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Ethnobotanical knowledge and socio-ecological significance of vernacular architecture of *Adi* community of Arunachal Himalaya in North-Eastern India

Wishfully Mylliemngap[a,*], Om Prakash Arya[a,!] & R C Sundriyal[b,c,#]

[a]North-East Regional Centre, G.B. Pant National Institute of Himalayan Environment (NIHE), Itanagar 791 113, Arunachal Pradesh, India

[b]Centre for Socio-Economic Development, G.B. Pant National Institute of Himalayan Environment (NIHE), Kosi-Katarmal, Almora 263 643, Uttarakhand, India

[c]Department of Forestry and Natural Resources, HNB Garhwal University, Srinagar (Garhwal) 249 169, Uttarakhand, India

E-mail: *wishfully.m@gbpihed.nic.in, !om.arya89@gbpihed.nic.in, #sundriyalrc@yahoo.com

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The present study describes ethnobotanical knowledge and socio-ecological significance of vernacular architecture of local house construction styles of *Adi*, one of the major ethnic communities inhabiting Upper Siang district of Arunachal Pradesh. The community uses 21 plant species belonging to 15 genera and 12 families in vernacular architecture constructed as per local needs and traditions exhibiting native designs. The community possesses significant traditional knowledge and skills regarding the utilization of species in vernacular architecture. The houses capitalize on the availability of resources close to the construction site and fulfill basic community needs, values, economies, and ways of life as per local cultures. The study recommends that the vernacular architecture of *Adi* community is best suited to the local environment, climate, and culture; and therefore, needs to be preserved along with sustainable management and conservation of the plant resources used. Further multidisciplinary research is required to capture the overall significance of these vernacular architectures in terms of raw materials, structural designs, and environmental suitability and sustainability.

Keywords: Conservation, Environment, Indigenous knowledge, Upper Siang district

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Vernacular architectures are buildings that are designed in accordance with a community's culture, lifestyle and the physical and climatic conditions prevailing in the region[1]. These architectures represent an important cultural mosaic worldwide deriving from the surrounding natural environment, which varies greatly from one region to another. The structure, colours, and designs of vernacular architectures strongly reflect the culture, weather, geographic location, and socio-economic conditions of the concerned community or region[2,3]. The essence of vernacular architecture lies in the use of locally available materials, application of traditional skills and knowledge designed to suit the local climate and topography, as well as exhibit a harmonious relationship of people with their environment.

In the Himalayan region, designing settlement has been regarded as one of the most daunting tasks due to the rugged terrain, harsh climatic conditions, steep gradient, and proneness to natural hazards[2]. Despite these difficulties, the indigenous communities residing in the mountains have developed different types of vernacular architectures using their traditional ecological knowledge that has been orally passed down from one generation to another. Consequently, numerous vernacular styles using locally available resources have evolved to adapt to these environmental challenges and cause minimum damage to the landscape, flora, and fauna. The state of Arunachal Pradesh, in Northeast India, occupies a significant portion of the Eastern Himalaya in the Indian Himalayan Region (IHR) and is well-known for its rich bio-cultural diversity. It is home to 26 major tribes and more than 100 subtribes, each having unique traditional and cultural background. Each of these communities possess a rich ethnobotanical knowledge in utilizing locally available plant resources for the construction of vernacular architectures that are unique and diverse in layout, form, building materials, methods of construction and structural systems.

*Corresponding author

Documentation of different types of vernacular architectures in Northeast India, including Arunachal Pradesh, regarding their construction, layout, and raw materials used has been carried out by a number of researchers[4-8]. These studies have clearly demonstrated the uniqueness of each vernacular architecture style in terms of human skills, building techniques, and social structures of that particular community, which holds an invaluable source of indigenous knowledge that should be preserved at any cost. However, in recent times, due to the fast growth of the human population and the easy availability of new construction materials and modern designs, the benefits of these vernacular practices have been overlooked, and the traditional knowledge associated with them is on the verge of extinction. Therefore, documentation of this knowledge is of utmost importance since these vernacular designs have a promising scope for integration with modern building designs that would help evolve 'hybrid technologies' for better conservation and maintenance of ecology, economy, and environment, especially in the fragile Himalayan landscape. The present study describes ethnobotanical knowledge and socio-ecological significance of vernacular architecture of local house construction styles of *Adi* community inhabiting the Upper Siang district of Arunachal Pradesh. The need for sustainable management and conservation of the plant species used and prospects of vernacular architecture have also been discussed.

Materials and Methods

Study area

The study was conducted in the Upper Siang district, Arunachal Pradesh in the Eastern part of the Indian Himalayan Region. The district covers a geographical area of 6188 sq. km. with a population of 35,320 (Census of India 2011). It lies between 28°09'09''N to 29°19'10''N Latitude and 94°17'36''E to 95°25'35''E Longitude. It is bounded by East Siang district in the south, Upper and Lower Dibang Valley in the east and West Siang district in the west (Fig. 1). The district can be demarcated into three climatic zones, *i.e*., tropical (300-900 m asl), subtropical (900-1500 m asl), and sub-temperate (>1500 m asl)[9]. The *Adi* tribe forms the major part of the population of the district, while the other tribes like *Memba*, *Khamba*, and *Idu-Mishmi* also inhabit the area. The *Adi* is one of the indigenous

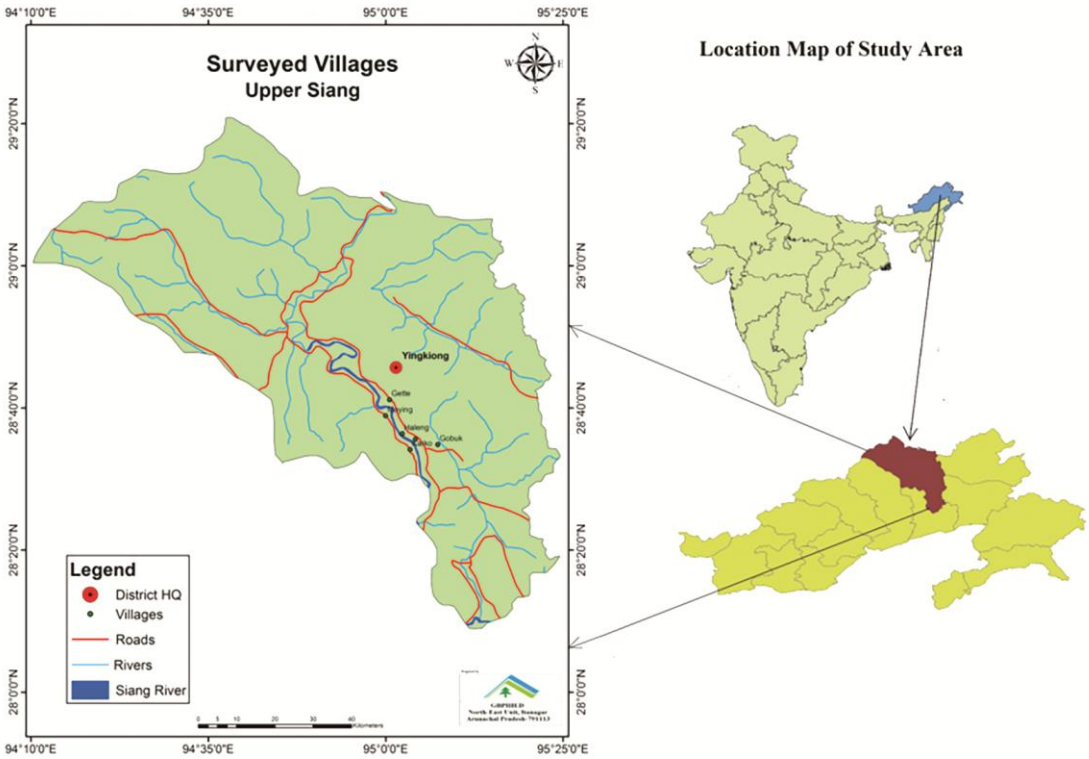

Fig. 1 — Map showing the geographical location of the surveyed villages

communities of Arunachal Pradesh inhabiting major parts of East Siang, Upper Siang, the eastern part of West Siang, and western part of Lower Dibang Valley districts of Arunachal Pradesh. The *Adi* tribe possesses rich traditions, culture, myths, legends, tales, and folklore and is divided into subtribes such as Bori, Ashing, Tangam, Shimong, Karko, Milang, Panggi, Minyong, and Pasi[10].

The study was carried out in six *Adi* inhabited villages, *viz*., Gobuk, Moying, Simong, Haleng, Karko, and Gette, situated within an altitudinal range of 404 m to 1201 m asl (Fig. 1). Among the surveyed villages, Simong was the largest, with 179 households and a total population of 672 people. Haleng was the smallest village with 19 households and a population of 50 people (Table 1). The overall literacy percentage of the surveyed villages ranged from 23% to 56%, with Gette village having the highest literacy rate and Simong the lowest. The literacy rate of the male population was higher than that of females in all the surveyed villages. Among the villages, Gette and Moying have the highest male literacy rate of more than 60%, and that of Simong was the lowest. The female literacy rate was lower than 50% in all the villages, the highest percentage being in Gobuk while the lowest was in Haleng village (Census of India 2011; Table 1).

Data collection

Primary data was collected through household survey among the traditional house dwellers of the targeted villages. In each study village, prior permission was taken from the village Headman (locally called as *Gao Burah*) for conducting the study within the village. Open-ended questionnaires were used as a mode of data collection to document the types of plant species used for vernacular house construction, parts used, mode of use and past, and the present availability of the plant species. A total of 65 households were surveyed in the six selected villages (Fig. 2). Additional information was also collected through focused group discussion (FGD) and Key Informants Interview (KII) conducted with knowledgeable people of the concerned villages skilled in constructing vernacular houses. Key informants were selected following a snowball sampling approach[11]. The *Gao Burahs* were always the first key informants, being the Head of the village have rich knowledge and experience on the past and present socio-cultural status of their respective villages. Other key informants were subsequently selected based on the suggestion by the previous informants. All the informants were previously explained about the purpose and objectives of the study and prior consent was obtained before proceeding with the interviews and group discussions. Plant species mentioned by the informants were collected from the field with the help of locals and identified by consultation with herbarium materials and experts at the Botanical Survey of India, Arunachal Pradesh Regional Centre, as well as taxonomic literature and flora. Secondary sources of information from published literature were also consulted to gain knowledge on the properties of different species used by the community that make them suitable raw materials for construction, as well as to understand the ecological and environmental significance of the vernacular architectures.

Table 1 — Demographic profile of the surveyed villages

Village name	Total Households	Population			Literacy rate (%)
		Total	Male	Female	
Gette	75	306	148	158	56
Gobuk	117	634	323	311	51
Halleng	19	50	24	26	32
Karko	91	244	128	116	39
Moying	117	590	393	197	52
Simong	179	672	322	350	23

Data source: Statistical Abstracts of Arunachal Pradesh – 2014, Directorate of Economics and Statistics, Govt. of Arunachal Pradesh, Itanagar-791 113

Results and Discussion

Vernacular architecture style and its significance

To the *Adi* community, rites and rituals are regarded as indispensable part of the socio-cultural

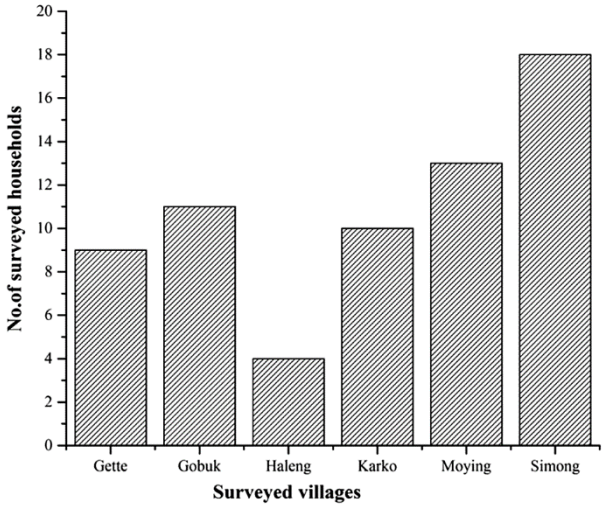

Fig. 2 — Number of households sampled in the surveyed villages

norms that need to be followed before starting any activity, including building a house. Apart from physical observation, land suitability for construction is also determined through performing certain rituals. This showed that a house to *Adi* community is not simply a dwelling place but also has a profound cultural and spiritual significance. Vernacular houses have compact planning, small footprints, and low built-to-open ratio, with a lot of open space around the built area used for different activities particularly for kitchen garden, fruit trees and ornamental plants. The size and style of the house depend on the number of family members and the location of the plot. Construction of a house takes about one or two days depending on the number of people involved and size of the house.

The houses are usually rectangular and raised above the ground by wooden stilts (Fig. 3a and 3b). Building a house on stilts shows the builders' ingenuity in solving the physical and natural constraints of the site. Since the study area is mostly situated on mountainous terrain, houses on stilts are ideally suited as the elevated foundation gives full advantage to construct on a sloped land with minimum damage to the land or incur extra expenditure for extensive excavation to level out the area. Wooden stilts driven deep into the ground stabilize the house structure, preventing it from lateral sliding in case of soil subsidence or earthquakes, given that the area is situated in an earthquake-sensitive zone. The indigenous solution also provides substantial rigidity to the overall structure in balancing heavy wind load prevalent in the high mountainous regions.The roof is inclined and covered by thatch made of cane leaves and supported by a bamboo scaffold tied with cane ropes. An inclined roof is well suited to this high rainfall area, as it allows rainwater to drain off quickly, thus preventing dampness of the thatch, which may cause the thatch to rot and eventually collapse the roof. Moreover, the thatch acts as a natural insulator from both heat and cold thus maintaining a comfortable temperature in the summer and winter seasons. The front part of the house consists of an open or covered balcony used as seating space for guests and for drying grains and other items. The inside of the house consists typically of a large hall that serves the purpose of living, cooking, dining, and sleeping. Some houses may be divided into many chambers and have separate rooms for married couples and young girls. In the central part of the house, there is a square-shaped fireplace or hearth with mud plinth, which serves as a place for cooking food, warming the inmates and space for family gatherings. Above the hearth, rectangular racks made of bamboo and wood are suspended for drying meat, grains, corn, chilies, or keeping other household items. There is efficient division and segregation of space inside the house for all inmates and for carrying out daily activities. Houses are constructed using locally available raw materials and voluntary help of the whole community - which avoids the need for hired labour and results in construction with minimum expenses. The low cost of construction, which is made possible using locally available plant materials, makes these vernacular houses affordable to the poor and economically weaker section of the community in the study area.

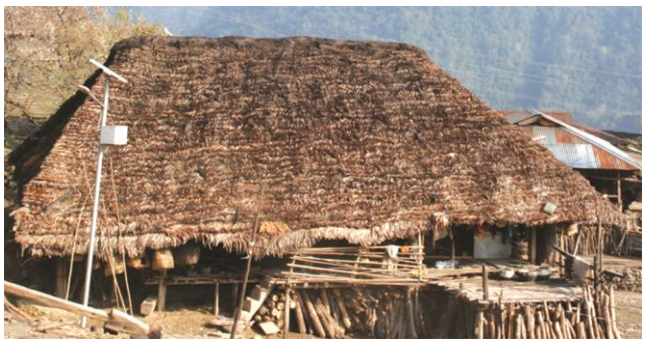

Fig. 3a — Vernacular architecture of *Adi* community at Gobuk village

Fig. 3b — Vernacular architecture of *Adi* community at Moying village

Ethnobotanical knowledge in vernacular architecture

During the present study, a total of 21 species belonging to 15 genera and 12 families used by the local community in the construction of vernacular architecture have been documented (Table 2). A

maximum number of species belong to the Aceraceae family (6 species) followed by Poaceae (3 species), Fagaceae, and Moraceae (2 species each), while the remaining 8 families were represented by single species only. The traditional ecological knowledge (TEK) developed by the community through long association with nature has enabled them to identify durable and most suitable tree species for the construction of different parts of the house and determine the favourable harvesting seasons of the plant material. Usually, the plant materials are harvested before the appearance of the new moon. According to informants, the materials harvested during this period are more resistant to termite and pest infestation than those harvested in other periods. The timber of *Castanopsis indica, Altingia excelsa,* and *Artocarpus heterophyllus,* known in local dialect as *Hirang, Jutli and Belang* respectively, mainly were used for main post or pillars of the house. Apart from being used as post/pillar, *C. indica* is also used in the construction of rafters and flooring. Timber of *Ailanthus grandis, Duabanga grandiflora, Morus laevigata, Phoebe cooperiana, Terminalia myriocarpa, Toona sureni* and *Saurauia napaulensis* were used in the construction of other components of the house such as door, floor, rafters, and walls. Split stems of bamboo, *Bambusa* spp., and *Dendrocalamus hamiltonii* were mainly used for walling and flooring purposes. The roofs were made using sun-dried leaves of *Livistona jenkinsiana* (locally known as *Toko* patta) or *Calamus erectus* (locally known as *Tara*). It has been reported that roofs made of *Toko* leaves can last for about 10 years while those made of *Tara* last only for 4-5 years[12]. However, according to information gathered from informants, the choice of roofing material was determined by the availability of the species in the proximity of the construction site rather than quality or durability of the plant material. Cane split into thin strips was used as cordage material for binding the joints. The commonly used species for this purpose were *C. erectus*, *C. flagellum, C. tenuis* and *C. leptospadix* (Fig. 4).

Previous studies in the *Adi*-dominated areas around the Dihang-Dibang Biosphere Reserve of Arunachal Pradesh revealed that species of *Morus laevigata, Terminalia myriocarpa, Altingia excelsa* and *Duabanga grandiflora* were valued as best quality timber species. At the same time, *Castanopsis* spp. and *Artocarpus heterophyllus* were regarded as medium quality by the local community[13]. Studies conducted in other parts of the world on timber quality, durability, and suitability of different species for construction purposes, supported the Adi community's inherent ethnobotanical knowledge in identifying suitable

Table 2 — Plant species used in construction of vernacular house of *Adi* community

Scientific name	Vernacular name	Family
Ailanthus grandis Prain	Hileng	Simaroubaceae
Altingia excelsa Noronha	Heri/Jutli/Siri	Hamamelidaceae
Artocarpus heterophyllus Lam.	Belang (Jackfruit)	Moraceae
Bambusa pallida Munro	Era, libang/dibang	Poaceae
Bambusa tulda Roxb.	Era, libang/dibang	Poaceae
Calamus erectus Roxb.	Tara/Rakut	Arecaceae
Calamus flagellum Griff.	Takat	Arecaceae
Calamus floribundus Griff.	Yoyi	Arecaceae
Calamus leptospadix Griff.	-	Arecaceae
Calamus tenuis Roxb.	Jeying	Arecaceae
Castanopsis echinocarpa King	Hirang	Fagaceae
Castanopsis indica (Roxb. ex Lindl.) A. DC.	Sirang/Hirang	Fagaceae
Dendrocalamus hamiltonii	-	Poaceae
Duabanga grandiflora (DC.) Walp.	Kobo	Lythraceae
Livistona jenkinsiana Griff.	Tadek/Toko	Arecaceae
Mesua ferrea L.	Nahar	Calophyllaceae
Morus laevigata Wall.	Eyum (Bola)	Moraceae
Phoebe cooperiana P.C. Kanj & Das	Tapir	Lauraceae
Saurauia napaulensis DC.	Tan	Actinidiaceae
Terminalia myriocarpa Van Heurck & Mull. Arg.	Hollock/Silok	Combretaceae
Toona sureni (Blume) Merr	Keji	Meliaceae

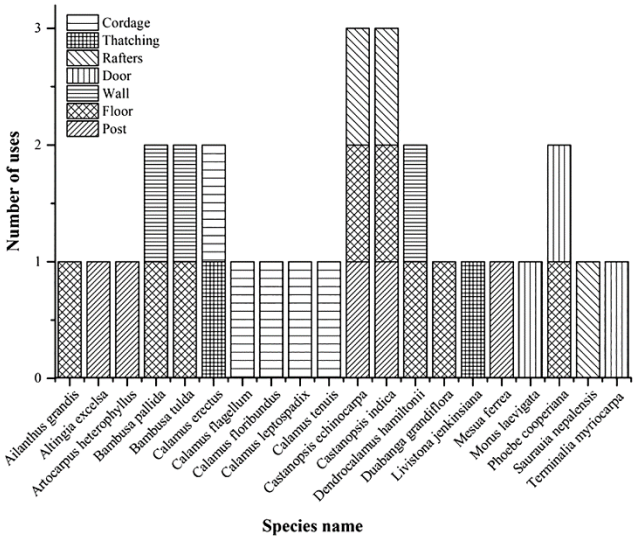

Fig. 4 — Modes of utilization of the plant species in vernacular architecture of *Adi* community

species for use in their vernacular architecture. Studies have shown that timber of *A. heterophyllus* tree is very durable, with anti-termite properties and resistance to fungal and bacterial attack[14]. The wood of *Castanopsis indica* is hard and resistant to termites and insects[15]. The species (*C. indica*) has also been reported to be indigenously used in house construction and furniture by people of Syabru village of Langtang National Park in Nepal[16]. The wood of *Altingia excelsa* is very durable and does not rot easily when used in direct contact with the soil, therefore is highly suitable for use as columns or beams of the house[14]. Because of its long branchless bole, *Altingia excelsa* is favoured for frames of bridges, columns and beams for construction, power and telephone transmission poles, and railway sleepers. The timber is used in heavy construction, vehicle bodies, ship and boat building, heavy flooring, rafters, veneer, plywood, and pulp. A review on field and laboratory estimation of natural durability of wood of different timber species by Scheffer & Morrell (1998) reported the natural durability classes of timber obtained from five species documented in the present study, *viz*., *Altingia excelsa, Artocarpus heterophyllus, Dendrocalamus hamiltonii, Duabanga grandiflora* and *Terminalia myriocarpa*[17]. Among these species, *A. heterophyllus* has been assigned durability Class-I with an estimated lifespan of over 120 months. *A. excelsa* has been assigned Class-II, with a life span between 60-120 months while *D. hamiltonii, D. grandiflora* and *T. myriocarpa* were assigned Class-III with a life span of up to 60 months.

Bamboo and cane are common building materials for traditional construction in different parts of Northeast India and most regions of Southeast Asia. In Northeast India, utilization of bamboo and cane for construction of vernacular houses by indigenous communities has been reported in many states, including Assam, Arunachal Pradesh and Mizoram[5-8,18]. Despite its versatile vernacular application, bamboo has gained the reputation of engineering material recently. It is regarded as 'poor man's timber' due to its mechanical properties such as high strength-to-weight ratio, ductility of fibrous microstructure, low cost, faster production and simple manufacturing processes, making it suitable for structural applications[19]. Research indicates that bamboo structures have high endurance against storms and earthquakes[20]. Therefore, bamboo material has a high potential for developing low-cost construction material after treatment to enhance its durability.

Socio-economic and cultural importance of the recorded plant species

The species used for house construction reported in the present study were also used for multiple purposes by the same community for food, medicine, handicrafts making, cultural beliefs, and rituals. Among the recorded species, the highest number of species yield edible parts, while others were used for handicraft making, traditional medicine, or in rites and rituals (Fig. 5). The species of *Castanopsis* yield edible nuts while *Artocarpus heterophyllus, Morus laevigata, Saurauia napaulensis, Phoebe cooperiana, Calamus* spp., and *Livistona jenkinsiana* yield edible fruits. Young shoots of *Bambusa* spp. and *Dendrocalamus hamiltonii* are essential food items used in variety of traditional food recipes either in fresh, dried, or fermented forms. These wild edibles were also sold in local markets for additional income, thus forming an alternative livelihood option. For example, fresh bamboo shoots can fetch a price of about Rs. 25-30 per piece while fermented ones can be sold at Rs. 100-150 per kg. Bamboo, cane and Toko leaves are also used in making traditional handicraft items such as baskets, mats, rain shield, hats, decorative and ornamental pieces, and other items of daily use. *Duabanga grandiflora, Terminalia myriocarpa* and *Toona ciliata* were some of the important commercial timber species in the state of Arunachal Pradesh as well as in the Northeastern region of India.

Previous studies revealed the rich ethnobotanical knowledge of the *Adi* community residing in different

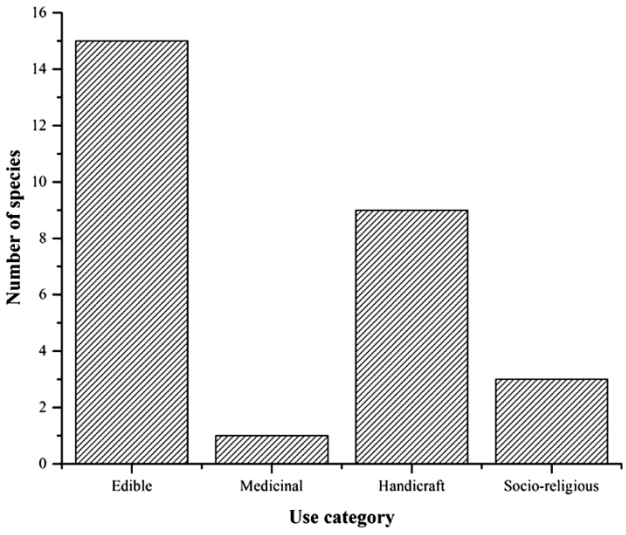

Fig. 5 — Alternative uses and cultural importance of the documented plant species

parts of Arunachal Pradesh in using different species for food, medicine, spices and condiments, paper pulp, fibre, dyeing, hunting and fishing[21,22]. Among the species reported in the present study, species such as *Tan* (*S. napaulensis*), *Hirang* (*C. indica*) and *Hollok* (*T. myriocarpa*) hold an important position in the cultural and religious beliefs of the *Adi* community. According to the informants, *Hirang* and *Hollok* were regarded as sacred trees by the *Adi* community, and used in different ways in performing community rituals and festivals. Leafy branches and nuts of *Hirang* (*Castanopsis* spp.) are used in certain community rites and rituals. During *Sobo Panam* (Mithun sacrifice), a ritual performed by certain sub-tribes of the *Adi*, the stem of *Hollok* (*T. myriocarpa*) tree is broken into two pieces and used for sacrificing the Mithun (*Bos frontalis*). Mithun is a semi-domesticated animal with high socio-cultural value in the *Adi* community, the possession of which defines the social status and wealth of an individual or family. The wood used for the sacrifice is kept for a year and then burned down. Similarly, *Tan* (*Saurauia napaulensis*) is used along with other plant species and bamboo to make altars for the deities and as one of the items for performing rituals during cultural festivals such as *Unying/Aaran, Solung* and *Etor*.

Socio-ecological significance of plant materials used in vernacular architecture

Vernacular practices and styles adopted in traditional *Adi* settlements in hill areas have great potential to become the basis for new development and formulation of eco-friendly buildings for other hill areas. The use of locally available materials in vernacular architecture has several economic, social and environmental advantages. Generally, the most relevant environmental advantages of local materials are less energy-intensive production process, and consequently lower embodied energy, and CO_2 emissions. They are natural materials, often organic, renewable and biodegradable with low environmental impact during maintenance operations[23]. In the present study, the building materials (wood and bamboo) from the dismantled old houses were usually re-used as fuel or for building other less sophisticated structures such as granary, fencing, and animal enclosure after simple reshaping. This practice would not aggravate climate change due to the carbon-neutral feature of wood[24].

According to the IPCC report (2014), the greenhouse gas emissions from the building sector have more than doubled since 1970, representing around 19% of global emissions[25]. This puts pressure on the building sector to improve its environmental impact. On the other hand, it presents an opportunity for improvements and reduction of emissions of buildings by incorporating vernacular designs. Therefore, the use of naturally occurring materials such as wood and bamboo looks promising in designing climate-smart houses. Several comparative studies between wood-frame, concrete, and steel frame buildings in different parts of the world have reported that wood-frame buildings have much lower energy use and carbon emission than the other building materials[26,27]. Similarly, another study in different climatic zones of India revealed that vernacular dwellings exhibit higher resilience in response to climate change compared to modernized dwellings[28]. In this situation, the traditional housing architecture qualifies for higher energy efficiency and lesser C emission; thus, it can be one way of mitigation of climate change. A recent simulation-based study in northeast India suggested that incorporation of passive cooling features in vernacular houses can make the building more energy efficient and eco-friendly[29]. Modern structures need to be environmentally and culturally sensitive while at the same time representing the cultural legacy in their architectural styles, designs, and construction materials[30].

Previous studies in other parts of Northeast India have emphasized the environmental and economic advantages of using locally available building materials in house construction: (i) The materials are relatively cheap; (ii) lower cost of construction compared to modern concrete buildings; (iii) less energy requirement involved in processing and transportation of material; (iv) structure are light and flexible, therefore more resilient to disasters like earthquake, flood, landslide etc., and (v) low environmental impact in their production, renewability and even natural dissolution[4,31]. Edum-Fotwe & Price (2009) defined a set of social parameters to be considered in choosing materials for improving the sustainability of the built environment, such as employment, health, safety, wellbeing, education and training skills, and culture/heritage[32]. Locally available materials fit these criteria since they can be processed by local skilled workers, thus providing employment opportunity within the community. The people already possess inherent skills in making traditional handicraft items using

bamboo and cane; they can also be trained in using bamboo for construction purposes using different designing and jointing techniques to fit to the requirements for modern housing designs. Since the materials are produced from native resources, they are suitable to the environment, local climate, topography and the culture of the community.

Implications for conservation and management

The present study revealed the rich diversity of plant species used by the *Adi* community for construction of vernacular houses. Observations during the field surveys in the study areas showed that the plant raw materials used for vernacular house construction is mostly extracted from natural forests. Continuous extraction of timber and other raw materials from the forest are likely to threaten the existing population of the widely used species, which may lead to their depletion. Therefore, to ensure sustainable utilization and supply of resources for community needs, conservation efforts are urgently needed. Like other areas of Northeast India, in the state of Arunachal Pradesh, maximum forest areas, including those in the present study, were owned by the community and governed by customary laws through traditional institutions of respective villages. In this case, forest conservation strategies would be more effective if the local communities can be involved and sensitized about forest conservation and management benefits. A few relevant practices have already been reported from some indigenous communities of the state and may serve as an example for replication in other areas for locally important species. The *Adi* tribe of East Siang and Upper Siang districts have been actively involved in conserving two bioculturally important species, *viz.*, Toko (*L. jenkinsiana*) and Tara (*C. erectus*)[33,34]. Apart from *in situ* conservation efforts, the local community has also started raising plantations of these two species in *Jhum* (shifting cultivation*)* fields and fallows, *Morangs* (community/clan forests), and homestead gardens. Another example of community-based forest conservation and management practice is of the *Apatani* tribe of Ziro valley in Arunachal Pradesh for one species of bamboo (*Phyllostachys bambusoides*) and blue pine (*Pinus wallichiana*). Pure plantations of *P. bambusoides* and mixed plantations of blue pine and oak species were raised by almost every *Apatani* household, and sustainably managed mainly to meet the requirements for house construction, fencing, handicrafts and firewood[17]. Such initiatives would greatly reduce pressure on resource extraction from natural forests and provide a sustainable supply of raw materials for community use, thus serving the double purpose of forest conservation and livelihood security. Similar kind of participatory approach may be adopted for community-based conservation and management of other economically and socio-culturally important species of the study area through awareness and capacity building of the local community and other stakeholders.

Conclusion

The present study highlighted the rich traditional ecological knowledge embedded in the vernacular architecture of the *Adi* community inhabiting the mountainous terrain of the Arunachal Himalayas. Documentation of this knowledge is therefore important to identify promising quality timber species and prioritize their propagation and value addition to make them more durable and appealing to modern housing design. Therefore, we recommend that in-depth multidisciplinary research is required to examine and reinterpret this valuable knowledge embedded in the vernacular architectures for developing socially acceptable, energy-efficient and environmentally sustainable architectural designs for the Himalayan region.

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Conflict of Interest

The authors declare that they have no conflict of interests.

Authors' Contributions

WM and OPA carried out the fieldwork, analyzed the data, and wrote the first draft of the manuscript. RCS supervised the study and reviewed the draft manuscript. All the authors read and approved the manuscript.

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