Climate and economic benefits of agroforestry systems

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Introduction

Agriculture is well known as a significant contributor to global greenhouse gas emissions, but emerging practices in land management have the potential to curtail these emissions and reverse much of the ecological and climate harm caused by overly intensive systems. One such practice, cultivation and conservation of trees in agricultural practices, or agroforestry, is an important climate-smart solution with many important co-benefits.

There are a range of practices, that can be used for agroforestry, some of which have been employed for thousands of years. Such methods include alley cropping (planting single rows of trees and growing crops in the alley ways in between), silvopasture (combining trees with pasture or livestock grazing areas), forest farming (the cultivation of shade-tolerant crops under the protection of a managed forest), and others.[1] Integrating trees in agricultural systems can certainly be complex and might be difficult to implement in various situations, and there is no one model that works for every region, but the benefits are significant. Overall, incorporating trees introduces more species types in usually one- or few-species systems, and this in turn has been shown to increase crop productivity, improve nutrient cycling, create and change microclimates, and more.

Because of its carbon sequestration potential, agroforestry has been for many years considered a leading agricultural practice for reducing climate impact. Carbon sequestration is the process by which carbon is pulled from the atmosphere and stored elsewhere. In agricultural systems, carbon is stored in above- and below-ground biomass and in soil.[2] In 2010 (authors) published an article thoroughly investigating how agroforestry compared to other farming systems like cropping and grazing, since it had previously not been well studied against such methods. In their research, the authors found that while the amount of carbon that can be stored in soil depends on silt and clay content and soil quality, long-term agroforestry systems tend to store equivalent or higher amounts of soil organic carbon (SOC) than neighboring natural forests. They also found that there was a correlation between organic carbon concentrations, species richness, and tree density and that soil near trees tended to store more carbon than in soil farther away from trees.[3]

Additionally, studies have shown that agroforestry can improve and restore soil quality in degraded lands. In countries that rely on small-scale farms as their main source of income, these practices could improve the standard of living through increased agricultural productivity while also reducing carbon emissions. Pastures can also be restored through agroforestry, allowing communities to better sustain their livestock and benefit from other land-based practices.

The various impacts of agroforestry tie into three main areas where agroforestry can play a positive role: reducing climate pressure, improving soil quality and biodiversity, and strengthening local economies. Because of its impact in these areas, agroforestry should be considered a leading practice in agricultural systems, small and large.

Exploring the Benefits of Agroforestry

Increased Carbon Sequestration

Soil has long been acknowledged to be an important carbon sink, storing vast amounts of stable organic carbon. However, it is estimated that over the course of human history, soil cultivation and clearing has released about 50 to 70 gigatons of carbon into the atmosphere (this represents roughly 23-33 parts per million of the 400ppm of our current atmospheric concentration of carbon dioxide).[4] Fortunately, agroforestry has created an opportunity to cut back on the amount of carbon that agriculture releases, by instead increasing levels of soil organic carbon.

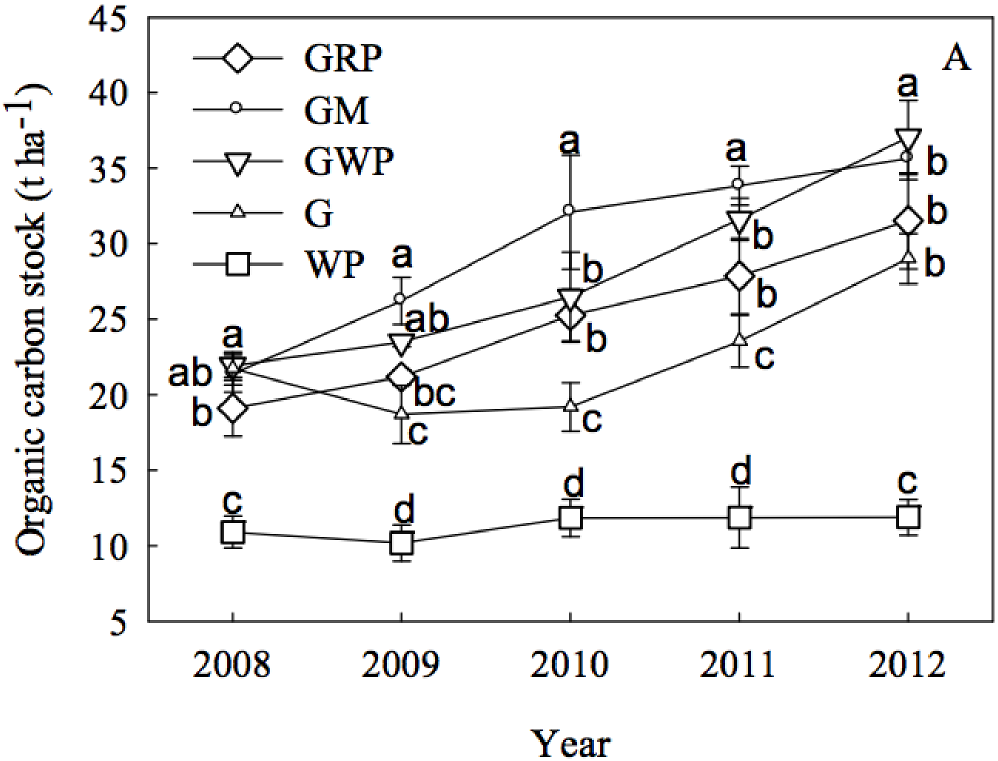
The climate mitigation potential of agroforestry can be seen in agricultural systems around the world. One study released in 2015 explored soil organic carbon levels in five different systems in the Jiangsu Province of China.[5] These systems included 3 agroforestry plots – mixing ginko trees with wheat and peanut crops (GWP), ginko and mulberry (GM), and ginko and rapa and peanut (GRP). The study also considered an area reforested with ginko trees (G), and another traditional agricultural plot growing just wheat and peanut crops (WP). The overall study site was roughly 11 hectares and was farmed as agricultural land for various crops for at least a decade prior to the start of the experiment. Soil nutrient levels were examined at the start, and each of the five treatments were randomized in 3.5 hectare blocks 3 times in the site (each treatment received an approximate total of 2.1 hectares of land area). These were planted in 2008 and studied over a course of 4 years.

This experiment reaffirmed the findings of so many agroforestry system studies. For each soil level (0 to 80 centimeters in 20 cm increments) over the four years, the traditional agricultural system showed the lowest rate of carbon sequestration. For all treatments except WP, particulate organic carbon, light fraction carbon, and water extractable carbon increased over the course of the study. SOC levels up to 20 cm in depth and total soil carbon up to 80 cm was greater in all treatments with ginko trees, and lowest in the crop-only system. Mean concentrations of total soil carbon, measured in tonnes per hectare, is presented in the table below:

Soil layer	Planting treatment	Year				
		2008	2009	2010	2011	2012
0–80 cm	GRP	60.5 ± 1.3 *b*	61.3 ± 3.5 *c*	64.0 ± 2.8 *b*	68.6 ± 3.8 *c*	74.3 ± 3.5 bc
	GM	78.2 ± 2.9 *a*	75.1 ± 3.5 *a*	87.4 ± 4.4 *a*	90.5 ± 3.5 *a*	93.3 ± 3.8 *a*
	GWP	64.3 ± 2.7 *b*	68.32 ± 2.9 *b*	65.0 ± 2.9 *b*	74.8 ± 1.7 *b*	78.9 ± 3.6 *b*
	G	60.5 ± 1.1 *b*	60.4 ± 3.5 *c*	65.1 ± 3.3 *b*	66.2 ± 3.8 *c*	72.4 ± 1.2 *c*
	WP	34.5 ± 3.1 *c*	30.6 ± 2.9 *d*	32.9 ± 2.3 *c*	34.5 ± 2.4 *d*	33.9 ± 3.4 *d*

Source: Enhanced Soil Carbon Storage under Agroforestry and Afforestation in Subtropical China

Soil organic carbon concentrations sat the 0 to 20 cm level are shown in the chart below, which makes clear that each system with ginko trees (GRP, GM, GWP, G), including the afforestation method, show higher levels of SOC over four years than the crop-only treatment with wheat and peanut alone.



Source: Enhanced Soil Carbon Storage under Agroforestry and Afforestation in Subtropical China

Similar results have been observed in various parts of the world, making it clear that agroforestry is an important climate mitigation strategy. Many studies have been conducted in small farms in Africa and others in temperate climates like silvo-arable agroforestry plots in France.[6] Of course, continuing to study agroforestry in different regions and with different crops help us better understand the nuances of such systems. For example, coffee agroforestry studies in Uganda have revealed that while agroforestry does consistently increase SOC, concentrations vary depending on the types of trees paired with each coffee species.[7] Agroforestry has time and again been proven to help reduce agriculture's climate impact, and should continue to be expanded to better understand how to maximize benefits.

Improved Soil Quality

Not only does agroforestry play an important role in terms of increasing the amount of carbon stored in soil—it also increases the concentration of various nutrients or enhances nutrient cycling, improving overall soil quality. This can be particularly significant in tropical regions like Amazonia where soil is poor in nutrients and population pressure drives more intensive and expanded land use.

In tropical areas, high temperatures and rainfall accelerate soil processes, meaning not only do nutrients cycle through more quickly, but they are also lost more quickly. This means that compared to temperate regions, nutrients are more concentrated in biomass rather than in the soil itself. In order for nutrients to be released again, decomposition of organic matter – like fallen leaves, branches, or trees – is vital to reintroduce important particles like potassium, calcium, and magnesium in the soil and to allow other plants to absorb these nutrients. Additionally, tree roots can often access nutrients at deeper soil levels and can be more efficient at extracting nutrients than other plants. When their leaves fall, more nutrients are reintroduced to the soil, and this process, which is often most productive in in native forests, can be replicated by introducing diverse tree species into agricultural systems.[8]

It has been found that in many Amazonian regions, often in areas with indigenous populations and their descendants, some of the most fertile soils have been linked to agricultural systems diversified with tree management. Many modern homegardens in these regions include a range of tree species, and are managed by adding organic matter and by low-intensity burning of residues collection from sweeping and weeding. These systems have shown much higher levels of levels of potassium, phosphorus, calcium, and magnesium compared to surrounding savannah soils. The table below details changes in nutrients in the soil in homegardens in Araçá Indigenous Land in Roraima, Brazil over the years. Any value with one or two asterisks shows a concentration of statistically significant difference compared to neighboring savannah soils:

	Savanna ($n = 15$)	New homegardens ($n = 5$) (0–10 years-old)	Estabilished homegardens ($n = 5$) (15–35 years-old)	Old homegardens ($n = 5$) (40+ years old)
P (mg Kg^{-1})				
0–10 cm	2,1	14,3**	26,5**	43,7**
10–20 cm	1,1	8,5*	12,2**	37,9**
20–30 cm	0,6	7,5*	7,5**	31,2**
K (cmolc Kg^{-1})				
0–10 cm	0,07	0,08	0,11*	0,18**
10–20 cm	0,06	0,08	0,10*	0,15**
20–30 cm	0,06	0,07	0,10*	0,13**

Source: Agroforestry and the Improvement of Soil Fertility: A View from Amazonia

Where deforestation occurs or where monocropping and intensified agriculture expands, soil quality and nutrient concentrations are often at risk. However, agroforestry provides an opportunity to restore soil quality and nutrient cycling, and can be used in degraded or at-risk systems. Because of these potential benefits, agroforestry should continue to be explored in all regions.

Economic and Social Impact

In terms of its potential to mitigate climate impact and to improve soil quality, agroforestry can offer significant economic and social impact, especially for smallholder famers in developing countries. This can have a profound impact, especially given the estimates that around 500 million smallholder farmers live on less than 2 dollars a day.[9] Improved soil quality could help farmers produce more crops. Introducing trees in traditional agricultural systems can allow for more efficient nutrient cycling, meaning farm output can be more substantive and reliable. It is well understood that climate change affects disadvantaged populations most, so smallholder farmers around the world could benefit greatly by adopting agroforestry practices. Improved soil quality and climate mitigation potential are just some of the many important agroforestry benefits. Crops and products derived from introducing trees in agricultural systems can also drive positive social and economic change.

The benefits of agroforestry are many. Competing together, crops can push trees to send roots deeper into the soil, improving not only nutrient cycling but also the storage and retention of rainwater. This can help improve water availability, meaning populations that rely heavily on agriculture for their income and nutrition could feel less strain during droughts. Additionally, introducing trees could provide additional resources like fuel from timber, fodder for animals, and nuts, fruits, or oils that could be used as food or be sold for additional income.[10] Not only can timber be used for fuel, but biofuels derived from tree sap, fruit pulps, and oils (like palm oil or jatropha) could also be advantageous. While this might be less commonly used by small communities, if production was expanded, biofuels from tree by-products could still play an interesting role in reducing dependency on fossil fuels and reducing greenhouse gas emissions.[11] In this way, agroforestry can not only improve food security from healthier soils but it can also introduce resources that can be used by households or sold for additional income.

Another important element of agroforestry's social and economic impact is improved conditions for women and children. One field study involving household surveys, in-depth interviews, focus group discussions and field observations explored a farmer-managed agroforestry project in the Nyando District in western Kenya.[12] Several communities in this district were given tree seedlings and agroforestry training in 2006 and 2008, and were surveyed in 2010 to learn about the effects of the project. In this region, some women would walk over 20 kilmometers to purchase fuel from neighboring districts. Very often women who must travel so far for basic resources are at risk of assault during their journeys and have less time to devote to other activities. Researchers found that the adoption of agroforestry in the Nyando District significantly reduced the amount of fuel wood purchased and the time that households spent collecting wood. These savings compared to control groups that were not involved in agroforestry can be seen in the table below:

	Lower Nyando			**Middle Nyando**		
	Treated	**Control**	**Difference**	**Treated**	**Control**	**Difference**
Weekly time spent on fuel wood collection (min)	360	540	180	220	260	40
Percentage of households purchasing fuel wood	17%	66%		3%	7%	

Source: Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya

Not only did matured trees in these observed agroforestry systems allow women to access a safer and more reliable source of fuel wood, but it also opened doors for women to spend more time on income-generating activities. Some women interviewed in this study reported increasing their incomes through local fuel wood sales, suggesting that agroforestry can help improve women's livelihoods.

Conclusion

Agroforestry clearly has great potential to improve social and economic conditions in developing countries. Its ability to improve soil quality and mitigate climate change through carbon sequestration should also make it an appealing agricultural method in countries with more significant economic resources or large farm systems. Because of these benefits, agroforestry should continue to be studied and expanded, but with careful considerations. For example, in smaller populations, agroforestry should not be introduced unless it is done so in a way that is compatible with local traditions and practices. Technical knowledge and accurate information should be carefully conveyed so that agroforestry practices can be sustained and to maximize benefits.[13]

Countless studies have been conducted on smallholder farms, but agroforestry could also have a place in large-scale, industrial farms. More studies should be done to show the numerous benefits in large agricultural systems, and policies should be put in place to better encourage the adoption of agroforestry. The climate mitigation potential of agroforestry should not be overlooked, especially as carbon emissions continue to increase. Intensive systems can be ecologically damaging, and agroforestry should be considered to reduce fertilizer use or to maintain and restore soil health. While there is no single agroforestry practice that suits every climate or region, if implemented effectively, it undoubtedly offers a wide-range of important benefits.

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Notes

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