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Carbon Sinks of Steel: Exploring Bamboo's Use to Combat Climate Change

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Abstract

According to the United States Environmental Protection Agency, conventional agriculture accounts for approximately 19-29 percent of greenhouse gas emissions worldwide—a proportion destined to increase with the rising world population. As a result, it is important to uncover areas where methods of sustainable agriculture can be implemented or improved, and fostering these opportunities in the agricultural communities of developing nations offers great potential for reducing international greenhouse gas emissions. For many areas of the world, one promising strategy can be found in the cultivation of bamboo. A perennial plant within the grass family (Poaceae), bamboo belongs to the subfamily Bambusoideae and consists of over 1500 known species in approximately 119 genera. Although endemic to nearly every continent, the greatest species diversity of bamboo can be found in the subtropical regions of Asia, Africa, and Latin America. This paper aims to examine the cultivation of bamboo in rural communities and developing nations as a strategy of climate change mitigation and land revitalization. The potential of bamboo to be used in international carbon trading schemes is also analyzed. As an agriculturally relevant crop for many remote communities, the cultivation and harvest of bamboo can provide a meaningful source of income to developing areas while also helping nations meet sustainability and emissions reduction goals.

Author's Note

As a botany student, I typically find myself immersed in the study of various physiological and biochemical processes of plants. I am often left with a strong desire to apply this knowledge to pressing issues that face our modern world, such as climate change. Over my years of study, I have realized that though solutions to climate change lie in natural science, the ability to implement them requires an understanding of international relations, social inequality, and world economies. Perhaps most importantly, however, is the fact that solving complex issues such as climate change will require participation of all peoples and integration of Indigenous knowledge with existing science, especially in rural areas of developing nations. It is my goal, therefore, to use this paper as a means of highlighting not only the climate science behind sustainable bamboo production, but also its positive implications for rural development and economic equity.

Keywords

Carbon sequestration, bamboo, sustainable agriculture, agroforestry, rural development

Introduction

The Twenty-Four Filial Exemplars is a collection of short stories written in the 13th century by Confucian thinker Guo Jujing. One of these stories, entitled “He Wept Until the Bamboo Sprouted,” features a young boy named Meng Zong. Zong’s mother grows very ill, and she desires bamboo soup. Finding no bamboo in the grove, Zong weeps. Moved by his piety, bamboo shoots miraculously sprout from the ground. Zong collects the shoots and makes his mother the soup. After consuming it, she is fully healed.

“He Wept Until the Bamboo Sprouted” represents just one of many references made to bamboo over the span of human history. Often regarded as a symbol of luck, health, and creation, bamboo has always served as a significant nexus between agriculture, nature, and humanity. Today, climate change poses significant threats to all three of those aforementioned aspects, as anthropogenic activities drive greenhouse gas emissions into the atmosphere. The adaptation of agricultural strategies that actively work to mitigate climate change, while also coexisting with local ecosystems, is therefore imperative. Moreover, it is ethically necessary for these strategies to address the socioeconomic inequalities that are often exacerbated by the consequences of climate change. Thus, climate change solutions are best achieved when they combine opportunities for greater access to world markets with mitigation and adaptation techniques.

One possible mitigation strategy lies in bamboo. As one of the fastest carbon-sequestering plants, bamboo stands have the potential to draw large amounts of carbon dioxide out of the atmosphere while rapidly accumulating biomass (Gu et al., 2019). In short periods of time, large quantities of bamboo can be harvested and sold to provide a source of income for rural communities and smallholder farmers. Therefore, sustainably grown, well-managed bamboo forests can act as powerhouses of carbon sequestration and increase access to capital for rural and developing areas that have been exploited by conventional agricultural markets worldwide. Thus, it is worthwhile to explore the use of bamboo as a crop to fight the climate change crisis.

Life Cycle and Biodiversity

Bamboo is a perennial plant belonging to the grass family (Poaceae). Despite being classified as a grass, bamboos tend to have tree-like growth habits, stretching up to one hundred meters in height (Nath et al., 2020). Bamboo shoots, also known as culms, arise continuously from an underground rhizome. Typically, a culm can grow to its full height within one growing season but requires roughly five growing seasons to become fully mature (Thokchom & Yadava, 2015). For this reason, bamboo is considered to be one of the fastest-growing higher plants (Nath et al., 2020). The conclusion of the bamboo life cycle begins with flowering. After pollination and seed maturation, the plant senesces and dies (Thokchom & Yadava, 2015). Therefore, any effort to harvest bamboo should be made before the flowering stage. However, since it takes several growing seasons for culms to reach this stage, there are numerous opportunities for usable product to be harvested over the course of its life cycle. The biomass lost from harvested culms can usually be replaced within a year, much faster than other forest plants of similar size, such as trees.

Bamboo is endemic to all continents, except for Europe and Antarctica, with the greatest diversity occurring in subtropical Asia, Latin America, and Africa (Thokchom & Yadava, 2015). It is one of the only grasses that have been able to successfully occupy forest land. Currently, it is estimated that about one percent—or roughly 30 million hectares—of the total worldwide forest area is occupied by bamboo (Kuehl, 2015). Within Poaceae, bamboo has been further classified into the subfamily Bambusoideae, with all extant members belonging to three tribes: Bambuseae, Olyreae, and Arundinarieae (Nath et al., 2020). In total, there are about 119 genera and 1500 known species of bamboo, ranging from herbaceous to “woody” in growth habit (Nath et al., 2020). Such geographic and physiological diversity makes bamboo an important crop in many regions of the world, and thus an even more important subject of study in the fight to combat climate change.

Carbon Sequestration, Agriculture, and Mitigation

There are over 1500 documented applications of cultivated bamboo, which range from human consumption to construction materials and bioenergy (Nath et al., 2020). Bamboo culms can be harvested after just one growing season for pulp or left to grow for longer. The longer the culms grow, the more carbon is sequestered as biomass, and the sturdier they become. In fact, bamboo that has been allowed to grow to structural maturity is known to have the tensile strength of steel and compressive strength of concrete (Muchiri & Muga, 2013). Currently, a majority of bamboo is harvested for construction purposes, ensuring that carbon sequestered as biomass does not rapidly reenter the atmosphere (Nath et al., 2020).

Bamboo cultivation also provides employment for small communities in developing countries, which helps local economies (Nath et al., 2020). At the communal level, it is imperative to evaluate and incorporate Indigenous knowledge related to species growth habits and ecosystem services when advocating for well-managed bamboo growth systems. It is also important to work with local smallholder farmers to integrate the growth of bamboo stands with other crops of economic importance. In some instances, agroforestry is employed, wherein bamboo is planted alongside another crop in order to increase revenues for smallholder farmers and sustain community nutritional requirements. For example, agroforestry practices in the miombo region of Africa, which includes Malawi, Mozambique, Tanzania, Zambia, and Zimbabwe, have synthesized the growth of timber-bearing forest plants with fruit and medicinal crops to help meet the human health needs of the region (Sileshi et al., 2007). The versatility of bamboo as a product, combined with Indigenous knowledge, creates enormous potential for the inclusion of smallholder farmers and developing communities in the fight to combat climate change.

One of the chief concerns regarding climate change is the rise in atmospheric concentration of carbon dioxide and other greenhouse gases. The increase of these gases in the atmosphere causes the planet to warm, which leads to various disruptions of the biosphere. Therefore, it is necessary that immediate steps be taken to sequester carbon from the atmosphere. Carbon sequestration occurs when carbon is stored for a long period of time in biomass or soil, and bamboo is known to sequester carbon faster than nearly any other plant (Gu et al., 2019). This is largely due to the tendency of bamboo to have a very rapid growth rate, such that harvested biomass is quickly replaced by new culms. The sequestration power of bamboo was demonstrated in a recent study focused primarily on Moso bamboo (*Phyllostachys heterocycla* J.Houz) cultivation in China (Gu et al., 2019). Moso bamboo is considered to have several highly desirable traits for cultivation, such as rapid growth, a short regeneration cycle, and the ability to be continuously harvested (Gu et al., 2019). Notably, it was determined that well-managed Moso bamboo stands sequestered two to four times more carbon than Chinese fir and red pine forests of similar acreage (Gu et al., 2019). Figure 1 illustrates the mean annual carbon sequestration rates per hectare for *P. heterocycla* and four other woody plants common to central Asian forests: the sal tree (*S. robusta*), the small-flowered crape myrtle (*L. parviflora*), axlewood (*A. latifolia*), and the Chinese fir (*C. lanceolata*).

The carbon sequestration potential of bamboo was also explored in a 2011 study focused on smallholder farming in Barak Valley, Assam, India (Nath & Das). This study found that bamboo stands grown, managed, and harvested by local smallholder farmers were more efficient at sequestering carbon than traditional plantations or natural bamboo forests (Nath & Das, 2011). Taken together, both studies offer evidence to suggest that bamboo cultivation managed by smallholder farmers increases the carbon sequestration potential of the land while also providing farmers with a harvestable and sellable crop. Moreover, these results provide further support for involving smallholder farmers and rural communities in participatory systems that integrate their existing knowledge with bamboo cultivation and management.

Bamboo has also been known to grow well in eroded and nutrient-poor soils, which are often characteristic of degraded lands. Degradation, caused by deforestation and other anthropogenic activities, can leave soils largely infertile and unable to support the growth of agricultural crops without substantial amendments, such as fertilizers. As incidences of severe weather increase with the progression of climate change, soil degradation is projected to increase (Borrelli et al., 2020). A study by the University of Las Villas in Santa Clara, Cuba, was performed in order to analyze the effects of bamboo production on the quality of degraded soils (Cairo et al., 2018). The study evaluated the prevalence of several mineral nutrients, in addition to beneficial fungi and bacteria, at different soil depths over a period of time in plots present and absent of bamboo stands (Cairo et al., 2018). It was determined that the presence of the bamboo and the resulting biomass it produced significantly improved the consistency, structure, and biological properties of the previously degraded soil (Cairo et al., 2018). Therefore, it is possible to use bamboo as a vessel for revitalizing soils while simultaneously sequestering carbon and providing an economically viable crop.

Opportunities for Growth

Generally speaking, research regarding the benefits of bamboo cultivation on carbon drawdown and land revitalization is only in its infancy, but current results are promising. The greatest opportunity for economic growth and improved sequestration lies in smallholder cultivation of bamboo on degraded soils not otherwise viable for more potentially lucrative food crops (which are likely to have carbon sequestration capabilities inferior to those of bamboo). Currently, it is estimated that bamboo is grown on roughly 33.52 million hectares of land (Project Drawdown, 2020). If bamboo production is increased to include an additional 69.8 to 174.3 million hectares of degraded lands by 2050, a total of 8.3 to 21.3 gigatons of carbon dioxide could be sequestered (Project Drawdown, 2020). Even if the amount of carbon dioxide sequestered were to reach the midrange of this prediction, it would roughly equate to the total net greenhouse gas emissions of the United States between the years of 2017 to 2019, on a CO_2-equivalent basis (US-EPA, 2021). An additional reduction in emissions can be achieved when bamboo is used in place of less sustainable construction materials, such as steel or aluminum. In total, it is estimated that such an increase in bamboo production could lead to a lifetime net profit anywhere in the range of $1.71to $4.35 trillion U.S. dollars (Project Drawdown, 2020).

On a global scale, one method by which the emissions of carbon dioxide can be regulated or mitigated is through carbon trading schemes. Broadly speaking, carbon trading schemes involve the generation of carbon offsets by farmers, which are then traded as “credits” with investors who are emitting carbon dioxide as a greenhouse gas. Presently, bamboo cultivation is not a significant contributor to carbon trading markets. Because bamboos have a fast growth rate and high carbon sequestration potential, they are worth exploring as a crop for carbon trading schemes. When bamboo is cultivated in a developing country, it is usually done at the smallholder farmer and village level. In some instances, bamboo is the primary source of subsistence and income for these villages (Nath et al., 2020). By involving these farmers in a carbon trading scheme, an additional source of revenue could be obtained through the acquisition of carbon credits. This could be especially useful as an incentive for farmers to plant bamboo on degraded lands or in situations where sustainable agriculture has not traditionally been an economically viable option. These carbon credits could be traded on a national or international scale, helping to mitigate carbon dioxide emissions worldwide. Certainly, there is exciting potential for bamboo be used as a vessel for bringing smallholder farmers into international carbon trading markets.

In recent years, the potential for bamboo as a lucrative crop has even gained attention in the media. Article headlines across the world, from Jamaica (“Gov’t Targeting Value-Added Production From Bamboo”) to India (“Bamboo Wood Industry: Dark Horse in NE Economy”), to Florida (“Why Bamboo Might Be Worth the Climb for Florida Farmers”) all suggest that interest in bamboo cultivation is growing. One such article even referred to bamboo as “green gold” (Saha, 2020). Such enthusiasm is a necessary and welcomed step in expanding the cultivation of bamboo worldwide.

Limitations

One of the many reasons why bamboo is aptly suited to mitigate climate change is its resiliency and its ability to grow rapidly in variable climatic regimes and precipitation conditions. However, these same characteristics also give bamboo the potential to become invasive. Invasive bamboo has been known to hinder the ecological succession of an area, often causing disruptions to natural forest structures and biodiversity (Buziquia, 2019). Therefore, when implementing bamboo cultivation, the use of species that are native to the area of interest must be utilized. This limits the growth of various bamboo species to areas where they are endemic.

In many countries, there are also political barriers that limit bamboo cultivation. In Uganda and Kenya, for example, the government has restricted and/or banned the harvest of bamboo since the late twentieth century (Muchuri & Muga, 2013; Sheil et al., 2012). The bans were intended to conserve bamboo stands and protect ecosystems and biodiversity. Recent studies, however, have suggested that these bans have actually hindered the optimal growth and reproduction of bamboo, due to a lack of harvest activity (Muchuri & Muga 2013; Sheil et al., 2012). These governmental limitations could be overcome by instead advocating for community-based, smallholder-managed sustainable bamboo cultivation and harvest. Governments should be made aware of the positive implications of bamboo cultivation on both economies and ecosystems, as well as the value of indigenous farmer knowledge when considering policies to ensure sustainable production is achieved.

There are also some technical constraints that pertain to use of bamboo in carbon trading schemes. The Reduced Emission from Deforestation and Forest Degradation program (REDD), which has instituted one of the principle international carbon trading schemes, currently only considers forest areas covered by trees (Nath et al., 2015). As a member of Poaceae, bamboo is not considered a tree in the botanic sense, though it does have a tree-like growth habit. A similar lack of clarity exists under the Clean Development Mechanism (CDM) instituted by the Kyoto Protocol, which does not define “trees” in its charter (Nath et al., 2015). To overcome this issue, the 2013 Warsaw Framework for REDD gave countries the responsibility of defining forestland, thereby opening up the possibility of bamboo to be used in international carbon trading markets (Nath et al., 2015). However, some international confusion still exists over this issue. In order to realize the full potential of bamboo in international carbon trading schemes, further clarification by REDD and the United Nations could be helpful.

Conclusion

Today, humankind faces a climate crisis that will undermine both the natural world and everyday life. In order to combat such a complex issue, innovative and sustainable solutions must be enacted. The cultivation of bamboo provides a unique opportunity to synthesize long-term carbon sequestration with lucrative agriculture, smallholder farming systems, soil revitalization, and global economies. In particular, bamboo growth and cultivation provide a novel opportunity to involve smallholder farmers and rural communities in gaining access to global carbon trading markets, thereby allowing these regions to develop robust and sustainable economies, societies, and nations. In order to realize the full benefits of bamboo cultivation and provide long-term, sustainable mitigation against climate change, such integrative solutions are necessary.

From the tale of the pious boy in Guo Jujing’s “He Wept Until the Bamboo Sprouted,” to the grandiose Philippine myth of human creation, the story of bamboo has always been intimately intertwined with the story of humanity. Upon first read, “He Wept Until the Bamboo Sprouted” seems fantastical at best. Perhaps, though, the great storytellers of centuries past underestimated the true healing, life-restoring power of bamboo.

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