***Review Paper***

# Role of Bamboo forest for mitigation and adaptation to Climate Change challenges in China

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## ABSTRACT

Bamboo is one of the fastest growing plants on the planet; with many attributes which make it a useful potential resource for humankind. Though having fast growth and good regeneration performance after harvesting is a unique characteristic of the specie. It enhances a high carbon storage potential particularly when the harvested culms are transformed into durable products. China has lots of bamboo species with distribution and area coverage's, and also highly connected in using the production of bamboo resources. Its characteristics make it an ideal solution for the environmental and social consequences of tropical deforestation. The aim of this review paper is to assess the contribution of bamboo in mitigating and adapting impacts of climate change and its importance in terms of ecological and socio-economic benefits. The review summarized the role of bamboo forests towards mitigating and adapting its potential to overcome the impacts of climate change currently seen globally and particularly to China. Therefore, advancing bamboo farming systems in different levels it's advantages to reduce greenhouse gas in atmosphere and expanding bamboo forests in future under wider use and intensive management is recommended.

**Key words**: - Bamboo; carbon sink; climate change; greenhouse gas

## 1. INTRODUCTION

Bamboo is a grass type of Gramineae family, and it's an important component of many forest environments. It adapts easily to a range of climatic and soil conditions, and is widely distributed in the tropical and subtropical zones approximately between 46° N and 47° S latitude, covering a total area of about 31.5 million ha, and accounted for about 0.8% of the World´s total forested area in 2010 [1]. It has unique features that distinguish it from most other woody plants. For example: culms that are connected by an extensive system of rhizomes, leading to emerge new culms by rapid asexual reproduction [2, 3, and 4].

The bamboo resources are distributed in many countries in the World, majorly found in Asia, Africa, and Latin America; however, the origin of most of species lie in Southeast Asia. Worldwide bamboo families categorized with more than 107 genera and 1300 species 6]. Along with this all China has the highest bamboo species diversity, with 39 genera and 509 species, accounting for 36% and 39%, respectively of the total bamboo genera and species with the rest of the World [6]. Besides that, China's bamboo forests cover an area of 4.84 million ha in 2005, which accounts for 2.8% of China's forested area and 15.4% of the World´s area of bamboo [7]. Bamboo forests is the most important non-wood forest product and substitute wood products. As a resource bamboo forests are an important part of eco-systems which provide a number of basic environmental services. Bamboo provides food and raw materials, reduces water erosion on slopes, regulates water flows and it act like windbreak in shelterbelts which offer protection against storms [1]. In addition to this because of its special root re-sprouting regeneration strategy bamboo forests it generates a good potential of carbon storage mechanisms, and water and soil conservation and many more advantageous [5].

Many studies have shown that well managed and regularly harvested bamboo can sequester more carbon than bamboo in natural state. Despite that, it can sequester more carbon than fast-growing tropical and subtropical trees under comparable conditions. If bamboo forests are not managed through annual harvesting practices, they would be significantly less effective in carbon sequestration. The aim of this review paper is to assess the contribution of bamboo in mitigating and adapting impacts of climate change and its importance in terms of ecological and socio-economic benefits

## 2. ROLES OF FORESTS IN MITIGATING CLIMATE CHANGE

Forests are one of the biggest reservoirs of carbon, so they help to keep the carbon cycle and other natural processes working and help reduce climate change. However, forests can also be one of the biggest sources of $CO_2$ emissions [8]. In addition, forests provide a wide range of ecological, social, and economic benefits, in the form of goods and services to society, that are much less easier to quantify. Besides that the demand for timber and related products will require more efficient and sustainable use of natural resources. Forests are the most vulnerable climate dependent systems, but have also been recognized to have significant and crucial contribution to address the challenges of mitigation and adaptation in tandem with the issues of livelihoods, economic growth and development. However, the most recent report from the International Union of Forest Research Organizations

(IUFRO) indicates the gloomy picture about the future of the World forests in changed climate, as it suggests that in a warmer World, the current carbon regulating services of forests as carbon sinks may be entirely lost as land ecosystems could turn into a net source of carbon dioxide later in the century [9]. It plays in combating climate change impact through reducing the emissions from deforestation and forest degradation has become a fundamental issue to international dialogues on preventing the current global temperature increases [10]. The challenges of climate change seen in affecting forest ecosystems in their structure and morphology, thus causing an implication on functionality of forests in every corner of the World [11, 12]. Beside that it's considered to be one of the greatest threats facing humanity in the current global situations. According to the Intergovernmental Panel on Climate Change (IPCC), global warming is unambiguous, with evidence towards the increases of average air and ocean temperatures which leads to aggravate melting of snow and ice and sea levels [8, 13].

## 3. BAMBOOS FOR CLIMATE CHANGE ADAPTATION

Bamboos are one of the World´s strongest and fastest growing woody plants capable of providing ecological, economic and livelihood security to the people, distributed over ranges of climate from mild temperate to tropical. Bamboo's fast growth ability to grow on varied soils and climate, renewability and positive socio-economic impacts make them an excellent alternative for combating climate change [14]. The high growth potential and ability to store large amounts of carbon make sequestration and on the other hand their environmental and socio-economic services can help communities in developing countries to adapt to the climate change impacts. According to the research result by International Network of Bamboo and Rattan (INBAR) had shown that well managed bamboos can be an effective in carbon sink and perform better than other species like Chinese fir and eucalyptus growing under similar conditions. Furthermore, the necessities of bamboo management with time frame, sustainable way and selective harvesting mechanism of stem which are turned into products that can hold carbon for many years. The increasing popularity of durable bamboo products ensures that for the foreseeable future, productive bamboo systems can be considered as an important carbon sink [15].

### 3.1 BAMBOO FOR TIMBER DEMAND AND CLIMATE CHANGE

The demand for timber and different agricultural products will continue to increase with the global population. Instead of satisfying the increasing demand for different commodities the global policies must need to shift towards using efficient and sustainable production systems [13]. Bamboo is one of an alternative resource that used to play an important contribution towards reducing the direct pressure on forest resources [13, 24]. Furthermore, one of the best example in China, following the logging bans of certain forests resources came into effect in 1998, while bamboo forests has been used as a possible substitute to timber.

Magel et al [16] argues that the growth of new shoots in a bamboo plantations occur as a result of transfer of the energy accumulated in culms through photosynthesis in the previous year. The result of such growth of bamboo culms is not driven by its own carbon sequestration, but by sequestration in previous seasons in other parts of the bamboo system, and such growth of new shoots is not an indicator of sequestration rate. Another report by Zhou [17] show that as bamboo system requires more inputs in the shooting period of young culms which means when new shoots developed during that time high growth of bamboo shoots can be equated with a high rate of carbon sequestration. The maturity period of most bamboo culms estimated between 7-10 years approximately, after that they deteriorate rapidly, releasing carbon from the above-ground biomass back into the atmosphere [18]. Therefore at a natural circumstance, bamboo will reach a stable level of above ground carbon relatively quickly, even though carbon accumulation through sequestration is offset by carbon release through deterioration of old culms.

### 3.2 SUITABLE ECOLOGICAL GROWING CONDITIONS FOR BAMBOO SPECIES

Naturally; bamboo species has a potential to grow at different altitudinal range from 0 to 4000 meter above sea level. It prefers well drained sandy loams to loamy clay types of soils originated from river alluvium or underlying rock.  In most of the bamboo thrive well at annual average temperatures range of 8.8 - 36$^0$C and annual rainfall of 1270 – 4050 mm. On the other hand, some bamboo species are also growing under high rainfall areas, while some can tolerate limited winter frost [19]. ICFRE [20] reported as one of the fastest growing species in the planet, under ideal environment; it can be growing up to one meter a day. The biomass of freshly planted bamboo plantation increases rapidly for the early six to eight years after which emergence and death of culms tend to become equal.

## 4. MANAGEMENT AND HARVESTING OF BAMBOO

Bamboos have well developed rhizomes with good root systems which help to obtain strengthen during their existence. Its culms mature within three to four years and naturally die after eight to ten years, if not used the products [21]. The periodic removal of mature culms from each and every bamboo clump and this cycle of removal may vary from two to four year.  Thus, provide a highly renewable resource with a high degree of sustainability. It makes bamboos acquiescent to sequester accumulated $CO_2$ from the atmosphere throughout the lifetime [22]. The sequestration rate of bamboo is higher during the initial eight to ten years period of fast growth. Numerous studies categorize the production management of bamboo management practices in different five major points: timber, shoot, pulp, ornamental and water/soil conservation benefits.

## 5. BAMBOOS FOR CLIMATE CHANGE MITIGATION

Bamboo grows more rapidly than any other trees and reach to give yield within three to four years after planting. Hence, it's one of the fast growing and responding well against drought which can make the species more acceptable in making ever green environment in addition to soil and water conservation, carbon storage and rehabilitation of degraded lands [23]. It offers one of the quickest ways to remove vast amounts of that $CO_2$ from the atmosphere. Lou et al [24] report that at the age of 9 -10 years old in moso bamboo (*Phyllostacys pubescens*) plantation the above ground carbon stock ranges between 25 to 32t $ha^{-1}$ in China. Furthermore, another study show that in *Phyllostacys pubescens* and *Phyllostacys bambusoides* from natural forests in Japan have an aboveground carbon stock of 78.6 t $ha^{-1}$ and 52.3 t $ha^{-1}$, respectively [25]. A four year mixed bamboo plantation (*Bambusa vulgaris, B. blcooa, B. cacharensis*) in India shows that the aboveground carbon stock is about 61.05t $ha^{-1}$ [26]. Despite that it provides a minimum $CO_2$ gas and generates up to 25% more oxygen than other trees within the same level. One hectare of bamboo can sequester up to 62 t of $CO_2$ $yr^{-1}$, whereas equivalent of young forest sequesters 15 t of $CO_2$ $yr^{-1}$. The *Guadua* plantations in Costa Rica estimated to absorb 17 t of $CO_2$ ha $yr^{-1}$ as the study showed by Janssen [27]. Another research study by INBAR states that over the past 15 years, areas under bamboos in Asia grew by 10%. Studies have estimated that the carbon stored in Chinese bamboo forests will increase from 727.08 Tg C in 2010 to 1,017.54 Tg C in 2050, which equates to an increase of nearly 40% in 40 years. This represents a significant contribution to the Chinese forest carbon stock and a range that shows that policies aiming at combating climate change with bamboos can indeed have significant promise [28]. For example: by INBAR's as modeling shows that a managed moso bamboo forest accumulates about 300 t of carbon $ha^{-1}$ after 60 years. As well, it does also produce more biomass under well managed and regular harvesting of mature culms. Another report by Lou et al [24], confirmed that the amount of carbon sequestration between a fast growing Chinese Fir plantation and monopodial (*Phyllostachys pubescens)* plantation modeled for subtropical agro-ecologies in South East China and the results showed that, bamboo sequestered more carbon than the Chinese Fir in the first 5 years. This might be due to rapid early growth; bamboos sequester more carbon in the early years of a plantation than comparable forest trees. In the other way, unmanaged bamboo stands do not store high levels of carbon, as their productivity is low and the accumulated carbon returns quickly to the atmosphere as the older culms decompose [28].

## 5.1 CARBON SEQUESTRATION POTENTIAL OF BAMBOO

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. Naturally, the performance of bamboo plantation is different comparing with other tree species since it has a fast growth rate with high re-growth behavior after harvesting. Despite that it has a high carbon storage potential according to Zhou and Jiang studies [29], especially when the harvested culms are transformed into durable products. The increased lifespan of durable bamboo products made possible by modern technology can ensure that the sequestered carbon will not return quickly in to the atmosphere, thereby prolonging the carbon storage of bamboo. According to Agarwal and his colleague [30] research result in the Mid Himalayan region conducting in comparing the carbon sequestration potential under different bamboo species, Monopodial species (*Phyllostachys nigra*) has showed a high potential to sequester carbon than other Sympodial species this might be due to high density of culms and high percent dry matter in the Himalayan region [31]. Currently in China about 53 M ha of forest plantation is there with a volume stock of 1.5 billion $m^3$. Between 2005 and 2020, China has pledged to establish more than 40 million ha of plantations, referred to as carbon sink forest. As plantations have been recognized as the national strategy for mitigating atmospheric $CO_2$, it is essential to assess the potential of fast-growing and high yield plantations in carbon storage and sequestration at stand, regional and national scales [32].

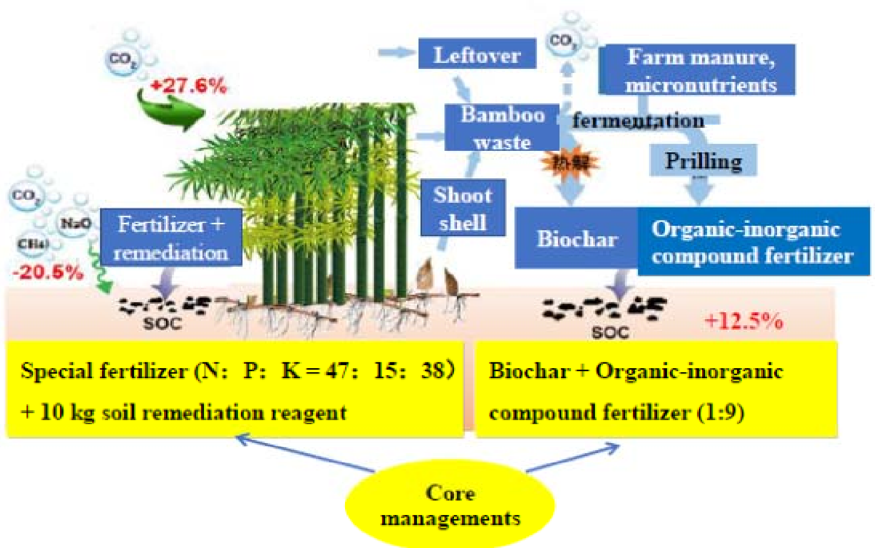


Figure 1. Contribution of bamboo on adding C sink and reducing C emission (Source: Yuen [33].

The area coverage of bamboo forests in China is about 6 million ha[2], which stores about 780 Tg carbon, accounting for 14% of total forest carbon stock in China. Beside the carbon density of bamboo forest ecosystems in China, the estimated global bamboo carbon stock is about 4 Pg, accounting for 0.43%-0.61% of total global forest carbon stock [33].

To combat climate change, bamboo should be a core development resource – providing countries and development partners with a wealth of practical solutions to reduce the negative effects that changing climate patterns have on millions of rural communities.

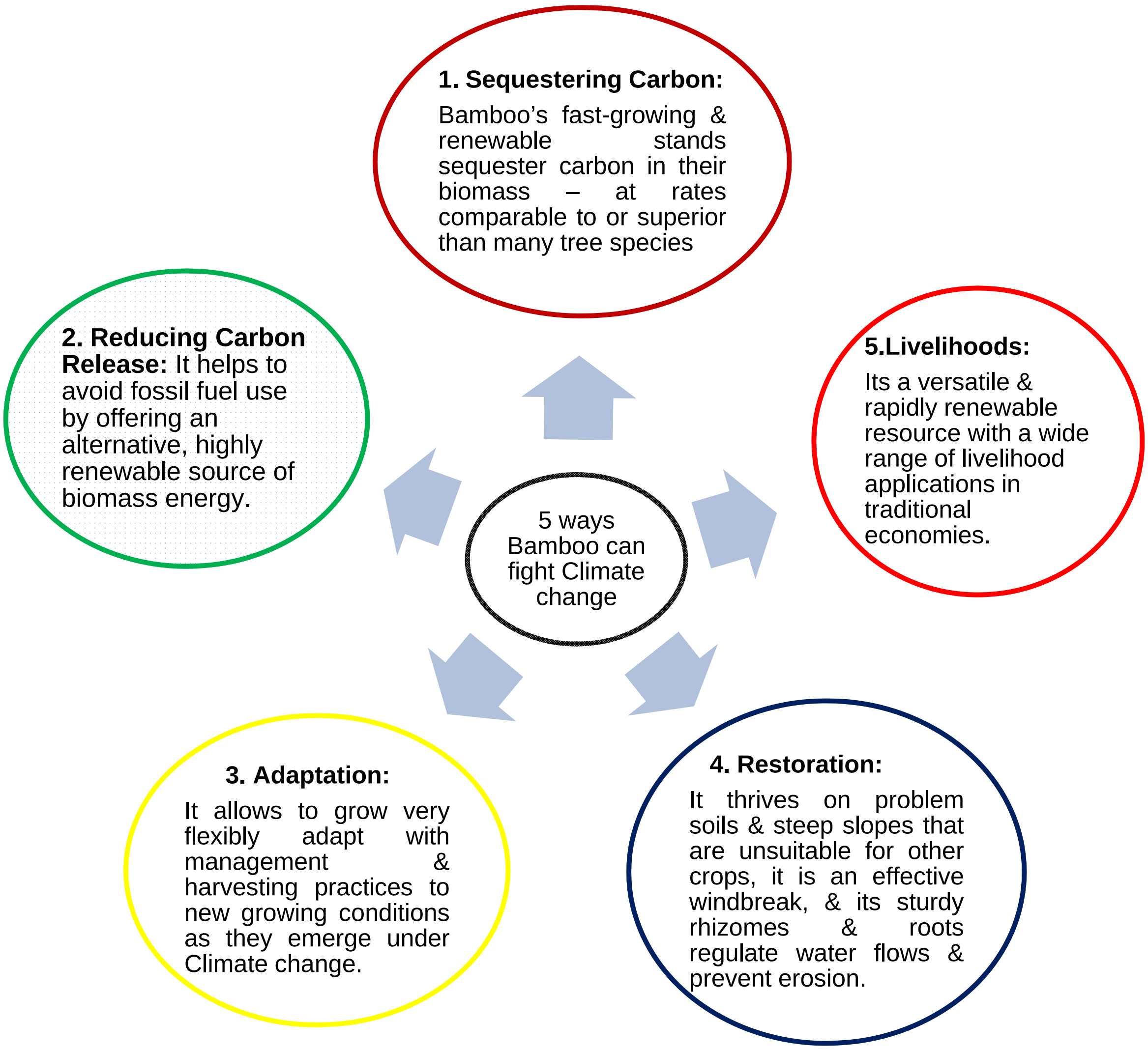


Figure 2. The five key functions of Bamboo help to mitigate/adapt the impacts of Climate Change.

## 6. SUMMARY

Currently the concern of climate change is a very serious and burning issue of global agendas. In this paper we tried to review the contribution of bamboo forests towards mitigating the impacts of climate change and the versatility of its ecological and socioeconomic development benefits. It offers one of the quickest ways to remove huge amounts of $CO_2$ from the atmosphere. It minimizes $CO_2$ gas and generates more amount of oxygen than an equivalent stand of other tree species. Many scholars suggested that bamboo forest ecosystems provide significant services for human adaptation and development at the same time mitigate climate change impacts through carbon sequestration. Under well managed bamboo plantations it shows an effective carbon sink and better performance than other tree species growing under similar conditions. Despite this it's a source of income in rewarding the diverse requirements at small and large-scales in rural areas. Generally; this review prepared to demonstrate the role of bamboo forests towards mitigating and adapting potential to overcome the impacts of climate change seen in the world and particularly to China. Therefore, advancing bamboo farming systems in different levels it's advantageous in reducing greenhouse gas in atmosphere and expanding bamboo forests in future under wider use and intensive management is recommended.

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