



## GHGs Reduction Capacity of Agroforestry Systems in Tropical Africa: A Review

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### Abstract

The main crucial agroforestry systems (AFS) of tropics Africa are homestead, woody species planting, multistory dwelling and spread the woody plants. Traditional AFS interaction is important for shading Coffee tree, improving soil fertility, climate regulation, alternative income source, and reducing the pressure on natural forests. These systems are important for ecological balance and human wellbeing. This review was aimed to explore the capacity of AFS for reduction of GHGs from atmosphere and mitigate climate change in tropical Africa. AFS has sequestered significant amount of CO<sub>2</sub> and reduced GHGs sink from the atmosphere. Several research reports were recognized as AFS has been substantially carbon-capturing from the atmosphere compared to the mono-crops, dry woodlands, and pasture land. In tropical Africa region AFS has been estimated to 2.11 × 1091 Mg C yr<sup>-1</sup> of aboveground biomass carbon sequester. Multi-strata AFS was reported highest (16-36 Mgt ha<sup>-1</sup> yr<sup>-1</sup>) amount of carbon sequestration. Soil organic carbon (SOC) stock of fruit-coffee, coffee-enset and enset system agroforestry systems were estimated 186.41 Mg ha<sup>-1</sup>, 178.8 Mg ha<sup>-1</sup> and 177.8 Mg ha<sup>-1</sup> respectively at 0-60 cm soil depth. According to Intergovernmental Panel on Climate Change (IPCC) and several research results, nowadays AFS development was one of well recognized to climate change mitigation strategy. Multipurpose tree management on farm land and grazing land is strongly recommended for increased GHG emission reduction capacity of AFS in tropics.



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### Introduction

Today climate change is a global problem that has already had a practical force on species diversity and

natural as well as made ecosystems.<sup>1</sup> According to IPCC, <sup>2</sup> temperature is expected to rise at a range of 1.10–6.40°C at the end of the twenty-first century

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from 1980–1999 baselines. The tropical Africa region is vastly susceptible to climate change. In general, temperatures of this region have already been risen by 0.7°C throughout the 20s.<sup>3</sup> In Africa temperature rise is predicted with a range of 0.2°C per decade to more than 0.5°C by low scenario and high scenario, respectively,<sup>3,4</sup> while the rainfall distribution of tropical Africa region is sensitive to variability.

The magnitude and occurrence of extreme events such as episodes of El Niño–Southern Oscillation, that is, El Niño and La Niña are linked to climate change in the tropical Africa region.<sup>5,6</sup> Climate variability and extreme events have impacts on Ethiopian ecosystems.

The Ethiopia agriculture productions are substantial depend on precipitation patterns especially crop, loss of livestock, natural resource degradation, and even famines in the past. According to the National Meteorological Agency (NMA),<sup>7</sup> Ethiopia has faced ten dry years and eleven wet years over the last 55 years. The annual minimum temperature between 1951 and 2006 was increased by about 0.37°C every 6 decades; that is 0.3°C high lands and 0.4°C low lands in Ethiopia. However, the outcome of IPCC midrange release scenario shows that compared to 1961-1990 average, the average yearly temperature throughout the country will rise by ranging from 0.90°C to 1.1°C in the year of 2030s and with ranging 1.70°C to 2.1 90°C in the year 2050s.

Afforestation and reforestation activities have the potential to change about 20- 30% reduction of atmospheric CO<sub>2</sub> through carbon capturing and also by assisting in adaptations for sustainable development.<sup>8</sup> Agroforestry is considered as exceptional consign to reducing emissions from deforestation and forest degradation (REDD+) and national appropriate mitigation actions (NAMAs) strategies and also recognized GHGs emission reductions capacity well as conserve biodiversity and enhance livelihood benefits in different countries. Agroforestry systems can reduce outward flux of CO<sub>2</sub>. Mitigation studies were identified as the capacity of agroforestry systems (AFS) to have long term greenhouse gas (GHG) capturing.<sup>9</sup> it has been well acknowledged the capacity for sequestration rate of carbon through the growing process with all the system of in the agricultural and forest land dynamics, and Forestry report of the IPCC.<sup>10</sup>

The integration of woody plants on farmland or pastures can raise the quantity of sequestered carbon, which has a substantial total biomass carbon stored with relative to a single crop plant or pasture lands.<sup>11,12</sup>

For these reasons, AFS are more fruitful for taking up a huge quantity of CO<sub>2</sub> from the source and stoking carbon in live vegetation biomass, organic matter of soil, and harvested wood products.<sup>13</sup> Now day AFS is expected to be experienced on 1000 to 1023 Mg C ha<sup>-1</sup> worldwide and to sequester from 30.0 to 322 CPgyr.<sup>14,15</sup> This review paper aimed to assess the AFS capacity of environmental services and mitigation reduction capacity in tropical Africa and Ethiopia.

In many African countries sustainability of different land uses management and ecosystem change is facilitated in REDD+ policies. For example, the farming systems are taking the majority serious threat to the sustainability of the natural resource and it also highly contributes to GHG emissions in Ethiopia. Hence REDD+ is predictable to facilitate reverse this trend.<sup>10</sup> Most time land-use competition, land tenure forest resources, continuous population growth, and rudimentary farming techniques were significantly affected forest resources in Ethiopia.<sup>16</sup> To maintain those problems, established agroforestry can aid to decrease demands on remains of natural forests from deforestation and to enhance the soil fertility and productivity.<sup>17</sup> The AFS are “triple win”; i) important that reduction of CO<sub>2</sub> from the atmosphere, ii) adaptation option as support or improved the livelihoods incomes of society , and iii) sustain the productivity as does REDD+ and also enhances to economical benefits through carbon funding to support the forestry development in the region.

### Materials and Methods

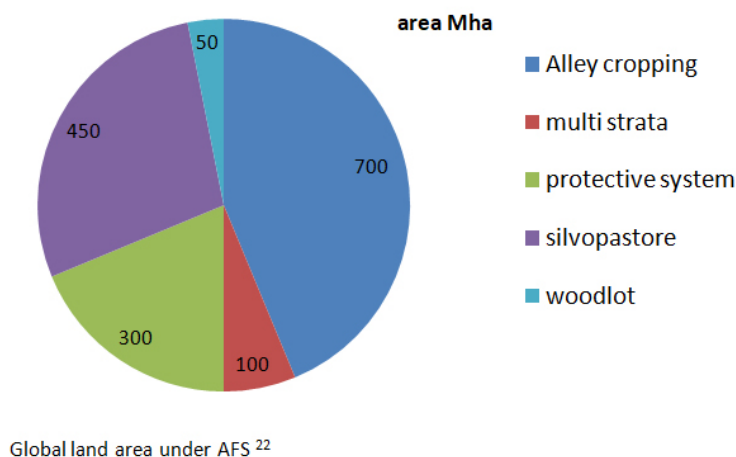
The presented data in this were compiled from open access documents in wide relevant sources (such as, published articles, books, dissertations and conference proceedings) and also including Google Scholars were browsed by putting some important key words. The main target reaching phrases/terms are biomass carbon in AFS, soil carbon stock in AFS, climate change, carbon sequestration of AFS, factors affecting carbon stock. The collected material were targeted traditional AFS in tropical region.

**Result and Discussion**

**Concept of Agroforestry**

The concept of agroforestry is a land ecosystem that integrates woody plants with crops, and/or animals on the same piece of the land system to enhance productivity, larger financial income, and more societal benefits on a sustained basis.<sup>18</sup> According to Nair,<sup>19</sup> AFs generally were categorized into three main aprts viz. agrisilvicultural, silvopastoral, and agrosilvopastoral. The familiar conventional

agroforestry practices (AFP) are scattered trees on crop fields, homestead tree planting, and multistory home garden in the tropical region.<sup>19</sup> land coverage of global agroforestry system is presented in Figure 1. According to Ashagre,<sup>20</sup> and Bekele,<sup>21</sup> common AFP in various parts of this region as coffee shade based sprinkled woody plant on the cropland, homestead, pieces of a land plantation, border of plantation practices, and woody plant on pasture lands.



**Fig.1: common AFS land cover in the world**

**Major Agroforestry Practices in Tropical Africa**

The agroforestry concept in tropical Africa is not new. This is a much old practice whereby small holder farmers maintain various woody plants on croplands. Major tropical agroforestry practices are alley cropping (hedgerow intercropping), homestead,

boundary planting, improved fallow fast-growing, versatile woody plants on farms land and grazing land, silvopasture, grazing systems, cut and carry system (protein banks), shaded perennial–crop systems, shelterbelts, windbreaks and taungya.<sup>22</sup>

**Table 1:Area coverage and production of the three cash crops during 2010-11 in Ethiopia**

cash crops	No. farmers	Area of cultivation		production	
		Area (ha)	Sharing (%)	Ton	Share (%)
Fruit	2658415	51,078	9	403459	45.6
Khat	2068262	214112.19	37	244641.96	27.1
Coffee	3049120	313608.98	54	253038.38	28.3
Total	7775797	578799.17	100	901139.34	100

Source: Woldu, et al., 15

Parkland and home gardens are the well-accepted AFS in most parts of the tropical region especially in Africa (e.g. Ethiopia, Kenya etc.).<sup>23</sup> Additionally, nine types of profitable AFPs for ecological and socio-economic services were identified in various parts of Ethiopia. These are, banana-based multi-story gardens, teff, and acacia species integrated with crop, boundary eucalyptus and cereal crops, conservation-based vertically and horizontally packed agroforestry, multi-strata perennial crop, enset-coffee-tree-spice-based, fruit trees-bamboo combined with enset-vegetable farming and bamboo combined with cereal farming agroforestry.<sup>24</sup> Area coverage and production of some major cash crops are presented in Table 1.

The main Cash crop AFS are coffee, khat, and fruit-based systems in the country. According to,<sup>24,25</sup> the coffee-based system is occupying over

9.80 million ha of land worldwide. Ethiopia has four coffee production systems of AFS such as forest coffee, semi forest coffee, garden coffee, and plantation coffee.<sup>25</sup>

### Agroforestry for Ecosystem Services

Ecosystem services are defined in different aspects, including “the benefits human populations derive, directly or indirectly, from ecosystem functions”.<sup>27</sup> According to the millennium ecosystem assessment (MA)<sup>28</sup> a worldwide program was set up in 1999 to evaluate how ecosystem change would affect human well-being. The communities are benefited from the ecosystem in the form of supporting services, provisioning services, regulating services, and cultural services. The benefits community gain from ecosystems through religious enrichment, cognitive development, education, recreation, and aesthetic experiences.

**Table 2: Ecosystem service of AFS for local, regional and worldwide level.<sup>35</sup>**

Ecosystem Services	Special Scale		
	Farmer/ Local Level	Landscape/Regional Level	In the world
Production of net primarily			
Control of pest			
Pollination/Seed dispersal			
Soil improvement			
Soil stabilization/ control of erosion			
Maintain hydrology and Air cycle			
Regulation of flood			
Carbon Sequestration rate			
Genetic resource conservation			
Aesthetics/Cultural			

Agroforestry systems can contribute to environmental functions. Humans have always depended on the natural world for ecological assets like freshwater, nutrient cycling, and soil formation. Simultaneously reducing greenhouse gas concentration by sequestration of CO<sub>2</sub>.<sup>29</sup> The systems have been understood as one of the incorporated forest and soil resource management interventions for addressing a variety of ecological and community challenges. Integration of woody plants, cash crops and field

crops or livestock into an AFS has the likelihood to improve soil productivity, decrease soil degradation, maintain water cycle, enrich biodiversity, and increase the aesthetics and storage of carbon. The Ecosystem service of AFS in local up to worldwide level was presented Table 2. According to Sileshi *et al.*,<sup>30</sup> agroforestry practices services have been three category in southern and east Africa. A. Provisioning services such as genetic resources, food, basis of power, and feed, e.g. over 80% of

the rural society in southern Africa also depends on therapeutic plants for most of their health needs. B. regulatory services including microclimate stabilization, regulation of flood, alleviation of land degradation, reduction of GHG emission, and pest control, and C. supporting services namely, soil fertility enhancement, diversity maintenance, and pollination in the miombo eco-region.

Agroforestry has a great role to mitigate climate change and different sources of income in developing countries, especially during the systems for storing and compensating for carbon sequestered in agroforestry become communal obtained to the small-scale farmers.<sup>31, 32, 33,34.</sup>

### **Agroforestry and Climate Change Mitigation**

Tropical agriculture systems are highly exposed to climate variability and prone to change, which are agriculture is substantially vulnerable to climate variability and/or change, especially smallholder farmers do not have sufficient wealth to adapt to climate change. While AFS are recognized for REDD+ strategy, that has a great play of substantial function in mitigating climate change through the reduction of GHG emission from the atmosphere this is also contributing to play in serving human being adapt to climate change.<sup>36</sup>

Agroforestry practices are containing annual, perennial plants and- livestock. Climate elements (temperature, relative humidity, and ambient CO<sub>2</sub>) concentration affect all organisms involved in an AFS, possibly in very different ways, and climate change is projected to alter all of these factors. For climate change mitigation, woody plant-based farming systems are at present being encouraged in many parts of developing regions including tropical Africa.<sup>37</sup> Trees management based agroforestry systems have a substantial play in the reduction of GHG concentration from the atmosphere and also direct targets of reduced emissions from deforestation and forest degradation (REDD+) programs.

### **Carbon Sequestration Rate Capacity of Agroforestry Systems**

Sequestration rate of carbon is the subtraction of additional carbon from the ambiance and depositing it in another reservoir principally through the

change in land use,<sup>10</sup> And also also defines carbon sequestration as the process of removing C from the atmosphere and depositing it in a reservoir. From the agro forestry point of view, C sequestration primarily involves the uptake of atmospheric CO<sub>2</sub> during photosynthesis and the transfer of fixed C into vegetation, detritus, and soil carbon pools for protected (i.e. long-term) stock. Different studies are encouraging widely implemented AFS as a strategy of carbon sequestration rate that is focused on carbon-rich multistory AFS in the moist tropical forest.<sup>38,39</sup> Drylands tropics have a shortage of information on the capacity of carbon sequestration<sup>38</sup> and also in meticulous about AFS carbon sequestration rate in sub-Saharan Africa<sup>40</sup> and Eastern Zambia.<sup>41</sup>

The agroforestry system offer opportunities for creation between adaptation mitigation that have the potential of carbon accumulation from 391,000 Mg C yr<sup>-1</sup> from 2010 to 586,000 Mg C yr<sup>-1</sup> 630 M ha of marginal crop and grasslands could be converted to AFS by 2040 in the tropics.<sup>35</sup> Estimation of capacity of sequestration rate of carbon from aboveground biomass to be  $2.1 \times 10^9$  Mg C yr<sup>-1</sup> from AFS in tropics,<sup>42</sup> as well as agroforestry systems, were practiced by individual farmers have potential to C sequestration rate ranged from 1.50 to 3.50 Mg C ha<sup>-1</sup>yr<sup>-1</sup> in the tropics.<sup>43</sup> However, net carbon balance in all carbon pools varies based on the kind of AFS, with reported C changing from a range of 0.31 up to 7.71 Mg C ha<sup>-1</sup> y<sup>-1</sup> in biomass and 1.01 up to 7.40 Mg C ha<sup>-1</sup> y<sup>-1</sup> in soil.<sup>45</sup> It has indirect effect on systems structure, composition, and management on carbon capturing ability in each component.

Agroforestry systems are alternative resource for reducing natural forests overutilization and also it is one of the largest sinks of terrestrial carbon, enhance carbon storage in woody (tree) and soil. However, estimating the carbon sink capacity of AFS in the drylands is important for carbon accounting purposes. Due to low vegetation growing and cover and inherently low soil C levels, these areas have low C stocks. However, these dryland areas transformed into agroforestry land use seems to possess a massive capacity to capture carbon from the ambiance. Moreover, the extent to which planted tree fallow systems, such as rotational woodlots, reduce harvesting pressure of the native forests in

semiarid zones and thereby offset CO<sub>2</sub> emissions has been minimally investigated Biomass Carbon Stock in Agroforestry Systems

### Biomass Carbon Stock in Agroforestry Systems

According to Kyoto protocol, action of afforestation and reforestation (A & R), AFS was accepted as an action which paid attention to special recognition as a C sequestration policy. This recognition was the reason for growing structure that accumulated the highest amount of aboveground biomass (AGB) and root development process of the woody plant in the AFS. So far several types of research outputs were indicated AFS under different ecosystem regions have C sequestration potential became obtainable since the mid 1990s starting. Most of these available reports on biomass carbon sequestration rates

and stocks in tropics are presented in table 3. The above ground biomass- and belowground (root biomass plus soil) are estimates ranging from 0.29 up to 15.210 Mg C ha<sup>-1</sup> yr<sup>-1</sup> in AFS.<sup>31</sup> The Cocoa-dominant AFS are recognized for storing a substantial quantity of carbon in the systems.<sup>33</sup> For this reason, it has been possible to mitigate climate change. Besides, shaded agroforestry systems with perennial crops like coffee (*Coffea arabica* L.), rubber (*Hevea brasiliensis*) (could help to mitigate climate change and cocoa may vary between 12 MG C ha<sup>-1</sup> and 228 Mg C ha<sup>-1</sup>.<sup>22</sup> Similarly, Negash and Starra<sup>32</sup> fruit-coffee, coffee-Enset and Enset systems of carbons stock vary within 22 Mg ha<sup>-1</sup> and 122 Mg ha<sup>-1</sup> in Refit valley Ethiopia.

**Table 3: Mean biomass carbon stock potential agroforestry systems in some tropical regions**

AF System	Sub systems	Location	Mg C ha <sup>-1</sup>	citation
Multi strata	Inga-coffee, pines-coffee, coffee	Humid tropics	60.6,124 &107	Lenka et al., <sup>47</sup>
Multi strata	Home garden	Tropics	101-126	
Silvopasture	Browsing system	Sami tropics	6.55 yr	Shreshtha & Alavalupati <sup>12</sup>
Woodlot	Fodder (acacia. Spp.)	Tropics	180	
Parkland	Faidherbia albida	West African Sahel	54	Takimoto <sup>40</sup>
Parkland	Vitellaria paradoxa	West African Sahel	22.4	Takimoto <sup>40</sup>
Live fence	Acacia nilotica	West African Sahel	8.3	Takimoto <sup>40</sup>
Fodder bank	Gliricidia sepium	West African Sahel	4.1	Takimoto <sup>40</sup>

Source: Nair et al.,<sup>22</sup>

Major Agroforestry systems of biomass carbon stock in the tropical regions AFS help in locking higher amounts of C, and their CO<sub>2</sub> mitigation capacity can be enhanced by substituting suitable tree and annual crop species in existing agroforestry systems.<sup>46</sup>

Many factors are affecting biomass carbon accumulation, including the species growing nature, land suitability, age, application and type of managing carry out and their interface within the woody plant and cash crops of the understory in an AFS.<sup>5</sup> Total (above + below ground) biomass carbon stock in the specific country was indicated in Table 4. The highest of 239 Mg C ha<sup>-1</sup> from the woodlot, followed by 123 Mg C ha<sup>-1</sup> in alley cropping

and 77 Mg C ha<sup>-1</sup> in the multi strata systems total biomass carbon stocks were reported.<sup>48 32</sup> in Ethiopia, Malawi, and Ethiopia, respectively.

### Agroforestry systems and Soil Organic Carbon Stock

Soil is one of the large amount of carbon storage pool, it contains about 2,500 pg and it is four times a biotic pool (560 pg) and also it has three times higher than the full of atmospheric carbon concentration (760 pg).<sup>53</sup> The soil organic carbon content 58- 81% was taken up to 50cm depth. The recent studies reported a global SOC across all estimates of mean value 1460.50 Pg carbon, ranging within 504 to 3000 Pg C.<sup>53</sup> The soil C stock agroforestry varies

based on systems 124.29, 160.42 and 84.69 Mg ha<sup>-1</sup> on mixed multistory, taungay, and falcata-coffee multistory AFS respectively.<sup>54</sup> The different scholars, AFS soil organic carbon stock reports in table 6. The soil organic carbon (SOC) stock was highest in fruit-coffee, coffee-enset and enset agroforestry

systems were estimated 186.4 Mg ha<sup>-1</sup>, 178.8 Mg ha<sup>-1</sup>, and 177.8 Mg ha<sup>-1</sup> at 0-60 cm depth respectively. The lowest amount of SOC stock was present 24 Mg ha<sup>-1</sup> in live fence at 0-100 cm depth in Mali and land Agri silviculture (Gmelina arborea + field crops) for 27 t ha<sup>-1</sup> at 0-60 cm depth in central India.

**Table 4: Mean biomass (above +below) carbon stock in humid tropics and tropical African countries including Ethiopia**

AF System	Sub systems	Country	Mg C ha <sup>-1</sup>	citation
Woodlots	L. leucocephala species.	Zambia	24.5 - 55.9 & 74	Kaonga, <sup>41</sup>
Woodlots	Fodder bank	Mali (ST)	0.29 yr	Kumaret al. <sup>49</sup>
Woodlots	Live fence	Mali (T)	24	Kumar et al. <sup>49</sup>
Multi-strata	Shade coffee system	Togo	6.31/yr	Dossa et al. <sup>50</sup>
Multi-strata	L. leucocephala + maize	Nigeria (HLT)	13.6/yr	
Alley cropping	Gliricidia sepium +maize	Malawi(H& s hT)	123-149	Makumba, <sup>41</sup>
Woodlot	Different acacia spp.	Ethiopia	239.43	Bajigoet al. <sup>48</sup>
Multi-strata	Fruit-coffee, Enset -coffee & Enset	Ethiopia	77.4, 77.5 & 46.	Negash & Starra, <sup>32</sup>
Multi-strata	Home garden	Ethiopia	24.83	Bajigoet al.. <sup>48</sup>
Multi-strata	Sami forest coffee	Ethiopia	61.5	Denu et al. <sup>52</sup>

**Table 5: Mean Soil carbon stock in different soil depth in the different tropical countries**

AF systems	Countries	Depth (cm)	Soil C Mg/ha	Reference
Shade coffee	Togo	10	97.3	Dossa et al., <sup>50</sup>
Mixed story, taungay & Falcata- coffee AFS	Philips	30	124.3, 160.4 & 84.7	Labata et al., <sup>54</sup>
Home garden , Park land & woodlot	Ethiopia	0-30	61.57, 49.05 & 48.6	Bajigoet al., <sup>48</sup>
Fruit -coffee, Enset-coffe & Enset	Ethiopia	0-60	178.8, 177.8 & 186.4	Negash & Starra, <sup>32</sup>
Live fence (Acacia spp. & Ziziphus mauritania). & Fodder bank	Mali	100	24 & 33.4	Takimoto et al., <sup>40</sup>
Fodder plat +maize	Malawi	200	123-149	Makumba et al., <sup>51</sup>
Leucaena leucocephala woodlots	Zambia	100	140	Kaonga, <sup>41</sup>
Leuceana leucocephala woodlots	Nigeria	0-10	13	

The SOC amount varies based on the biomass input received from foliage, litterfall and on the recycling of fine roots.<sup>55</sup> Relation to the plant's carbon in the soil system recycling is influenced by availability of organisms (macro and micro faunal activity), on litterfall quantity and rate of decomposition<sup>56</sup> and also, climate and vegetation coverage influences spatial circulation of soil organic carbon.<sup>57</sup>

According to Garg V,<sup>58</sup> the carbon pool of soil depends on agroforestry practices that have been an increase by 2-3 Mg C ha<sup>-1</sup>yr<sup>-1</sup>. Moreover, carbon sequestration rates ranging from 16-36 Mg ha<sup>-1</sup> yr<sup>-1</sup> were observed in the tropical home gardens. The reports were shown, GHG mitigation potential of AF is 0.44- 1.89 MgCO<sub>2</sub>-eq/ha/yr.<sup>59</sup>

### Tree Species under Agroforestry Contribution to Carbon Stock

Total ecosystem forest biomass and soil were shares more than 80% and 70 % of all terrestrial and all SOC carbon stores, respectively. In another way, the judicious land system and recommended agronomic practices also increase SOC stocks through another form of carbon pool<sup>60,61</sup> and, also trees can contribute substantially and more efficient in promoting to soil carbon sequestration. Manging trees that are integrated with grassland or pasture systems can be increased considerably carbon sequestration in the SOC content. According to several reports, woody plant components of AFS are possible sinks from source carbon due to their fast growth, productivity, accumulation of high and long term biomass, and extensive root system. In another study, the agri-silviculture carbon sink was higher than 40% and 84% in mono-cropping of woody plants (tree) and provisions crops, respectively. It is represents that complex agroforestry practice has more capacity to carbon sequester rate from the atmosphere.<sup>33,62,63</sup> Considering the individual woody plants on the soil organic carbon as beneficial effects, the different arguments were indicated that increasing biomass production (above and below) depends on tree density, which could substantially influence of SOC storage through litterfall and fine root decomposition. Hence the high amount of biomass produced that would help increased total biomass production including litter and fine root activities and then trees are incorporating with cash crops is a vital issue for carbon sequestration rate in soil.<sup>64</sup>

The most suitable land management systems for reduction of GHG emission through established agroforestry, afforestation and reforestation have been suggested as woody plant-based practices and or systems in the tropical AFS.<sup>43</sup> The soil carbon sequestrations are significantly influenced by the litter biomass and fine root activities.<sup>64</sup> The quality litter biomass is higher sources of SOC stock and carbon sequestration rate through time.

The enormous quantity of root biomass carbon transfers from the root into the soil, so roots are a significant role in soil carbon balance. The below-ground biomass is a vital contribution to soil carbon sequestration through litterfall accumulation and decomposition rate, development of root, and

turnover, root exudates (of organic substances). Additionally, it is influenced by rooting depth and then a substantial quantity of carbon is stored below the plow layer and better secluded from disturbance, which leads to longer dwelling times in the soil. Root carbon inputs can be substantial, although the amount declines sharply with soil depth, same reports were indicated that rooting depths of some woody plants having greater than 60 m.<sup>65</sup> During photosynthesis around 50.0% of the fixed carbon is transported belowground and partitioned among root growth, rhizosphere respiration, and assimilation to soil organic matter.<sup>66,67</sup>

Factors Affect Agroforestry Systems Carbon Stock According to 68, the potential of agroforestry ecosystem carbon stocks were varies across species and geographical location. Moreover, the quantity of C stock affected by the arrangement and purpose of various components of agroforestry within the systems put into practice. The other fact present reports have been argued AFS as a function of both the source and sink of carbon. There is also an obvious confirmation to suggest that the kind of AFS very much influences the source or sink role of the integration of woody plants. For example, agrisilvicultural systems where the woody plants incorporate in crop fields are net sinks while agro silvopastoral systems are possible sources of GHGs.<sup>68</sup> Besides, the unmanaged practices have significant emissions of GHGs which are practices like the application of chemical fertilizers, manuring, frequent soil disturbances, tillage, and controlled burning. Other reports on intercropping of trees AFS reported an enhancement in SOC by greater than 50% due to leaf litter. The AFS storage of carbon potential in different components (biomass and soil) were influences by tree density, age, structure, and composition of. 5

Carbon of soil may be preserved for centuries to accumulate under normal circumstances, but it has significant direct and indirect effects related to human induced land use cover on soil organic carbon stocks by changing the equilibrium between carbon sequestration and carbon losses, which are extremely difficult to restore in the short term. Numerous researchers have discussed possible soil carbon changes with land use and management practices.<sup>69,70</sup>



### Conclusion

Agroforestry systems are the integration of woody plants growing with crop and tree with livestock production. The integration of trees with other land use has the highest capacity for a sequestration rate of carbon than grazing and field crops. The woody plant (trees) is incorporated in the crop field and pasture lands indicated a total biomass and soil carbon sequestration rate. The establishment of well-managed agroforestry systems has substantially the role of reducing the external change of CO<sub>2</sub> and similarly importance on the significant long term GHG sink and mitigation. According to different reports, the agroforestry system has been predictable as having the largest capacity for sequestration rate carbon than all other lands. The integration of woody plants on cropland or pasture areas can enlarge the quantity of carbon sequestered related to single crop field or grassland. Although some estimates of the so called "C-sequestration potential" of AFS are obtainable, these are mostly prediction of storage of net carbon. As per research reports, estimation of biomass and soil carbon sequestrations as

methodological difficulties under AFS are several confines in exploiting this cheapest environmental advantages of agroforestry. Now a day the financing or trading of carbon is quickly increasing in the world. So far, the Kyoto Protocol clean development mechanisms propose a smart economic opportunity for subsistence farmers the major practitioners of agroforestry in developing countries.

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