

Importance of bamboo for immediate earthquake recovery: A study from Nepal

Pramod Ghimire^{*}, Uchita Lamichhane

Faculty of Forestry, Agriculture and Forestry University, Hetauda, Nepal

ARTICLE INFO

Keywords:

Bamboo
Earthquake
Recovery
Temporary houses

ABSTRACT

This study was conducted in four districts of Nepal, Sindhupalchok, Gorkha, West Rukum and Jajarkot. It analyzed the importance of bamboo in immediate earthquake response and recovery. A total of 464 respondents were sampled from four districts struck by earthquakes. 83% of the households had bamboos on their own land, as well as trees such as *Pinus* spp., *Castanopsis* spp. and *Schima wallichii*. 85% of the households used bamboo for pillars, poles, and other supporting materials to hold and adjust roofing and wall materials during the time of the disasters. Moreover, 96% households believed that bamboos were highly useful and thus significant during the time of disasters such as earthquakes. People were aware of the importance of bamboo for coping with disasters; however, they were lacking appropriate knowledge about the socio-economic and environmental significance of bamboo species due to limited knowledge and research.

1. Introduction

A catastrophic earthquake of 7.6 magnitude struck central Nepal on April 25, 2015, followed by a major aftershock of 7.3 magnitude on 12 May 2015 (MoSTE, 2015). This was one of the worst earthquakes to strike Nepal in recent history. It caused widespread destruction, impacting around 8 million people and 31 of the 75 districts in the country (NPC, 2015). About 9000 people were killed, thousands were injured, and more than 600,000 structures in Kathmandu and other nearby cities were either damaged or destroyed (NPC, 2015). Another devastating earthquake (magnitude 6.4) struck Jajarkot district, Karnali Province, Nepal on 3 November 2023, killing 154 people and injuring at least 375 (The Kathmandu Post, 2023). This earthquake was widely felt in western Nepal, and was the deadliest to strike the country since 2015 (The Kathmandu Post, 2023). Both earthquakes severely damaged the country's physical and economic infrastructures including thousands of houses, schools, hospitals, government offices, roads, irrigation canals and market centres.

During the 2015 earthquake, more than 2600 government buildings and 602,257 private houses were destroyed across 31 districts of Nepal. 285,099 private houses and 3757 government buildings were partially damaged (MOHA, 2015). In the 2023 earthquake, about 62,039 houses were affected across thirteen districts of the country, with 26,550 collapsing, mostly in Rukum West district (The Japan Times, 2023;

UNICEF, 2023). Human lifestyles and normal living patterns were severely disrupted by this catastrophic disaster. People were forced to live in temporary shelters or houses utilizing locally available materials such as bamboo, reusing timber from existing house, timber from their farm land, zinc plates, and other supplies provided by the government and non-government organization as relief materials (MoHA, 2015). Bamboo was used extensively for immediate earthquake recovery during the period. It was obtained from every possible source, although bamboo growing on farmland was amongst the most readily available sources (Ghimire et al., 2020).

Bamboo is a widely distributed, socially and commercially significant plant that has been utilized on a daily basis for millennia by millions of people in tropical and subtropical countries (Ahmad et al., 2021; Kafle et al., 2023). According to the latest estimates there are 1662 species of bamboo, representing 121 genera, with an estimated land cover of 35 million hectares worldwide (Canavan et al., 2017; FAO, 2020). Bamboo has been used in the construction industry for a very long time, but generally only as a secondary and aesthetic material (Jeffery et al., 2023; Kafle et al., 2023). Because of its great compressive strength and light weight, bamboo is one of the most used building materials to support concrete, especially in those locations where it is found in abundance and timber is less available (Yadav and Mathur, 2021; Ghimire et al., 2020). Additionally, bamboo has greater impact flexibility than that of timber. As a construction material, bamboo has a

^{*} Corresponding author.

E-mail address: pghimire@afu.edu.np (P. Ghimire).

<https://doi.org/10.1016/j.bamboo.2024.100059>

Received 24 December 2023; Received in revised form 16 January 2024; Accepted 16 January 2024

Available online 18 January 2024

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solid fiber and it has a compressive strength that is two times greater than concrete. Therefore, bamboo is regarded as an exceptionally strong building material (Yadav and Mathur, 2021). It is also light and convenient to move from one location to another. Compared to trees, it emits 35% more oxygen and absorbs 40% more carbon dioxide (Xu et al., 2023). Bamboo-based housing systems have massive potential for mass housing, disaster-prone housing, earthquake-resistant structures/houses, and other applications. Due to its low cost and environmentally friendly attributes, bamboo has been strongly recommended for use in contemporary construction, especially during rapid response (Emamverdian et al., 2020; Ghimire et al., 2020).

Nepal is rich in bamboo species. The Forest Research and Training Center (FRTC) estimates that there are around 53 species of native and introduced tropical and temperate bamboo growing across the major ecological regions of the country (INBAR, 2022; Karki et al., 1998; MoFSC, 2004). In Nepal every farmer has two to ten clumps of bamboo growing on their private land as it is indispensable for their livelihoods and used in almost all the aspects of life from construction, marriage to death (Khanal, 2015). Also regarded as "poor man's timber", bamboo is one of Nepal's most significant plants both within and outside of forests (Jha and Yadav, 2015). Although the Nepalese bamboo resources could play a valuable role in enhancing sustainable development and people's livelihoods, the potential of this resource has largely been overlooked. This study explored the importance of bamboo in immediate earthquake recovery or response, especially in relation to the construction of temporary houses during a time of disaster.

2. Materials and methods

2.1. Study area

This study was conducted in four districts: Sindhupalchok, Gorkha, West Rukum and Jajarkot, which were the worst-affected districts during earthquakes of 2015 and 2023 in Nepal (NPC, 2015; UNICEF, 2023). The epicentre of the 2015 earthquake was east of Gorkha district at Barpak village, about 85 km northwest of central Kathmandu, and its hypocentre was at a depth of approximately 8.2 km (NPC, 2015). It was

the worst natural disaster to strike Nepal since the 1934 Nepal-Bihar earthquake (NPC, 2015). The epicentre of the 2023 earthquake was Jajarkot district in Karnali province and it was the deadliest to strike the country since the 2015 earthquake (The Japan Times, 2023; The Kathmandu Post, 2023). One village in each of the four districts was selected for the study: Thulosirubari village in Sindhupalchok, Barpak Sulikot village in Gorkha, Barekot village in Jajarkot and Aathbiskot village in Rukum district (Fig. 1). The selected villages were all highly affected during the earthquakes of either 2015 or 2023 (Table 1).

Major land use practices in the study area are agriculture and forestry. The majority of the houses are constructed using mud-bound stone walls (CBS, 2012; CBS, 2021). Wood is the primary source of energy used for cooking in all four villages. Livestock rearing is another source of income for people in the study villages. The plantation or conservation of bamboo and other tree species on farm land and wood lots has been long practiced in the area, and bamboo and trees are maintained for multiple purposes.

2.2. Sampling and data analysis

This study was based on primary data collected in October 2015 and November 2023. A semi-structured questionnaire survey was administered in person or by telephone and was used to analyze the use and importance of bamboo in immediate earthquake recovery or response. Simple random sampling was applied to select the households for the questionnaire survey. Altogether 464 respondents (i.e. 348 in person and 116 by telephone) were sampled (Table 2). In the telephone interview, a total of 116 respondents connected to the questionnaire. Of these, 27 individuals partially answered and 89 fully answered the questionnaire. Other primary data were collected through a key informant's survey and by informal meetings held during the field observations. The secondary data were compiled from district profiles and other related documents and incorporated into the study accordingly. The information was coded and analyzed through SPSS statistical analysis and presented in the form of tables and charts. Table 3.

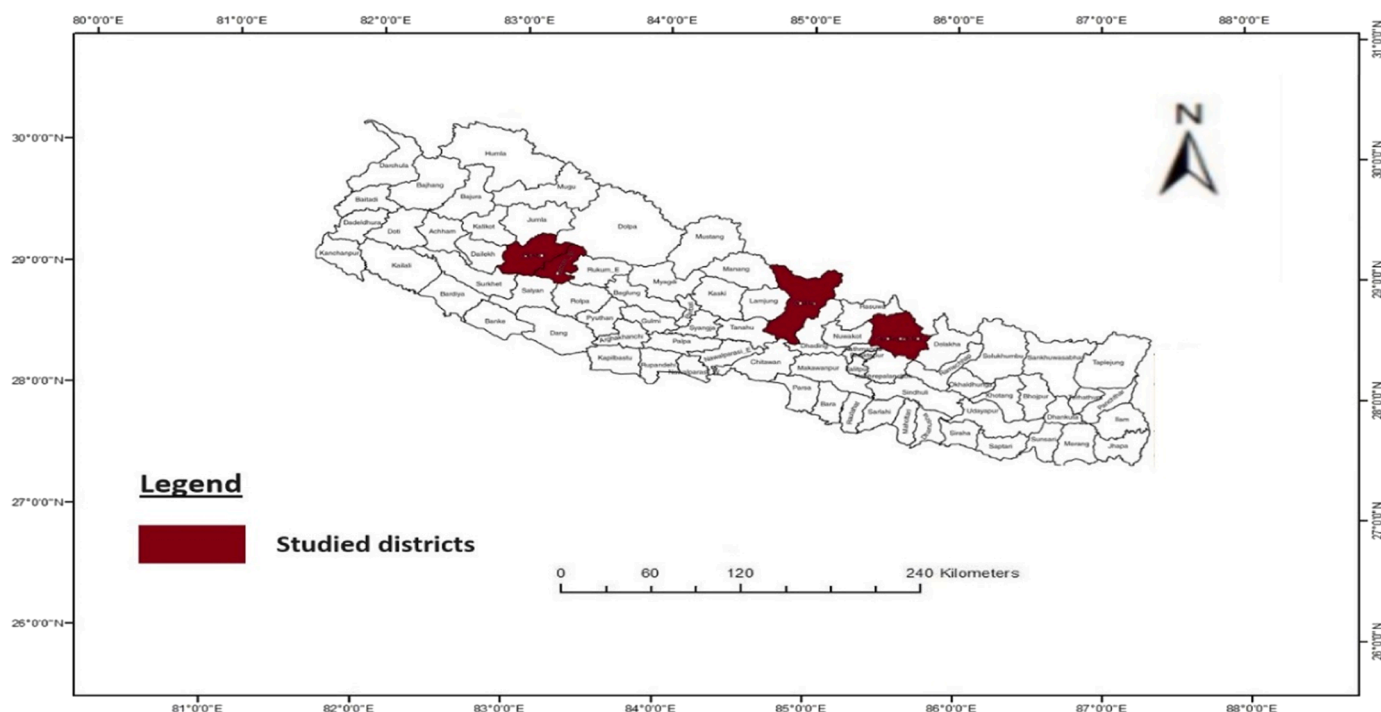


Fig. 1. Map of the study area.

Table 1
Summary of casualties and damage due to the 2015 and 2023 earthquakes in the studied districts.

S. N.	District	Fatalities	Injuries	Number of Residential Buildings		Number of Health Facilities Damaged	Number of Schools Building damaged	Year of Earthquakes
				Collapsed	Partially damaged			
1.	Sindhupalchok	3440	1753	63,885	2751	97	546	2015
2.	Gorkha	238	952	59,527	13,428	79	495	2015
3.	Jajarkot	101	91	905	2745	20	213	2023
4.	West Rukum	52	103	2136	2642	13	82	2023

(Source: Gautam and Rodrigues, 2018; NPC, 2015; Republica, 2023)

Table 2
Number of households studied in the respective districts.

S.N.	District	Sampled Households
1.	Sindhupalchok	138
2.	Gorkha	113
3.	Jajarkot	109
4.	West Rukum	104

Table 3
Construction materials obtained from various species.

S.N.	Species	Major purposes
1.	Bamboo	Pillars, poles, roofing materials, wall materials
2.	<i>Pinus</i> spp.	Pillars, poles, planks
3.	<i>Schima wallichii</i>	Pillars, poles
4.	<i>Shorea robusta</i>	Pillars, poles, planks
5.	<i>Alnus nepalensis</i>	Pillars, poles, planks

3. Results

3.1. Frequency of bamboo on farm land

83% (387 households) of the respondents had bamboo on their private land. Those who did not (77 households) were either poor with very small land holdings or were living on marginal land. Bamboos were being cultivated on hill slopes (71.4%) and on fallow land (66.7%). A few households had bamboo growing near the house, on terrace risers or near river banks for control of bank erosion. Fig. 2.

3.2. Major forest species in the study area

More than 30 tree species (individual species of bamboo were not distinguished) were recorded on the farmland, with bamboo (71.3% of properties) being the most prevalent (Fig. 3). *Schima wallichi* (62.7%) was the second most abundant species followed by *Pinus* species, *Litsea*

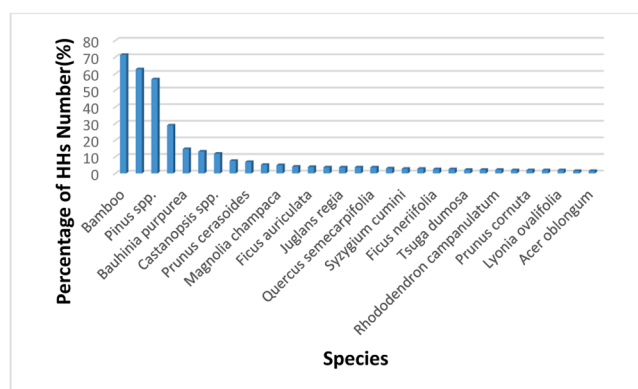


Fig. 3. Frequency of species present on farm land.

monopetala and *Bauhinia* spp. Bamboos were mostly found on hill slopes, fallow land, and water-scarce areas whereas other tree species were found predominantly on terrace risers, fallow land, property margins and home gardens.

3.3. Land holding and bamboo

Households with average land holding 10–20 ropani (0.5–1.02 ha) had the greatest numbers of bamboo clumps, ranging 16–142 clumps with a mean of about 73 (Fig. 4). The average numbers of bamboo clumps owned by respondents with land holdings greater than 20 ropani (1.02 ha) or less than 10 ropani (0.5 ha) were lower.

3.4. Forest species use for construction of temporary houses

Temporary shelter constructed immediately after the earthquakes required some form of timber; mostly pillars, poles and other supporting materials. Some temporary shelters used planks as wall materials

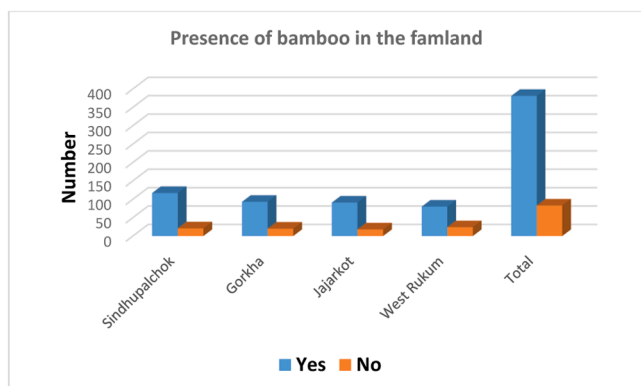


Fig. 2. Presence of bamboo species in studied districts.

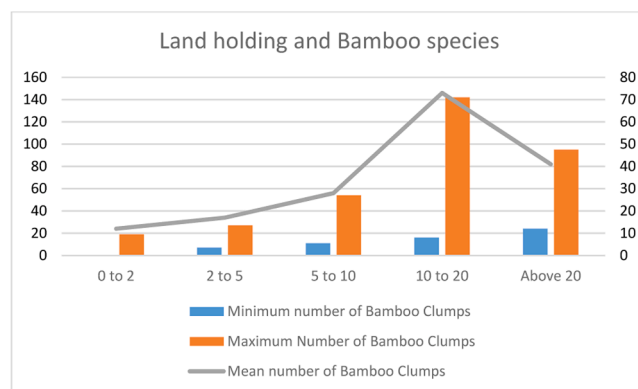


Fig. 4. Presence of bamboo clumps in relation to area (expressed in ropani) of land holding.

whereas in most cases Zinc sheets were used as roofing materials. In the study areas, about 85% of the households used bamboo for pillars, poles, and other supporting materials to hold and adjust roofing and wall materials. 64% of surveyed households used *Pinus* spp. and 40% used *Schima wallichii* timber for pillars and poles (Fig. 5). Very few households used other species such as *Shorea robusta* or *Alnus nepalensis* to construct temporary houses due to their very limited availability.

Among the five most commonly used plants for the construction of temporary houses, bamboo was the most frequent. Bamboo was either collected from house-holders' own land or obtained from a neighbor's land, but was not extracted from community forests. Similarly, *Schima wallichii* and *Alnus nepalensis* were extracted mainly from a house-holders' own land or from a neighbor's land. However, in some cases, these two species were extracted from community forests. *Pinus* spp. and *Shorea robusta* were mainly extracted from community forests. Table 4.

3.5. Importance of bamboo species during times of disaster

To verify all the information obtained from the respondents, they were asked about the importance and use of bamboo during times of disasters such as earthquakes. About 96% responded that bamboos were highly useful and thus significant during such times (Fig. 6).

A χ^2 -test was performed to test the preference for bamboo in terms of availability, economic viability, usefulness and earthquake-resistant materials for re-construction in comparison to other tree species during times of disaster. Bamboos were significantly more important than tree species ($p < 0.0001$, at 5% level of significance). This indicates the great potential of bamboo species for economic uplift and environmental conservation.

4. Discussion

Bamboos are socially and economically significant plants that have been used for a variety of purposes in many different cultures and countries worldwide (Ahmad et al., 2021; Kafle et al., 2023). The presence of bamboo on private land or farmland is an integral part of both traditional and modern farming systems in rural areas of Nepal. On the one hand, bamboos are crucial for maintaining and restoring the physical environment, especially by improving soil fertility, improving air and water quality, enhancing biodiversity, and sequestering carbon. On the other hand, they are significant sources of income for rural households (Hogarth and Belcher, 2013; Jha and Yadav, 2015; Kafle et al., 2023). Bamboo is the backbone of the Nepalese rural economy and long been utilized in toolmaking, furniture design, and construction. Out of 464 households surveyed, 96.3% (447 households) reported the importance of bamboos in disaster situations (Fig. 6). However, 3.66% (17 households) had no response to the situation. Most of the households in the study area cultivated bamboo in their farm land due to easy production and can be used when needed. Moreover, bamboo-based

Table 4
 χ^2 -test on importance of bamboos with respect to other tree species.

Attributes	χ^2 -value	d.f.	P- value	Remarks
Importance of bamboo	64.44	3	0.0001	*Significant

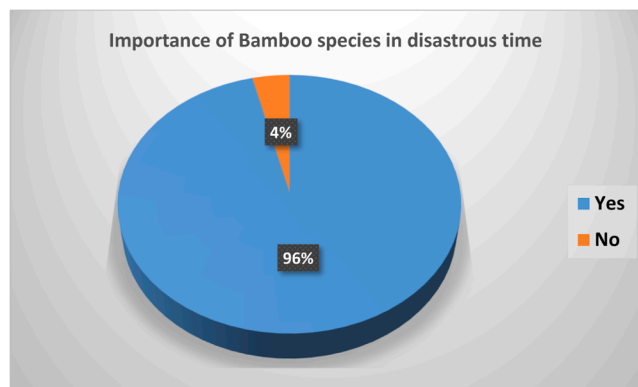


Fig. 6. Importance of bamboo in times of disaster.

enterprises are important sources of employment for both the rural as well as urban workforce.

Bamboos and forest trees on farmland implicitly offer a wide range of ecological, economic, social and religious functions (Idol et al. 2011; Jha and Yadav, 2015; Kafle et al., 2023). In the study areas, bamboos are either protected or preserved on fallow land, hill slopes and water-scarce areas. Farmers in hilly areas cultivate bamboos on fallow land, hill slopes and on degraded land where tree species are difficult to grow (Ghimire et al., 2020; Khanal, 2015). Bamboos are mainly cultivated for fodder, fuel wood, and construction materials. However, their role in reducing soil erosion, stabilizing slopes, improving soil quality and preserving the landscape should not be undervalued. Bamboos in Nepal have been particularly associated with the livelihoods of rural people in hilly areas, where people are growing trees on private land to fulfill their basic needs for forest products and to generate alternative sources of income (Jha and Yadav, 2015; Khanal, 2015; Oli, 2002). The number of households without bamboo on their farmland was quite small. The size of a farmer's land holdings has a significant impact on the number of bamboo clumps available and cultivated. In the study areas, on average each household had 6 bamboo clumps. Khanal (2015) reported that in Nepal every farmer has two to ten clumps of bamboo on their private land as it is indispensable for their livelihood.

Local Disaster Risk Management Plans (LDRMP) have identified various disasters that are probable in the studied districts. Among these, earthquakes were seen as one of the major disasters that could affect the districts (NPC, 2015). This study indicated that the contribution of bamboos to the timber/poles required for reconstruction after an earthquake was determined by three major factors: number of bamboo clumps present, forest tree species present and the proximity to forest. Bamboos were among the most favoured plants, primarily being utilized to support mud between stories. Households living near to forests choose to use more durable tree species from community forests. The result so the study indicate that bamboo can provide a range of products and services for sustainable development and environmental conservation (Jha and Yadav, 2015; Kafle et al., 2023; Khanal, 2015).

5. Conclusions

Bamboos had a substantial and visible impact on the quick recovery from earthquakes and other catastrophic events. Bamboos were the prime source (about 85%) of timber for construction of temporary

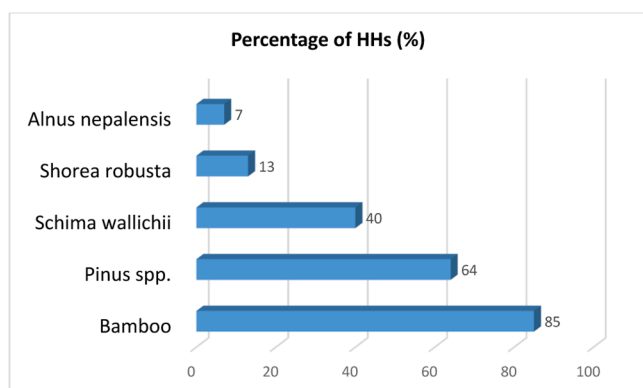


Fig. 5. Major species used for construction of temporary houses.

households. They were followed in importance by tree species from neighbours' land and community forests. Very little timber was extracted from community forests or other government-owned forest for the construction of temporary houses. 96% of respondents believed that bamboos are very important during disaster situations such as major earthquakes. Although the reconstruction process was only just beginning in study area, it was evident that the potential contribution of bamboo species to permanent house construction varied with the number of bamboo clumps available on householders' farmland. Households having a sufficient number of clumps on their farmland pointed out that bamboos would contribute greatly to permanent household constructions if we could rightly assess the construction material value of bamboos. This perception has been developed as result of the role that bamboo resources have played during the reconstruction process of permanent houses, thus signifying their great importance during times of disasters such as earthquakes.

Funding

This research did not receive any external funding.

CRediT authorship contribution statement

Lamichhane Uchita: Writing – review & editing, Writing – original draft, Validation, Data curation. **Ghimire Pramod:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known conflict of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. As corresponding author, I confirm that the manuscript has been read and approved for submission by all the named authors.

Data Availability

Data will be made available on request. Data will be made available on request to correspondence.

Acknowledgement

The authors express sincere gratitude to the local people of Thulo-sirubari village (Sindhupalchok), Barpak Sulikot village (Gorkha), Barekot village (Jajarkot) and Aathbiskot village (West Rukum) for providing information support during questionnaire survey. We are also thankful to Mr. Badri Prasad Lamichhane (Under Secretary, Government of Nepal) for his support and co-ordination during data collection in Jajarkot and West Rukum districts.

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