

## 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;

## 36        **1. Introduction**

37        Bamboo **it's** a grass type of Gramineae family, is an important component of many forest  
38        ecosystems. Bamboo adapts easily to a range of climatic and soil conditions, and is therefore  
39        widely distributed in the tropical and subtropical zones between approximately 46°N and  
40        47°S latitude, covering a total area of about 31.5 million ha, and accounted for about 0.8% of  
41        the world's total forested area in 2010 (FAO, 2010). Bamboo has unique features that  
42        distinguish it from most other woody plants. For example, culms that are connected by an  
43        extensive system of rhizomes, leading to rapid asexual reproduction of new culms (Janzen,  
44        1976; Isagi, *et al.*, 1997; Li, *et al.*, 1998).

45        The bamboo resources are distributed in many countries in the world, majorly found in Asia,  
46        Africa, and Latin America, however, its origins lie in Southeast Asia. As a major non-wood  
47        forest product and wood substitute, bamboo has been widely used for numerous purposes.  
48        Compared with other types of forest, the bamboo forest generates different ecosystem  
49        services, such as carbon storage, and water and soil conservation because of its special root  
50        re-sprouting regeneration strategy and selective cutting utilization system (Lobovikov *et al.*,  
51        2009). Therefore, the bamboo forest is playing an increasingly important role in  
52        socioeconomic development and international trade. In the world the bamboo family includes  
53        more than 107 genera with more than 1300 species (Zhu, 2001). Among this all China has the  
54        highest bamboo species diversity, with 39 genera and 509 species, accounting for 36% and  
55        39% (respectively) of the total bamboo genera and species in the world (Zhu, 2001). Due to  
56        its vast territory, complex terrain, and diverse climate, China has one of the richest bamboo  
57        resources in the world. Moreover, China's bamboo forests cover an area of 4.84 million ha in  
58        2005, accounting for 2.8% of China's forested area and 15.4% of the world's area of bamboo  
59        (SFAPRC, 2006). As a resources bamboo forests is an important part of eco-systems,  
60        providing a number of crucial environmental services. It provides food and raw materials

61 (provisioning services) for consumers in developing and developed countries. It regulates  
62 water flows, reduces water erosion on slopes and along riverbanks, can be used to treat  
63 wastewater and can act as windbreak in shelterbelts, offering protection against storms  
64 (regulating services) (FAO, 2010). Many studies have shown that appropriately managed and  
65 regularly harvested bamboo can sequester more carbon than bamboo in natural state.  
66 Moreover, it can sequester more carbon than fast-growing tropical and subtropical trees under  
67 comparable conditions. If bamboo forests are not managed through annual harvesting  
68 practices, they would be significantly less effective in carbon sequestration.

69 The objectives of this review paper is to assess the role of bamboo on mitigating and adapting  
70 impacts of climate change and the versatility of bamboo in terms of its ecological benefits  
71 including carbon sequestration, water and soil conservation, its benefits for socioeconomic  
72 development, and its potential to mitigate climate change.

## 73 **2. Role of Forests in Mitigating Climate Change**

74 Forests and natural areas play a very important role in maintaining natural processes. Forests  
75 are one of the biggest reservoirs of carbon, so they help to keep the carbon cycle and other  
76 natural processes working and help reduce climate change. But forests can also be one of the  
77 biggest sources of CO<sub>2</sub> emissions (IPCC, 2007). Furthermore, forests provide a wide range of  
78 ecological, social, and economic benefits, in the form of goods and services to society, that  
79 are much less easier to quantify. Besides, the demand for timber and related products will  
80 continue to increase as the population expands, requiring more efficient and sustainable use  
81 of natural resources. Forests are the most vulnerable climate dependent systems, but have  
82 also been recognized to have significant and crucial contribution to address the challenges of  
83 mitigation and adaptation in tandem with the issues of livelihoods, economic growth and  
84 development. However, the most recent report from the International Union of Forest  
85 Research Organizations paints a rather gloomy picture about the future of the world forests in

86 changed climate, as is suggests that in a warmer world, the current carbon regulating services  
87 of forests as carbon sinks may be entirely lost as land ecosystems could turn into a net source  
88 of carbon dioxide later in the century (Seppala *et al.*, 2009). Deforestation and degradation  
89 represent over one third of total emissions in developing countries, where many large tropical  
90 forests are found. The important role that forest-rich developing countries can play in  
91 combating climate change by reducing emissions from deforestation and forest degradation  
92 has become central to international dialogues on preventing global temperature increases as a  
93 global public good (Wei *et al.*, 2013). Climate change affects forest ecosystems in their  
94 structure and morphology, thus causing an implication their functionality. Vulnerability  
95 analysis of forest ecosystems in the national communications demonstrates that climate can  
96 significantly affect the availability of forest goods and services in terms of quality and  
97 quantity (MoEF, 2012). Climate change is considered to be one of the greatest threats facing  
98 humanity. According to the Intergovernmental Panel on Climate Change (IPCC), global  
99 warming is unequivocal, with evidence from increases in average air and ocean temperatures,  
100 melting of snow and ice and sea level rise (IPCC, 2007). If global emissions continue down  
101 the Business as Usual (BAU) trajectory, the scientific evidence points to increasing risks of  
102 serious, irreversible impacts (Stern, 2006). In order to avoid the most damaging effects of  
103 climate change, it is estimated that global levels of atmospheric greenhouse gases (GHGs)  
104 need to be stabilized at approximately 445-490 parts per million CO<sub>2</sub>e (CO<sub>2</sub> equivalent) or  
105 less. To achieve this target, it is essential that urgent international action is taken. Forests will  
106 have a central role in meeting this target (Eliasch, 2008).

### 107 **3. Bamboo and Adaptation to Climate Change**

108 Bamboos are one of the world's strongest and fastest growing woody plants capable of  
109 providing ecological, economic and livelihood security to the people, distributed over ranges  
110 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.

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

#### 148 **4. Bamboos for Climate Change Mitigation**

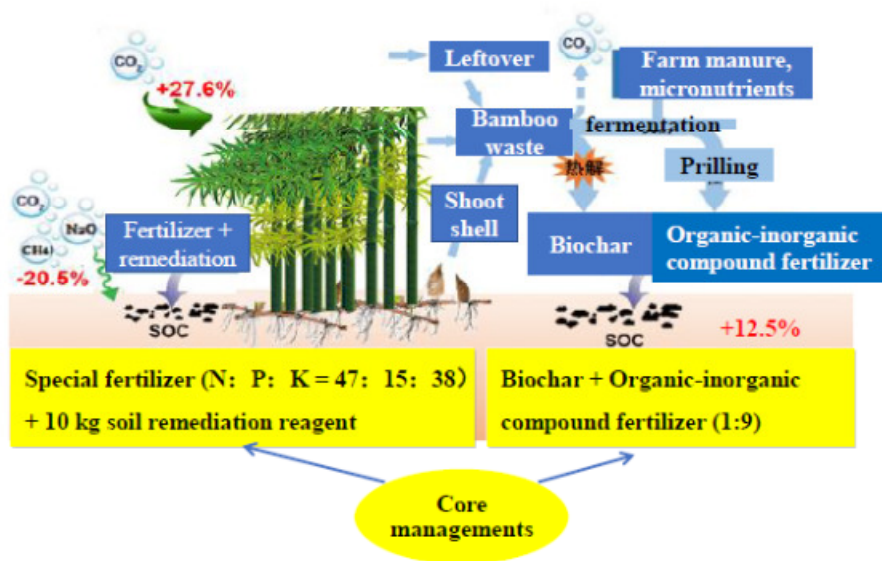
149 Bamboos offer one of the quickest ways to remove vast amounts of that CO<sub>2</sub> from the  
150 atmosphere. It minimizes CO<sub>2</sub> gas and generates up to 25% more oxygen than an equivalent  
151 stand of trees. One hectare of bamboo can sequester up to 62 t of CO<sub>2</sub> yr<sup>-1</sup>, whereas  
152 equivalent of young forest sequesters 15 t of CO<sub>2</sub> yr<sup>-1</sup>. The *Guadua* plantations in Costa Rica  
153 estimated to absorb 17 t of CO<sub>2</sub> ha yr<sup>-1</sup> (Janssen, 2000). Another research study by INBAR  
154 states that over the past 15 years, areas under bamboos in Asia grew by 10%. Studies have  
155 estimated that the carbon stored in Chinese bamboo forests will increase from 727.08Tg C in  
156 2010 to 1,017.54TgC in 2050, which equates to an increase of nearly 40% in 40 years. This  
157 represents a significant contribution to the Chinese forest Carbon stock and a range that  
158 shows that policies aiming at combating climate change with bamboos can indeed have  
159 significant promise (Kuehl and Yiping, 2012). Let's see one example; by INBAR's as  
160 modeling shows that a managed moso bamboo forest accumulates about 300 t of carbon ha<sup>-1</sup>

161 after 60 years. Furthermore, it's also produce the most biomass when managed by cultivation  
162 with selective, regular harvesting of mature culms. With harvested culms made into durable  
163 products, a managed bamboo forest sequesters more carbon than fast growing tree species,  
164 such as Chinese fir (Kuehl and Yiping, 2012). Due to rapid early growth, bamboos sequester  
165 more carbon in the early years of a plantation than comparable forest trees. Unmanaged  
166 bamboo stands do not store high levels of carbon, as their productivity is low and the  
167 accumulated carbon returns quickly to the atmosphere as the older culms decompose (Kuehl  
168 and Yiping, 2012).

#### 169 **4.1 Carbon Sequestration**

170 Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide. In  
171 nature bamboo's plantation growing in high fast rate with high annual re-growth behavior  
172 after harvesting, it has a high carbon storage potential (Zhou and Jiang, 2004), especially  
173 when the harvested culms are transformed into durable products. The increased lifespan of  
174 durable bamboo products made possible by modern technology can ensure that the  
175 sequestered carbon will not return quickly to the atmosphere, thereby prolonging the carbon  
176 storage by bamboo. Currently in China about 53Mha of forest plantation is there with a  
177 volume stock of 1.5 billion m<sup>3</sup>. Between 2005 and 2020, China has pledged to establish more  
178 than 40 million ha of plantations, referred to as carbon sink forest. As plantations have been  
179 recognized as the national strategy for mitigating atmospheric CO<sub>2</sub>, it is essential to assess the  
180 potential of fast-growing and high yield plantations in carbon storage and sequestration at  
181 stand, regional and national scales (Chen *et al.*, 2009).

182 The area of bamboo forest in China is 6 million hm<sup>2</sup>, which stores about 780 Tg carbon,  
183 accounting for 14% of total forest carbon stock in China. According to carbon density of  
184 bamboo forest ecosystems in China, the estimated global bamboo carbon stock is about 4 Pg,  
185 accounting for 0.43%-0.61% of total global forest carbon stock (Yuen *et al.*, 2017).



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

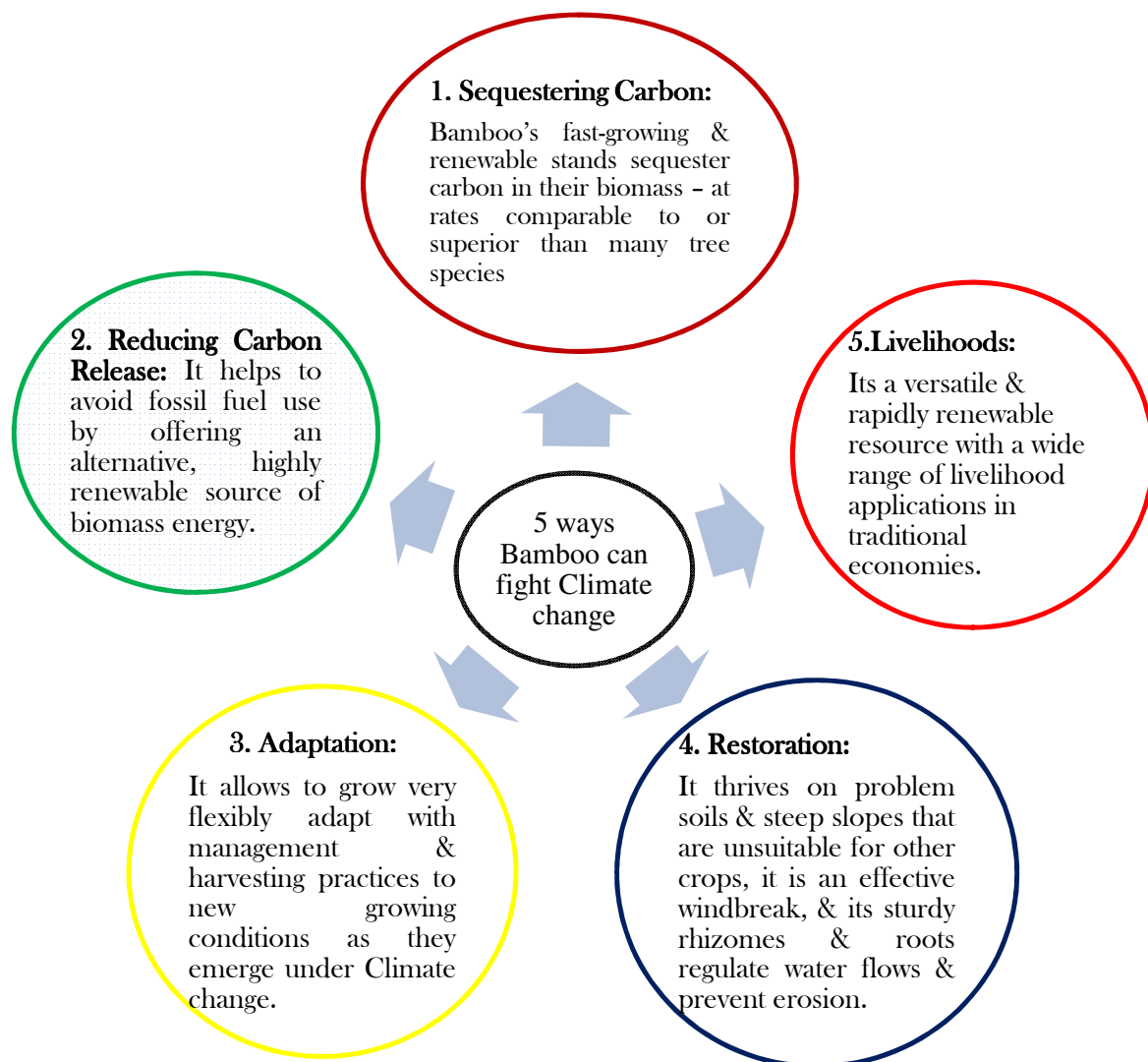
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191 To combat climate change, bamboo should be a core development resource – providing  
192 countries and development partners with a wealth of practical solutions to reduce the negative  
193 effects that changing climate patterns have on millions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

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





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## 199 5. Summary

200 This study has tried to reviews the role of bamboo forests in terms of mitigating the impacts  
 201 of current climate change and the versatility of bamboo in terms of its ecological benefits  
 202 including carbon sequestration, water and soil conservation, and its benefits for  
 203 socioeconomic development. Bamboos offer one of the quickest ways to remove huge  
 204 amounts of CO<sub>2</sub> from the atmosphere. It minimizes CO<sub>2</sub> gas and generates up to 25% more  
 205 oxygen than an equivalent stand of trees. One hectare of bamboo can sequester up to 62 t of  
 206 CO<sub>2</sub> yr<sup>-1</sup>, whereas equivalent of young forest sequesters 15 t of CO<sub>2</sub> yr<sup>-1</sup>. Due to its fast  
 207 growth rate and high annual re-growth after harvesting, the bamboo forest has a high carbon

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

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