Review Paper

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

Abstract: *Bamboo's fast growth is one of its many attributes which make it a useful resource for humankind. It is widely distributed in Southeast Asia, Africa, and Latin America. As a major non-wood forest product and wood substitute, bamboo is increasing interest to ecologists owing to its rapid growth and correspondingly high potential for mitigating current climate change problems. It is also commonly seen as an indication of a high ability to capture and sequester atmospheric carbon and consequently mitigate climate change, in a similar way that trees do. With a long history of production and utilization of bamboo, China is one of the countries with the richest bamboo resources and largest area of bamboo forest, and has paid unprecedented attention in recent decades to management of bamboo forests. The objectives of this review paper is to assess the role of bamboo on mitigating and adapting impacts of climate change and the versatility of bamboo in terms of its ecological benefits including carbon sequestration, water and soil conservation, its benefits for socioeconomic development, and its potential to mitigate climate change. The characteristics of bamboo make it a perfect solution for the environmental and social consequences of tropical deforestation. With its fast growth rate and high annual re-growth after harvesting, the bamboo forest has a high carbon storage potential especially when the harvested culms are transformed into durable products. So, under well managed bamboo forests it shows an effective carbon sink and better performance than Chinese fir and eucalyptus growing under similar conditions, this showed that the high potential of bamboo towards carbon sequestration. On the other hand, it's a source of income in rewarding the diverse requirements at small and large-scales in rural areas and has great potential in sequestering carbon and climate change mitigation. This review summarizes the role of bamboo forests for mitigation and adaption potential of bamboo to overcome the challenges of climate change currently seen in the world and particularly to China. Therefore, promoting bamboo farming systems in different levels is advantages to reduce greenhouse gas in atmosphere and expanding bamboo forests in future under wider use and intensive management is recommended.*

Key words: - Adaptation; Bamboo; climate change; mitigate; sequester;

1. Introduction

Bamboo it's a grass type of Gramineae family, is an important component of many forest ecosystems. Bamboo adapts easily to a range of climatic and soil conditions, and is therefore widely distributed in the tropical and subtropical zones between approximately 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 (FAO, 2010). Bamboo 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 rapid asexual reproduction of new culms (Janzen, 1976; Isagi, *et al*., 1997; Li, *et al.,* 1998).

The bamboo resources are distributed in many countries in the world, majorly found in Asia, Africa, and Latin America, however, its origins lie in Southeast Asia. As a major non-wood forest product and wood substitute, bamboo has been widely used for numerous purposes. Compared with other types of forest, the bamboo forest generates different ecosystem services, such as carbon storage, and water and soil conservation because of its special root re-sprouting regeneration strategy and selective cutting utilization system (Lobovikov *et al.*, 2009). Therefore, the bamboo forest is playing an increasingly important role in socioeconomic development and international trade. In the world the bamboo family includes more than 107 genera with more than 1300 species (Zhu, 2001). Among 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 in the world (Zhu, 2001). Due to its vast territory, complex terrain, and diverse climate, China has one of the richest bamboo resources in the world. Moreover, China's bamboo forests cover an area of 4.84 million ha in 2005, accounting for 2.8% of China's forested area and 15.4% of the world's area of bamboo (SFAPRC, 2006). As a resources bamboo forests is an important part of eco-systems, providing a number of crucial environmental services. It provides food and raw materials

(provisioning services) for consumers in developing and developed countries. It regulates water flows, reduces water erosion on slopes and along riverbanks, can be used to treat wastewater and can act as windbreak in shelterbelts, offering protection against storms (regulating services) (FAO, 2010). Many studies have shown that appropriately managed and regularly harvested bamboo can sequester more carbon than bamboo in natural state. Moreover, 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 objectives of this review paper is to assess the role of bamboo on mitigating and adapting impacts of climate change and the versatility of bamboo in terms of its ecological benefits including carbon sequestration, water and soil conservation, its benefits for socioeconomic development, and its potential to mitigate climate change.

2. Role of Forests in Mitigating Climate Change

Forests and natural areas play a very important role in maintaining natural processes. 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. But forests can also be one of the biggest sources of CO_2 emissions (IPCC, 2007). Furthermore, 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, the demand for timber and related products will continue to increase as the population expands, requiring 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 paints a rather gloomy picture about the future of the world forests in

changed climate, as is 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 (Seppala *et al*., 2009). Deforestation and degradation represent over one third of total emissions in developing countries, where many large tropical forests are found. The important role that forest-rich developing countries can play in combating climate change by reducing emissions from deforestation and forest degradation has become central to international dialogues on preventing global temperature increases as a global public good (Wei *et al*., 2013). Climate change affects forest ecosystems in their structure and morphology, thus causing an implication their functionality. Vulnerability analysis of forest ecosystems in the national communications demonstrates that climate can significantly affect the availability of forest goods and services in terms of quality and quantity (MoEF, 2012). Climate change is considered to be one of the greatest threats facing humanity. According to the Intergovernmental Panel on Climate Change (IPCC), global warming is unequivocal, with evidence from increases in average air and ocean temperatures, melting of snow and ice and sea level rise (IPCC, 2007). If global emissions continue down the Business as Usual (BAU) trajectory, the scientific evidence points to increasing risks of serious, irreversible impacts (Stern, 2006). In order to avoid the most damaging effects of climate change, it is estimated that global levels of atmospheric greenhouse gases (GHGs) need to be stabilized at approximately 445-490 parts per million CO_2e (CO_2 equivalent) or less. To achieve this target, it is essential that urgent international action is taken. Forests will have a central role in meeting this target (Eliasch, 2008).

3. Bamboo and Adaptation to Climate Change

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

111 soils and climate, renewability and positive socio-economic impacts make them an excellent
112 species for combating climate change. The high growth potential and ability to store large
113 amounts of carbon make sequestration and on the other hand their environmental and socio-
114 economic services can help communities in developing countries to adapt to the climate
115 change impacts. Research and growth modeling by the International Network of Bamboo and
116 Rattan (INBAR) had shown that managed bamboos can be an effective carbon sink and
117 perform better than Chinese fir and eucalyptus growing under similar conditions. Managing
118 bamboos involves the annual, sustainable and selective harvesting of stem which are turned
119 into products that can hold carbon for many years. The increasing popularity of durable
120 bamboo products ensures that for the foreseeable future, productive bamboo systems can be
121 considered as an important carbon sink (INBAR, 2009).

122 **3.1 Bamboo in Growing timber demand and Climate Change**

123 The demand for timber and agricultural commodities will continue to increase as the global
124 population expands and becomes wealthier. Global policies will need to shift towards more
125 efficient and sustainable production methods in order to satisfy the rising demand for
126 commodities. The sustainable management of forests will play a key role in meeting this
127 demand. Bamboo has an important role to play in reducing pressure on forestry resources.
128 For instance, in China, since nationwide logging bans of certain forests came into effect in
129 1998, bamboo has increasingly been seen as a possible substitute to timber and has entered
130 many markets traditionally dominated by timber. The successful use of bamboo in different
131 product lines, ranging from furniture and flooring to paper and packaging demonstrates the
132 high potential for bamboo as a more sustainable alternative material in production of many
133 products.

134 (Magel *et al*., 2005) argue that growth of the new shoots in a bamboo forest occurs as a result
135 of transfer of the energy accumulated in culms through photosynthesis in the previous year.

As such, the 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 as such growth of new shoots is not an indicator of sequestration rate. On the other hand, (Zhou, 2009) argues that as the bamboo system requires more inputs in the shooting season of young culms (when new shoots grow), high growth in bamboo shoots can be equated with a high rate of carbon sequestration. Bamboo culms of most species reach maturity after approximately 7-10 years, after which they deteriorate rapidly, releasing carbon from the above-ground biomass back into the atmosphere (Liese, 2009). Therefore in a natural state, bamboo will reach a stable level of above ground carbon relatively quickly, where carbon accumulation through sequestration is offset by carbon release through deterioration of old culms. In order for the bamboo system to continue to be a net sink, carbon has to be stored in other forms, so that the total accumulation of carbon in a solid state exceeds the carbon released to the atmosphere.

4. Bamboos for Climate Change Mitigation

Bamboos offer one of the quickest ways to remove vast amounts of that CO_2 from the atmosphere. It minimizes CO_2 gas and generates up to 25% more oxygen than an equivalent stand of trees. 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} (Janssen, 2000). 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 727.08Tg C in 2010 to 1,017.54TgC 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 (Kuehl and Yiping, 2012). Let's see one example; by INBAR's as modeling shows that a managed moso bamboo forest accumulates about 300 t of carbon ha^{-1}

after 60 years. Furthermore, it's also produce the most biomass when managed by cultivation with selective, regular harvesting of mature culms. With harvested culms made into durable products, a managed bamboo forest sequesters more carbon than fast growing tree species, such as Chinese fir (Kuehl and Yiping, 2012). Due to rapid early growth, bamboos sequester more carbon in the early years of a plantation than comparable forest trees. 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 (Kuehl and Yiping, 2012).

4.1 Carbon Sequestration

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. In nature bamboo's plantation growing in high fast rate with high annual re-growth behavior after harvesting, it has a high carbon storage potential (Zhou and Jiang, 2004), 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 to the atmosphere, thereby prolonging the carbon storage by bamboo. Currently in China about 53Mha 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 (Chen *et al*., 2009).

The area of bamboo forest in China is 6 million hm^2, which stores about 780 Tg carbon, accounting for 14% of total forest carbon stock in China. According to 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 (Yuen *et al*., 2017).

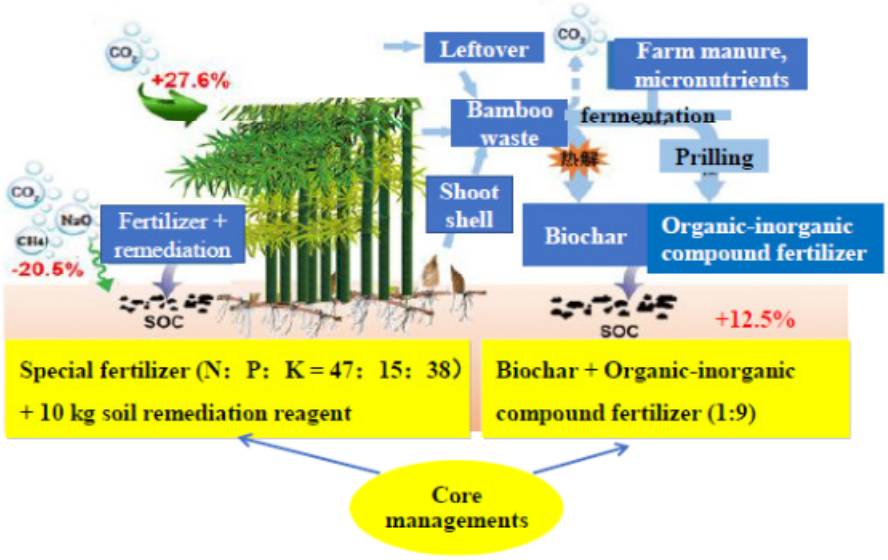
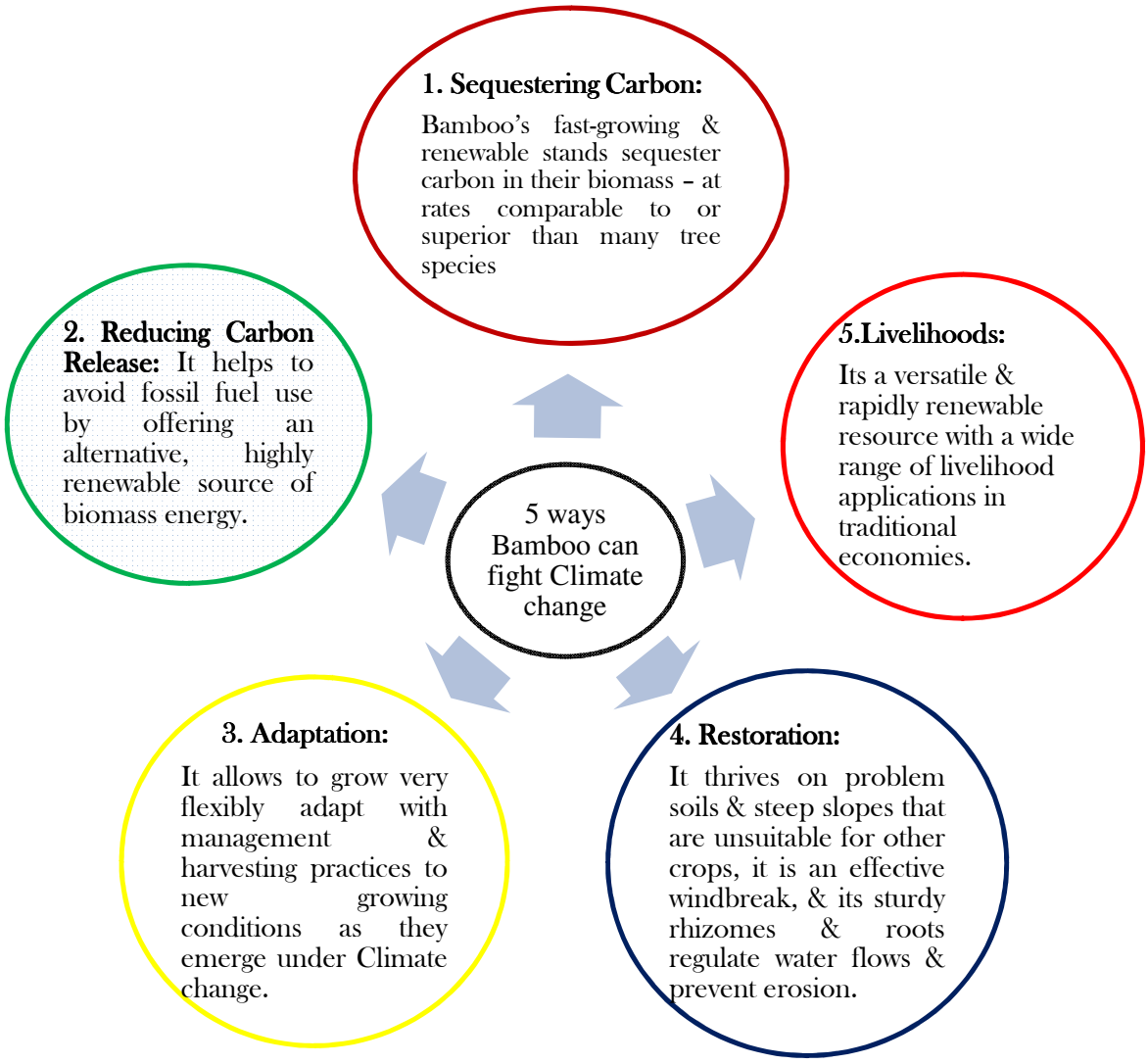


Figure 1. Contribution of Bamboo on adding C sink and reducing C emission (Source: Yuen *et al*., 2017).

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.



5. Summary

This study has tried to reviews the role of bamboo forests in terms of mitigating the impacts of current climate change and the versatility of bamboo in terms of its ecological benefits including carbon sequestration, water and soil conservation, and its benefits for socioeconomic development. Bamboos offer one of the quickest ways to remove huge amounts of CO_2 from the atmosphere. It minimizes CO_2 gas and generates up to 25% more oxygen than an equivalent stand of trees. 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}. Due to its fast growth rate and high annual re-growth after harvesting, the bamboo forest has a high carbon

storage potential especially when the harvested culms are transformed into durable products. Many scholars suggested that bamboo forest ecosystems can be providing significant services for human adaptation and development simultaneously mitigate climate change compared with other types of forests, through carbon sequestration different bamboo species possess higher potential contribution to climate change mitigation. So, under well managed bamboo forests it shows an effective carbon sink and better performance than Chinese fir and eucalyptus growing under similar conditions, this indicate that bamboo has an excellent potential on carbon sequestration comparing with others forest types. On the other hand it's a source of income in rewarding the diverse requirements at small and large-scales in rural areas and has great potential in sequestering carbon and climate change mitigation. This review summarizes the role of bamboo forest for mitigation and adaption potential of bamboo to overcome the problem of current global climate change impacts. Therefore, promoting bamboo farming systems in different levels is advantages to reduce greenhouse gas in atmosphere and expanding bamboo forests in future under wider use and intensive management is recommended.

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