen, H.A.M. (2005) provision of shade trees for coffee plantation has its own effects both on the surrounding environment and on the shaded plant it self. Those effects can be categorized in to positive and negative [13].

Positive effects

- Reducing the extremes in high (low altitudes) and low (high altitudes) air and soil temperatures.
- Breaking the force of wind and heavy rainfall.
- Controlling erosion on steep slopes.
- Suppressing weeds.
- Producing annually 5-15 t (dry weight) organic matter per ha from litter and pruning's.
- Recycling of nutrients otherwise not available to the coffee and reducing nutrient leaching.
- Preventing over-bearing and shoot dieback as a result of reduced light intensity.
- Providing additional revenue from the shade trees (timber, firewood and fruits) and support for secondary crops eg. Wine trees.
- Potentially reducing incidence of diseases (e.g. leaf rust) and pests (e.g. white stem borer).
- Improving cup quality, particularly in ecologically sub-optimal coffee zones (high temperatures).

Negative effects

- Progressively lower yields with increasing shade intensity, due to a reduction in flowering.
- nodes, inflorescences per node and flowers per inflorescence.
- Competition for water between shade and coffee trees in seasonally dry regions.
- Damage of the coffee trees by falling branches from the shade trees and occasional tree felling.
- Additional labour costs for regularly pruning of over-head trees to avoid excessive shading.
- Potential increase of some diseases (e.g. leaf spot) and pests (e.g. coffee berry borer).

Shade grown coffee and climate change mitigation

During this time the whole world affected by the impacts of climate change. Even if the cause climate change is different change due to deforestation is take a larger degree. Due to the severity of the problem, many country plan to change this atmospheric pollution by using different means. But the only way to reduce climate change impacts are by reducing the amount of CO_2 released in to the atmosphere and improve the vegetation cover swhich reduce atmospheric CO_2 by absorbing from the atmosphere [14].

Agroforestry system by its nature includes different types of components. But the tree components are one of the major components which are included in this system. Shade tree based coffee production system is also one of the agroforestry system which uses tree as a major components for the provision of shade. The other is due to global warm problem the weather condition of the physical environment was changing in rapid rate. To overcome different climate change problem expansion of climate change mitigation program is the only option. Agroforestry system which is adapting agriculture to climate change have been shown to increase on-farm production resilience to climate variability by buffering crops from the effects of temperature and precipitation variation as well as strong winds associated with storms. In shaded coffee agroforestry systems, crops grown under heavy shade (60%-80%) were kept 2°C-3°C cooler during the hottest times of the day than crops under light shading (10%-30%)) and lost 41% less water through soil evaporation and 32% less water through plant transpiration. Windbreaks planted in citrus groves have been shown to reduce wind speeds by 80%-95%,

reducing wind damage up to two times the distance of windbreak height. Agroforestry systems also tend to have increased crop diversity within the agroforestry systems such that a greater diversity in food, fuel, and fodder items is produced for the smallholder farmer. There are other naturally occurring co-benefits that occur in agroforestry systems including enhanced nutrient cycling, integrated pest management, and increased resistance to diseases, which will additionally protect farm production [15].

Creating agroforestry systems that reduce the outward flux of CO_2, N_2O, and CH_4 through better management will contribute significantly to reducing GHG emissions, and mitigation studies have identified agroforestry systems as a potential long term GHG sink. The carbon sequestration potential of agroforestry systems is estimated to be between 12 and 228 Mg C ha^{-1} with a median value of 95 Mg C ha^{-1}.

For smallholder agroforestry in the tropics, potential carbon sequestration rates range from 1.5-3.5 Mg C ha^{-1} yr^{-1}. Selling carbon credits may provide another source of income for farmers, diversifying their agricultural productivity. Policy analysis has shown that at prices of $100 per MgC, carbon sequestration in agroforestry systems would have the potential to raise per capita incomes of farmers by up to 15%. For these reasons, agroforestry systems may prove to be very useful component of agricultural adaptation as both an economically feasible adaptation strategy for smallholder farmers vulnerable to climate change as well as a profitable greenhouse gas mitigation opportunity [16].

CONCLUSION

Using of shade tree in coffee production is used to reduce excessive sun light from coffee and shades suffer the coffee from stress and have high biochemical and physiological potential for carbon sequestration both in the biomass and soil. Shade grown coffee plants also produce larger and heavier beans with a better coffee taste than coffee grown in the direct sun light. Also using of shade trees in coffee production provides additional income like fruits, fuel wood and timber.

In addition to this due huge carbon sequestration potential of trees and soils under the tree this system opens new financial income in the area of carbon trade. Since using of shade trees in coffee production system has various environmental uses and great impacts on the quality of yields, expansion of shade trees the most important thing. But during shade tree expansion detail information is must be required on the type of species and its density of planted shade trees. This system helps to reduce the negative effects of shade trees on the coffee. Because of the above mentioned reasons using of shade in coffee production is socially acceptable, economically more viable and environmentally sustainable.

Ethiopia is one of the most organic coffee producing and exporting country and Coffee is the back bone of Ethiopia economy due to its foreign currency.

But during time due to excessive deforestation and expansion of agricultural land the type of shade tree species and density of shade trees was declined. There for expansion of shade tree based coffee production of agroforestry system in this country in the most important solution to increase organic coffee quality and yield and to get more foreign currency.

Also to get additional income from carbon trade as well as to mitigate climate change impacts expansion of shade tree based coffee production agroforestry systems is one solution for this country.

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