Briefing: Bamboo for construction in Pakistan – a scoping review

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This scoping review explores the bamboo construction situation in Pakistan, including the species available, where they grow, built examples, perceptions, barriers to their use and the potential of the material, aiming to enable state-of-the-art use of bamboo in the country.

1. Introduction

Bamboo is a renewable material available worldwide in tropical, subtropical and temperate zones for use in construction, furniture, handicrafts and food. It has shown advantages as a construction material because it is a rapidly renewable sustainable resource and it has mechanical properties similar to those of timber (Sharma *et al.*, 2015). Despite these advantages, the quality and potential of bamboo as a construction material depend on good growing practices, cutting techniques, treatment and preservation, correct jointing, overall structural design and maintenance.

Between 2005 and 2016 more than 5 100 000 people were left homeless due to earthquakes and floods in Pakistan (Cred EM-DAT, 2017). In response to these events, different emergency, transitional and permanent shelters were built and many of them used bamboo with various degrees of success, acceptability and durability. Bamboo offers an affordable and sustainable solution for shelter; however, there are limited resources to guide communities on how best to use it. The main research question for this scoping review was ‘what types of bamboo species are suitable for construction purposes in Pakistan?’ The main objective was to map the range of species for the four primary systems: poles and columns (large diameter); rafters and studs (medium diameter); roof and wall battens (medium and small diameters); and wall and floor cladding (small diameter). In addition, this research looked for examples in construction, perceptions and barriers to the use of bamboo in Pakistan.

2. Bamboo species in Pakistan suitable for construction purposes

There are around 1200 species of bamboo globally and among these, three are native to Pakistan: *Arundinaria falcata*, *Bambusa bamboo* and *Dendrocalamus strictus* (Lobovikov *et al.*, 2007). Of these, *A. falcata* has been recorded in the North West Himalayas at 1200–2000 m and *B. bamboo* has been cultivated in Punjab and Sindh, and has occasionally

been found in the Ravi River to the east (Ahmad, 1997; Suleman, 2005). *D. strictus* has been recorded in the Margalla Hills, Chattar, the Eastern Salt Range, Shahpur and Mirpur, Ambela, Maskipur and Bagra in Burner up to an altitude of 800 m (Siddiqui, 1994). These sites lie at the limit of Chir pine-growing areas, indicating that bamboo used to grow as a scattered undergrowth in forests, between 350 and 800 m of altitude, and it was more widespread than it is now (Siddiqui, 1994). Some reasons for its decrease might be the cutting and removal of native groves, and the effects of fire, grazing and drought (Siddiqui, 1994). A number of species were introduced to the country; some authors indicate that 13 new species were introduced from China, Bangladesh, Sri Lanka and Thailand (Lobovikov *et al.*, 2007), while others say that 25 species were brought (Siddiqui, 1994; Suleman, 2005). Although some species grew successfully, others did not adapt due to poor post-harvesting and processing, leading to a fall in prices and plantations being uprooted (Rao and Ouedraogo, 1997).

A map of bamboo growth areas in Pakistan (Figure 1) and a table showing the bamboo species (Table 1) were created to show the information found in this scoping review. The districts of the Punjab province where bamboo is established in agricultural lands are Sargodha, Jhang, Kasur, Lahore, Khushab, Ganda Singh, Bhalwal, Mandi Bhahaudin and Dera Ghazi Khan (Karim Alm-Ns, 2016; Lobovikov *et al.*, 2007; Suleman, 2005), and the major species cultivated on private farmland are *D. strictus*, *Bambusa tulda* and *Dendrocalamus hamiltonii* (Lobovikov *et al.*, 2007; Suleman, 2005). These three species are used extensively for construction (Bauer, 2010; Ward *et al.*, 2010).

3. Local market for bamboo in Pakistan

Almost all of the demand for bamboo in Pakistan was met up to 1971 from the native forests of East Pakistan, but after the creation of Bangladesh, the prices of goods manufactured with bamboo increased (Siddiqui, 1994). However, in the

Figure 1. Map of bamboo growing areas in Pakistan. Sources: Based on information from (1) Suleman (2005), (2) Karim Alm-Ns (2016) and (3) Bystriakova *et al.* (2003)

late 1970s and early 1980s bamboo started to be cultivated in the country and the government allowed importation, which contributed to lowering prices (Siddiqui, 1994). In the last few decades, almost all bamboo resources have been grown on private farms in the Punjab region where most farmers use rhizomes for planting bamboos, although shoot cuttings are also used for cultivation (Suleman, 2005). While generally small, plantation areas increase or decrease with market demand and timber prices (Suleman, 2005). Bamboo grown for 3–4 years is used as structural support for dikes and for construction purposes, and bamboo grown on a 2-year cycle is commonly used for the paper pulp industry (Ward *et al.*, 2010).

It was estimated in 2005 that the average stock of bamboo grown on farmlands was 8 t/ha and that the total growing stock of bamboo for commercial purposes was 136 000 t for material with a culm diameter of >5 cm (Suleman, 2005).

Most bamboo farmers sell to traders who clear-cut the bamboo, coordinate transportation and sell the material to retailers or paper pulp factories (Ward *et al.*, 2010). There is little seasonal variation in prices or supply because bamboo is mostly harvested year round, and prices increase by ~5% every 2 years (Bauer, 2010; Ward *et al.*, 2010), almost in line with inflation, on average by 4% in 2016 (Trading Economics, 2017).

Inter-agency assessments of the impact of the monsoon floods of 2010 on market systems in Pakistan indicate that there were neither significant crop losses nor an impact on the bamboo market immediately after the floods (Bauer, 2010; Ward *et al.*, 2010). However, demand for bamboo for reconstruction started to increase 6 months after the floods, and a year later prices hit their peak of Pakistani rupee (PKR) 15–16 per foot, approximately twice the normal retail price of PKR 7–8 (Zyck *et al.*, 2015). The reasons for the increase were scarcity due to the use of bamboo for shelters and water and sanitation

Table 1. Bamboo species in Pakistan. Based on information from Chao and Renvoize (1989), Siddiqui (1994), Ahmad (1997), Rao and Ouedraogo (1997), Bystrakova *et al.* (2003), Suleman (2005), Lobovikov *et al.* (2007) and Zehui (2007)

Species	Description	Height: m	Diameter: cm	Possible use
Native				
<i>Arundinaria falcata</i>	Grows in the undergrowth in forests of oak, usually on northern slopes or in ravines. It is used for making baskets, mats and pipes	ND	ND	Wall and floor cladding
<i>Bambusa bamboo</i>	(Cultivated) This species is extensively used for construction	30	18	Poles/columns
<i>Dendrocalamus Strictus</i>	(Cultivated) Used for construction, pulp and paper and a variety of purposes. This forms part of a gene pool extending across Hindustan and usually seen in hilly areas ascending to 800 m and up to 1200 m	6–20	3–15	Rafters and studs
Introduced, most successful				
<i>Bambusa multiplex</i>	(Cultivated) This is a hedge bamboo, introduced from China. It is cultivated for general use and paper pulp	7–10	2.5–4	Wall and floor cladding
<i>Bambusa tulda</i> (Bengal or java bamboo)	Used for construction, scaffolding, furniture, fodder and edible shoots. Also used for pulp and paper, toys, mats, screens, baskets and fishing rods. Native of Assam, Thailand, Bangladesh and Myanmar	15–23	7–10	Rafters and studs, roof and wall battens
<i>Bambusa vulgaris</i> (golden bamboo)	(Cultivated) Extensively used for furniture, construction and edible shoots. From tropical Asia it has been introduced in tropical and subtropical regions in the world	20	10	Rafters and studs
<i>Dendrocalamus giganteus</i>	(Cultivated) Used for construction, fodder and edible shoots. Found in tropical and subtropical regions	30	25–30	Poles/columns
<i>Dendrocalamus hamiltonii</i> (kala baans)	Used for fodder, weaving and edible shoots, also for scaffolding, construction, basket making and mats. Naturally found in India, Bhutan and Bangladesh	30	5–13	Rafters and studs, roof and wall battens
<i>Dendrocalamus longispathus</i>	(Cultivated) Used for making baskets and ornamental items. Found in India, Myanmar and Bangladesh	12–18	7–13	Rafters and studs
<i>Phyllostachys aurea</i> (fishpole or golden bamboo)	(Cultivated) Used for furniture, edible shoots, handicrafts and as an ornamental bamboo. Native to China but cultivated in Japan and introduced to other countries as ornamental species. It withstands temperatures down to -17.7°C .	9–12	9	Wall and floor cladding
Introduced, others				
<i>Bambusa arundinacea</i> (thorny bamboo)	Used for construction, pulping, tools and edible shoots. Split culms used for mats and basket work. Mainly in India, Sri Lanka, Thailand, Indonesia and Myanmar (Burma). It grows rapidly (50–8 cm/d)	17–30	9–18	Rafters and studs
<i>Bambusa nutans</i>	Medium size bamboo used as an ornament and in the paper industry. Native in India and cultivated in Bangladesh and Thailand	6–15	5–10	Rafters and studs
<i>Bambusa polymorpha</i>	Used for construction. Popular for roofing and flooring. Found in India, Indonesia, Bangladesh, Thailand, Myanmar and China	15–25	7–17	Rafters and studs, Wall and floor cladding
<i>Melocanna bambusoides</i>	Used for building houses, woven ware, pulp and paper, tabashir, toys, mats, screens and umbrella sticks. Found in Eastern Bengal, Myanmar and Chittagong, Bangladesh	12–21	2–8	Wall and floor cladding
<i>Phyllostachys aureosulcata</i> (yellow groove bamboo)	Used for gardening and ornaments. Found in China, Europe and America	5–10	1–3	Wall and floor cladding
<i>Phyllostachys pubescens</i> (moso bamboo)	Giant hardy bamboo used for construction and shoots. Native to China and also cultivated in Japan	12–22	10–18	Poles/columns

facilities, and the willingness of aid agencies to pay above-market prices (Zyck *et al.*, 2015). Also, transport costs were raised due to the longer routes taken to avoid flood-damaged roads and bridges, and due to middlemen involved in the trade (Zyck *et al.*, 2015). Aid agencies drove up the quality of bamboo, pushing traders to stock more durable, extra thick, hence more expensive, bamboo (Zyck, 2014), inflating its price. Some local traders learned from experience and the bamboo sector grew in Sindh: larger dealers began to order more bamboo to be prepared in case of future flooding and began using raised shelving in their warehouses to prevent floods from damaging the stock (Zyck *et al.*, 2015). Due to the demand, when needed, importers bring additional bamboo from China, Bangladesh and other countries to supplement local production (Zyck *et al.*, 2015).

4. Local knowledge in bamboo construction in Pakistan

Bamboo is mainly used as a roofing material and scaffolding; however, it is also used to build latrines, ladders, carts and temporary shelters (Zyck *et al.*, 2015). Some examples were found of bamboo used as an important structural element in buildings.

4.1 Case 1: Emergency and transitional shelters after a disaster

After the 2010 floods in Pakistan, millions of people needed temporary shelters across five provinces of the country (IFRC *et al.*, 2014). Among different strategies to provide housing, traditional and local building designs and materials were encouraged, adapted and improved to achieve flood resistance and minimal environmental impact (IFRC *et al.*, 2014). Some shelter programmes used bamboo in a ‘versatile roofing kit’,

including bamboo poles, steel beams and plastic sheets, which were used for an emergency house first, the roof of the transitional house later and finally material for the permanent house (Figure 2).

4.2 Case 2: Heritage Foundation of Pakistan

The Heritage Foundation of Pakistan (HFP) is a not-for-profit organisation engaged in the research, dissemination and conservation of Pakistan’s cultural heritage (HFP, 2011a). The organisation worked on several projects for the rehabilitation of communities affected by the earthquake in the Kashmir region in 2005 and the monsoon floods in 2010. The foundation designed and built community buildings that are elevated from the ground, which effectively resisted the 2011 floods (HFP, 2011a). The structures of these buildings were made of bamboo, covered with mud plaster on the first floor, built on stilts and had a circular plan (Figure 3). Also, the organisation developed a roof system called karavan roofs designed for refuge during floods (HFP, 2011b). The United Nations International Organisation for Migration (IOM) adopted the models from the HFP and applied them in the One Room Shelter programme (Figure 4) after the 2010 and 2011 floods, building 22 800 shelters in Sindh province (IOM, 2014).

4.3 Case 3: Tipu Sultan Merkez school in Jar Maulwi, Punjab

This is a privately initiated school and development in the small village of Jar Maulwi, near Lahore, overseen by the organisation Tipu Sultan Merkez (TSM). The German firm Ziegert Roswag Seiler Architekten Ingenieure (ZRSAL) was in charge of the design and construction, in collaboration with the local architect Ghayyoor Syed Obaid. The project (Figures 5 and 6)

Figure 2. Bamboo in emergency roofing kit (left) that is later used in a transitional shelter (right). Courtesy of Magnus Wolfe Murray

Figure 3. A green women's centre built on stilts. Courtesy of HFP

Figure 4. House built under the programme 'One Room Shelter' by IOM based on HFP's design. Courtesy of HFP

Figure 5. Building finished. TSM school in Jar Maulwi, Punjab. Courtesy of ZRSAI

Figure 6. Construction process. TSM school in Jar Maulwi, Punjab. Courtesy of ZRSAI

follows earthquake design strategies using a brick foundation, 60 cm thick cob (earth and straw) walls on the ground floor, light bamboo frame structures filled with earth on the first floor, and a roof comprised of triple-layer bamboo beams joined with simple knots and steel rods covered with a layer of earth (ZRSAI, 2012). The bamboo frame structure is filled with straw–earth from inside and uses bamboo strips to create the exterior façade, which also overhangs the earth walls on the ground floor to protect them from rain (ZRSAI, 2012).

5. Perceptions, barriers and potential of bamboo in Pakistan

Some documents referenced in this paper explain a consumer preference for masonry houses in Pakistan, instead of timber or bamboo houses, due to an aspiration for 'durable concrete

and brick homes', even though these are less comfortable and more expensive (Bauer, 2010; ZRSAI, 2012). To complement this information, some interviews were conducted using convenience sampling as a method (with six experts in sustainability and disaster relief from different areas of Pakistan). No statistical conclusions can be drawn from the interviews, which only aimed to get a general idea of how bamboo is seen as a material for construction in Pakistan.

Perceptions: Bamboo is mainly recognised as a material used in rural areas and seen as 'part of the past' by those who aspire to have a 'modern' house. Some do not perceive the material as local, although others recognise bamboo as used extensively for the construction of ladders, scaffolding, animal sheds, general shading, furniture, ornamental landscape, roofing, and emergency and temporary shelters. **Barriers:** The small amount of knowledge about the possibilities of bamboo in construction limits its use. Also, the lack of appropriate techniques in the cutting, treatment and building processes results in bad-quality material, which discourages people from using it. The techniques used for building with natural materials take longer and people are not trained in them.

Potential: Bamboo is seen as an alternative to timber in some areas and it could contribute to tackling deforestation. There is growing interest in low-cost sustainable materials, and bamboo is seen as offering an opportunity in this area. Also, due to the recurrent floods in the country, there is a need for quick renewable materials that can be available for reconstruction.

6. Conclusion

This scoping review shows that information available about the types of bamboo growing in Pakistan and the areas where bamboo grows is very limited. However, the review allowed the identification of the species of bamboo that are cultivated in the country and their possible uses in construction. The review also shows that more research needs to be conducted and disseminated.

Regarding examples of buildings that use bamboo, during a consultation exercise and in the interviews, it was mentioned that bamboo is extensively used for transitional shelters and as a roofing material for vernacular houses. Despite this, few examples were found in the literature, except for those referring to post-disaster shelters and one case of a school built with bamboo.

Finally, in terms of perception, despite some barriers to the use of bamboo in construction, this material is seen as an alternative for sustainable, resilient and low-cost construction that could be used in the country, not only for temporary

dwellings but also for permanent ones, if well cut, treated, designed and built.

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