

Tropical Forestry

Ratan Lal Banik

Silviculture of South Asian Priority Bamboos

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Silviculture of South Asian Priority Bamboos

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Foreword

Recent years have shown that bamboo silviculture and management is entering a new era. Considering the vast variety of bamboo species, the basic requirement for the purposeful cultivation of bamboo is the knowledge and comprehensive understanding of the growth conditions and characteristics of individual species.

As editor of Springer's Tropical Forestry Series, I am especially pleased to have been able to engage Dr. Ratan Lal Banik as author for a book on bamboo species. He is a proven expert on the subject and has a record of numerous projects and activities in the field of bamboo silviculture in South Asia. With this book, Dr. Banik offers his overwhelming knowledge and expertise to scientists and practitioners.

I am confident that the current book will largely meet existing needs and wish it well deserved success.

Hamburg, Germany

Michael Köhl

Preface

Bamboo is a versatile group of plants, capable of providing ecological, economic, and livelihood security to the people: “It is to shelter, to fashion tools, to weave baskets, to help water obey, to provide beauty and sounds.” In the tropics, especially the rural areas in different countries of South Asia, most of the houses are made of bamboos. In the hilly areas of Bangladesh, Bhutan, Nepal, and India, the tribal people take bamboo shoots as one of their major food items since prehistoric days. Certainly, it saved many lives of our forefathers. Thus, bamboo has been identified as a symbol of life and became “the poor man’s timber” to the Indians, “the friend of the people” to the Chinese, and it is “the brother” of the Vietnamese. With high productivity and grass-like leaves, bamboo plants have been liked by most of the herbivore animals, such as elephants, wild cattle (*Bos gaurus* and *B. javanicus*), and various species of deer. The red panda in the Himalayas, primates, pigs, rats and mice, porcupines, and squirrels are also important incidental feeders on Southeast Asian bamboos. However, it is not that all bamboo species are liked by these animals; rather, they have some selection about the species. Reforesting and managing forest of these selected species is also important for sustainability of ecosystem and fauna of the region.

There has been a growing awareness in recent years about the values of bamboo, being an important means of economic growth and for improving the socioeconomic conditions of the rural poor. Bamboo as an industrial material can substitute wood and that too at low cost. Due to increasing demand and squeezing of bamboo area, the plants have been overexploited and the quality and quantity of resource alarmingly getting depleted. Besides, many new bamboo-based industries have come up which also urgently require uninterrupted supply of species-wise bamboo resource. The South Asia region has been bestowed with more than 300 bamboo species with enormous diversities at species, ecological, and genetic levels. People from their age-old experiences have selected only some of these bamboo species for their socioeconomic, specific ecologic, and modern industrial needs, and they started cultivating them with priority. A number of such priority bamboo species are found to be common among countries of the region, indicating their wide range of ability to adjust to the environmental conditions of these countries and various

utilization potentials. Both government and private planters in the countries of South Asia have started allocating funds, land, and other logistics to raise large-scale plantation of desired bamboo species. Often, they have queries to know the specific local and modern industrial uses of each bamboo species, how to recognize them at the field, traditional vernacular and correct scientific name of the bamboo species for making local and international trade contacts, what are the flowering (seeding) intervals and seed availability, how to have sufficient number of quality planting materials (QPM), and details of planting and management techniques. In many occasions, it has not been able to answer these queries to the satisfaction of the clients due to the lack of information. This book has been drafted to find out answers of these queries mostly based on my field observations on each of the bamboo species and knowledge learned from the indigenous people living with bamboos in different parts of Southeast and South Asian countries. During the last 45 years of my association with bamboo plant, I had the opportunity to observe flowering, seeding, and seedling of more than 30 bamboo species, and the relevant information are reflected in this book. The incidences of flowering in *Bambusa balcooa* and *B. vulgaris* has been reported to be very rare and without any seed production. Such rare flowering event of these two most commonly grown bamboos in the rural areas of the region was also luckily observed and included in this treatise. The production and nursery management of different types of planting material is a major bottle neck in bamboo cultivation. This has forced greater attention to bamboo propagation practices and techniques. Over the years, many new propagation techniques have been developed, tested and gradually being made suitable for field application. Detail step-wise practical notes along with pictorial guides have been drafted as Appendix-I in the book for obtaining better success in production of bamboo planting materials. Additionally, I tried to collate the available documented information, especially the culm wood properties of each of the bamboo species and added in this book for their proper engineering utilization. The overall purpose of this book is to make available all possible information on the above queries of each important bamboo species of the region and serve these in one tray to the consumers.

I believe this monograph would be interesting and useful to bamboo professionals, foresters, horticulturists, field level extension workers, nurserymen, planters, industrial entrepreneurs, and ecologists, and would be a valuable source of reference to the relevant researchers and students in the region.

New Delhi, India
January, 2016

Ratan Lal Banik

Acknowledgments

With great honor and gratefulness, I like to remember Mr. Syed Mortuza Hasan, the then silviculturist of BFRI, Chittagong, where I was working as a scientist as he had motivated me in 1969 to learn all about the amazing bamboo plants. Many innovative ideas and local ethnic knowledge I learned was gathered from the gracious support and sharing of wisdom and know-how about bamboos by local people living with this plant resource. I am indebted to my research and academic colleagues, foresters, and local indigenous people from the different parts of South Asia (especially BFRI, Chittagong; Tripura Department of Forests; and GBP University of Agriculture and Technology, Pantnagar, Uttarakhand) for their support and assistance while I was studying bamboos in the field.

I gratefully acknowledge the support of Prof. Dr. Michael Köhl, Center for Wood Sciences, World Forestry, University of Hamburg, Germany, and for his generous consent of editing the manuscript and inclusion of the draft for publication as a book in the Tropical Forestry Series, of which he is the editor. Further, I am indebted to Prof. Köhl for his untiring efforts in critiquing, reviewing, and editing the manuscript, and I am also expressing my deep gratitude to him for making it possible to publish this book as a monograph on priority bamboos under the aegis of Springer.

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With heartfelt respect, I am expressing gratefulness to the departed soul of my beloved parent for their fountain of blessings to complete the book.

New Delhi, 2016

Ratan Lal Banik

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Part I
Introduction

Chapter 1

Introduction to South Asian Bamboos

In the globe, South Asia or Southern Asia represents the southern region of the Asian continent, which comprises the sub-Himalayan countries, adjoining countries to the west and east. South Asia is bounded on the south by the Indian Ocean and on land by West Asia, Central Asia, East Asia and Southeast Asia. The current territories of Bangladesh, India and Pakistan form the central region of South Asia, while the mountain countries of Nepal and Bhutan in the north and island countries of Sri Lanka and Maldives in the south are generally included in the region. Often Afghanistan and Myanmar are also added.

South Asia is largely divided into four broad climate zones (Olive 2005).

- The northern Indian edge and northern Pakistani uplands have a dry subtropical continental climate.
- The far south of India and southwest of Sri Lanka have an equatorial climate.
- Most of the peninsulas have a tropical climate with variations:
 - Hot subtropical climate in northwest India
 - Cool winter hot tropical climate in Bangladesh
 - Tropical semi-arid climate in the centre
- The Himalayas have an alpine climate

Maximum relative humidity of over 80 % has been recorded in Khasi and Jaintia Hills of Meghalaya state of Northeast India and Sri Lanka, while the area adjustment to Pakistan and Western India records lower than 20–30 %. Climate of South Asia is largely characterized by monsoons. South Asia depends critically on monsoon rainfall. Two monsoon systems exist in the region (Tyson 2002).

- The summer monsoon: Wind blows from southwest to most of parts of the region. It accounts for 70–90 % of the annual precipitation.
- The winter monsoon: Wind blows from northeast. Dominant in Sri Lanka and Maldives.

The warmest period of the year precedes the monsoon season (March to mid-June). In the summer, the low pressures are centred over the Indus-Gangetic Plain, and high wind from the Indian Ocean blows towards the centre. The monsoons are second coolest season of the year because of high humidity and cloud covering. Moderately vigorous monsoon depressions form in the Bay of Bengal and make landfall from June to September.

A brief note about bamboo vegetation and utilization in different countries of the South Asia region is presented below.

1.1 Bangladesh

The country is bounded by India on the west and north and Myanmar on the east and the Bay of Bengal on the south. Except the hilly regions in the northeast and southeast, some areas of high lands in the north and northwestern parts, the country consists of low, flat and fertile land. Bangladesh is basically a plain land country. However, the hilly areas account for about 12 % of the total land surface covering about 1,733,503 km² in the greater districts of Chittagong Hill Tracts (hereafter CHT), Chittagong, Sylhet and some other areas. The CHT, an area of 13,295 km², is the south-eastern part of Bangladesh, bordering the Arakan and Chin States of Burma and Tripura and Mizoram States of India.

The country enjoys generally a tropical monsoon climate; the average annual rainfall in Bangladesh varies from 1500 to 5500 mm which falls mostly between last part of May and August and period of dry months is from October to March. The relative humidity is correspondingly high and ranges from 60 % and upwards. The atmospheric temperature ranges from 7° to 41 °C; it rarely falls below 5 °C, mostly remaining within 20° and 35 °C. Maximum rainfall is recorded in the hilly and southern part of Chittagong and northern hilly part of Sylhet districts, while minimum is observed in the western part of the country.

About nine genera and more than 33 species have been found in Bangladesh, out of which seven are occurring naturally in the forest areas either as understory in association with tree species or as pure stand naturally in the semi-evergreen and moist deciduous forests of the hills of CHTs, Cox's Bazar, Sylhet and northern Mymensingh (foot hills of Garo Hills). Among them, *Melocanna baccifera* is the most widely occurring common bamboo species of Bangladesh (Alam 1995, 2001; Banik 1980, 2000). *Melocanna baccifera* (commonly known as *muli bansh*) constitutes 70–90 % of the total bamboo forests of the country. The other species *Bambusa tulda*, *Dendrocalamus longispathus*, *D. hamiltonii*, *Gigantochloa andamanica* (syn. *Oxytenanthera nigrociliata*) and *Schizostachyum dullooa* occur sporadically either in association with *Melocanna* or in isolation forming small patches of pure bamboo vegetation. As regards abundance, *B. tulda* is next to *muli* bamboo. The remaining two species *Melocalamus compactiflorus* and *Dendrocalamus hamiltonii* are localized only in limited forest areas of the country. Bangladesh, being a part of the subtropics, has only clump-forming bamboos both

in forests and in villages. There are no temperate species, that is, non-clump-forming bamboos are available in the country. Among the cultivated species, *Bambusa vulgaris*, *B. balcooa*, *B. tulda*, *B. nutans* and *B. cacharensis* are most common throughout the country.

There are millions of people in rural Bangladesh who depend on bamboo for part or all of their housing, agricultural activities, construction works and also income from selling the green poles. In the hills, the livelihoods, shelter and foods of indigenous people depend almost entirely on the harvesting, processing and selling of bamboo poles, edible shoots and bamboo products such as baskets, mats and handicrafts. The demand of bamboo poles has been increasing in the housing sector (Anon 1983; Banik 2000), especially in construction of tall high-rise buildings for making scaffoldings to plaster and painting the walls. The demand of poles gets further high during religious (Eid, Puja, Buddha and Christmas gatherings), social (marriage, club meetings, etc.) or any other community gathering specially at villages mainly for constructing the pandals and tents. Due to increasing demand and squeezing of bamboo area, the plants have been overexploited, and yearly, there is about 3.0% loss of bamboo area in the bamboo forests, and simultaneously, the quality and quantity of resource are alarmingly getting depleted (Banik 2000). Besides existing main two pulp and paper mills at Chittagong and Sylhet, many new bamboo-based industries have come up which also require uninterrupted supply of species-wise bamboo resource. The steady supply of required quantity and quality of bamboo is an urgent need to keep pace with such present demanding situation of the resource.

1.2 Bhutan

Bhutan is located in Southern Asia, between China and India. The total area of the country is 47,000 km²; Thimphu is the capital of Bhutan. The country's climate varies: tropical in southern plains, cool winters and hot summers in central valleys and severe winters and cool summers in Himalaya.

Bhutanese bamboo is principally of Himalayan and Chinese-Japanese origins, with some Southeast Asian and Indian contributions. Bhutan has 15 genera and 31 species of bamboo. Possibly as many as 50 more species exist, but have yet to be identified. Major species found in subtropical areas include *Bambusa nutans*, *Dendrocalamus hamiltonii*, *D. sikkimensis*, *D. patelleries*, *D. strictus*, *Drepanostachyum hookerianum* and *D. intermedium*. Higher elevation species include *Arundinaria racemosa*, *A. maling* (local name: Hima) and *A. polystachya*. Other species are *Dendrocalamus hookeri* and *Arundinaria griffithii* (Griern dwarf rhododendron trees). In this Himalayan Kingdom, the distribution of bamboos is mainly influenced by the topography and altitudinal variation. In the lower hills, the main species of bamboo is *Dendrocalamus hamiltonii*. Near about 1200 m elevation, *Bambusa nutans*, *Dendrocalamus sikkimensis* and *Chimonobambusa intermedia* make their appearance, while between 1200 and 2000 m, the species seen are *Cephalostachyum capitatum*, *Pseudostachyum polymorphum*, *Dendrocalamus*

patellaris, etc. Still higher up between 2000 and 2800 m, *Arundinaria racemosa* occurs with other two species, namely, *Thamnocalamus aristatus* and *T. falconeri* (Sharma 1982). More accurate information is still needed on the distribution, uses and local names of all the species. Stapleton (1994a) published a book on *Bamboos of Bhutan* where the most common bamboo species of the country have been described. In the southern and eastern parts of Bhutan where large-sized bamboos grow, rural life without them is unimaginable. The small bamboos found in central and western part of Bhutan are used for weaving mats and employed as fencing and roofing material. Bamboo finds diverse uses in Bhutan. One of the most well-known uses of bamboo is for making bows and arrows, archery being a national sport and cultural event (Anon. 1995a). Bows are generally made out of *Dendrocalamus hamiltonii*, but only those culms that grow on particular microsites produce good bows. Arrows are made from high-altitude bamboos such as *Arundinaria* species. The species is used for making durable mats for building construction fencing material and high-quality woven handicraft products, such as food and drink containers, hats, arrows, quivers, etc. The leaves are used as livestock fodder during winter and dry season. The species provides shelter and food for endemic fauna in reserve areas. The bamboos are used for collecting, storing and then transporting most agricultural goods. Many rural houses are entirely made of bamboo. Roof, mats and fencing are the main uses at higher altitudes. *Thamnocalamus* species is mainly used for roofing, mats and fencing. In subtropical areas, bamboo is treated as a multipurpose plant from which almost anything can be made. Weaving of thin strips makes baskets and trays.

The shoots of *Arundinaria*, *Dendrocalamus* and *Drepanostachyum* sp. are edible. The culms of *Drepanostachyum* sp. are used for making finely woven domestic and agricultural equipment, such as baskets, trays, mats, sieves, etc. Further, the species is also used for constructing livestock shelters and temporary dwellings and parts of traditional houses. The *Bhutanese* farming system that supports 80% of the population is highly dependent on forests for sustenance, where bamboo is one of the important crops. Bamboos are harvested and used as part of Bhutanese daily life. People in bamboo houses may also employ bamboo baskets for storage and as water containers. The demand for bamboo is getting increase over time, particularly for use as fodder and other multipurpose uses. There is ample scope for greater bamboo production, especially in the country's higher areas where communities are widely dispersed and agriculture is less profitable, and bamboos have prime role in maintaining the watersheds in catchment of many rivers and controlling landslide and soil erosion and provide food and shelter to the wild lives and preserve hill ecosystem.

1.3 India

India has rich bamboo resources. According to Varmah and Bahadur (1980), there are about 19 principal genera of bamboos in India—*Arundinaria*, *Bambusa*, *Cephalostachyum*, *Chimonobambusa*, *Dendrocalamus*, *Dinochloa*, *Gigantochloa*, *Indocalamus*, *Melocanna*, *Neohouzeaua*, *Ochlandra*, *Oxytenanthera*, *Phyllostachys*,

Pseudostachyum, *Schizostachyum*, *Semiarundinaria*, *Sinobambusa*, *Teinostachyum* and *Thamnocalamus*. Areas particularly rich in bamboos are the northeast region, Western Ghat and Andamans. However, Sharma (1987) reported about 130 species belonging to 24 genera of bamboos from India. Out of these, 20 are indigenous and four are of exotic origin. Then, Tewari (1992) described 23 genera and 128 species. As per the latest compilation, 96 species are native bamboos and 40 species are cultivated ones (Kumar 2011). Among all the species, *Bambusa bambos*, *Dendrocalamus strictus* and *D. hamiltonii* are very common throughout mainland India (north, central, west and eastern part) and have great impact on socio-economy of people of the region. Additionally in eastern India, *Bambusa balcooa*, *B. tulda*, *B. nutans* and *B. vulgaris* are also extensively cultivated as important bamboo crops for rural economy. A special reed bamboo which prefers to grow in marshy land of southern India is *Ochlandra* sp., primarily used in housing, weaving, matting and pulping.

Continuous hills interspaced by vast plains along river valleys are two distinctive features in the northeast region which include seven states of India. Altitudes of the different states vary between 150 and 4521 m above mean sea level. Only three of these states have relatively large areas of plain lands. These plains are located in Assam, Manipur and Tripura states. The other four, Arunachal Pradesh, Meghalaya, Mizoram and Nagaland, are almost entirely composed of hills. The structure of these hills is quite rugged, with steep gorges created by narrow mountain streams and a great many peaks. The northeast zone experiences distinct five seasons in a year, viz. winter (November to February) with little or no rain, where night and mornings are misty; a short spring (March); summer that stretches from April to May; a prolonged rainy season (mid-May to September); and a short autumn (October to mid-November). The monsoon rains normally start around April to May and continue till September, though it may rain at other times of the year sporadically too. The average annual rainfall ranges from 2000 to 6500 mm. The temperature ranges from moderately warm in the plains in summer to freezing cold in the hills in winter. The atmospheric temperature ranges from 2° to 40 °C; it rarely falls below 0 °C, mostly remaining within 20° and 35 °C. The northeastern region accounts for 28 % of total bamboo-growing area of India and produces about 66 % of bamboo, while the rest of the country has 34 % only. Bamboos are found both naturally and cultivated in homesteads and farms. Forest-grown bamboos are natural, owned and maintained by the government. The northeastern part of India, being a part of the subtropics, has mostly clump-forming bamboos both in forests and in villages. Morphologically, forest bamboos are thin walled and comparatively smaller in size to village bamboo species. The forest bamboos are mainly used for thatching, roofing of housing and agricultural purposes.

Phytogeographically, the region is the convergent point of Indo-China vegetation at northeast and Indo-Malayan vegetation at southeast; thus, it has been recognized as one of the hot spots of biodiversity globally. The richness of forest in northeastern region is such that it is called as the storehouse of diversities of trees, bamboos, canes and medicinal plants. In moist deciduous forests of Northeast India, most common bamboo species, like *Melocanna baccifera*, *Bambusa tulda*, *Dendrocalamus*

hamiltonii, *Dendrocalamus longispathus*, *Gigantochloa andamanica* and *Schizostachyum dulloa*, have been growing naturally. These bamboos are lifeblood to the local indigenous people of Northeast India for food, housing and agricultural and fishing activities. Some commercially important species like *Bambusa balcooa*, *B. cacharensis*, *B. nutans*, *B. polymorpha*, *B. tulda*, *B. vulgaris* and *Thyrsostachys oliveri* are commonly cultivated in different states of Northeast India. In Meghalaya from Shillong to Cherrapunjee area, *Phyllostachys mannii* has been cultivated in the farmland as shelterbelt against cold wave. This is the only monopodial bamboo growing by a few villages in those areas. *Ph. bambusoides* is another one monopodial species growing by Apatani tribe in northeast corner of Arunachal only.

Bamboos have been integral part of the socio-economic life of the people of Northeast India. The size of the domestic bamboo economy has been estimated at around Indian rupees (INR) in 2000 crore by the Planning Commission. The market potential, however, is estimated around INR 4500 crore, which could grow to INR 26,000 crore by 2015. India's share in the global market is estimated to be \$1 billion (about 4000 crore) and expected to increase to \$5.7 billion (Bhattacharjee and Chakravarty 2008).

1.4 Myanmar

Old Burma now Myanmar is located between Bangladesh and Thailand, with India and China to the north; Myanmar covers an area of about 675,000 km². Biodiversity distribution of Myanmar forest resources is influenced by a wide range of locations between latitudes 9° 58'N–28° 29'N and longitudes 92° 10'E–101° 10'E, topography traversing from north to south through three major mountain ranges and four major river systems. A major topographical feature of Myanmar is the Irrawaddy River system. Since its deltaic plains are very fertile, it is considered to be the most important part of the country covering about 47,000 km². Myanmar weather climate is principally of the tropical monsoon type with three distinct seasons: summer, rainy season and cold season. From mid-February to mid-May are summer months; the rain falls from mid-May to the end of October and the cold season starts in November and ends in the end of February in Myanmar. Generally, Myanmar enjoys a tropical monsoon weather climate. However, Myanmar weather climate conditions differ widely from place to place due to widely differing topographical situations. For instance, central Myanmar has an annual rainfall of less than 40 in. while the Rakhine coast gets about 200 in. in Myanmar. Besides, the average highest temperature in central Myanmar during the summer months March and April is above 43.3° C, while in northern Myanmar, it is about 36.1° C. Temperature of towns varies according to their location and elevation. Generally, in Myanmar, hot season is from March to May, rainy season is from June to October and cold season is from November to February. The tropical monsoon weather in Myanmar is usually cloudy, rainy and hot and humid summers, and during winter less cloudy, scanty rainfall and mild temperatures with lower humidity.

Bamboos are found all over the country in the forests either as an understorey or as a pure stand from sea level to the mountain ranges to about 4000 m. There are sympodial types as well as monopodial types, with sizes varying from 3.0 to 33.0 m in height. The country has about 100 species with a wide diversity of 17 genera and four varieties of bamboos (Htun 1999). The genera are *Arundinaria*, *Bambusa*, *Cephalostachyum*, *Chimonobambusa*, *Dendrocalamus*, *Dendrochloa*, *Dinochloa*, *Gigantochloa*, *Klemachloa*, *Melocanna*, *Oxytenanthera*, *Phyllostachys*, *Pseudostachyum*, *Schizostachyum*, *Sinobambusa*, *Teinostachyum* and *Thyrsostachys*. In Myanmar, language bamboo is called as 'Wa'. It has been estimated that *M. baccifera* occurs as pure stands over 7800 km² in Arakan Yoma. Other species like *Dendrocalamus strictus*, *Bambusa longispiculata* and *Thyrsostachys oliveri* occur in scattered locations. Bamboo breaks of *Bambusa bambos* and *B. tulda* are found along stream banks and lower hill slopes. The commercially important species are *Bambusa bambos* (local name: Kyaket-wa), *B. longispiculata* (local name: Tabindaing-wa), *B. polymorpha* (local name: Kyathaung-wa), *Cephalostachyum pergracile* (local name: Tin-wa), *Dendrocalamus brandisii* (local name: Kyalo-wa), *D. giganteus* (local name: Wabo-wa), *D. hamiltonii* (local name: Wabomyetsangye-wa), *D. longispathus* (local name: Wanet-wa), *D. membranaceus* (local name: Waphyu-wa), *D. strictus* (local name: Hmyin-wa), *Dinochloa maccllelandii* (local name: Wanwe-wa), *Gigantochloa rostrata* (local name: Waya-wa), *Melocanna baccifera* (local name: Kayin-wa) and *Thyrsostachys siamensis* (local name: Htiyo-wa, Myin-wa).

Bamboo is an important species in the economy of Myanmar. Bamboos are used from toothpicks and chopstick industries to paper pulp and also as food and fodder. For aesthetic reasons, many bamboos are cultivated; examples are *Bambusa bambos* (hedge plants with thorns), *B. vulgaris* var. *striata* (the yellow bamboo with longitudinal green stripes) and *B. vulgaris* var. 'wamin' (short inflated internodes in the lower part of the culms, Buddha belly bamboo), also used for landscaping, house gardens, parks and zoological gardens, in and around big cities in Myanmar. Some species, like *Bambusa longispiculata*, *B. wamin* and *Thyrsostachys siamensis*, are planted in many Buddhist Monasteries, in the villages and gardens in urban areas for local sales. About 100 species grow in large quantities throughout the country. They are major construction materials, particularly in rural areas, and can be used for almost all parts of houses, including posts, roofs, walls, floors, beams, trusses and fences.

People use bamboo to make mats, baskets, tool handles, hats, traditional toys, musical instruments, umbrellas and furniture. In addition, bamboo shoots are edible and pickled-bamboo shoots are becoming very popular. As an industrial raw material, bamboo is commonly used in Myanmar by pulp and paper mills.

1.5 Nepal

Nepal is lying between China and India and located in 28° 00'N and 84° 00'E. The country is very mountainous and hilly. Its shape is roughly rectangular, about 650 km long and about 200 km wide, and comprises a total of 147,181 km² of land.

Nepal has great physical diversity, ranging from the Terai Plain—the northern rim of the Gangetic Plain situated at about 300 m above sea level in the south—to the almost 8800 m high Mount Everest, locally known as Sagarmatha (its Nepali name), in the north. Climate varies from cool summers and severe winters in north to subtropical summers and mild winters in south. Eastern Nepal receives approximately 2500 mm of rain annually, the Kathmandu area about 1420 mm and western Nepal about 1000 mm.

Bamboos are widely distributed throughout Nepal, but they are more common in the eastern half of the country, from Dhaulagiri to the Sikkim border. In higher rainfall areas such as those around Pokhara and Ilam, a wider variety of genera and species can be found. One unique feature of Nepal is that it has both tropical and temperate bamboo species. About 11 genera (*Ampelocalamus*, *Arundinaria*, *Bambusa*, *Borinda*, *Cephalostachyum*, *Dendrocalamus*, *Drepanostachyum*, *Himalayacalamus*, *Melocanna*, *Thamnocalamus* and *Yushania*) and more than 30 species of bamboos have been recorded from Nepal (Stapleton 1994b). The bamboos are abundant between the mid-hills and the Terai with most of the species being found in the mid-hills. It is estimated that there are close to 62,900 ha of bamboo stands in the natural forest of Nepal (Anon 1996a). In Nepal, big-diameter bamboos are known as *bans* where smaller ones as *nigalo* and the smallest diameter group as *malingo*. Among different species, *Arundinaria maling*, *Bambusa bambos*, *B. nutans*, *B. balcooa*, *Dendrocalamus hamiltonii*, *D. hookeri*, *D. strictus*, *D. patellaris*, *D. giganteus*, *Drepanostachyum* sp. and *Thamnocalamus* sp. are the most common and useful bamboos (Das 1988). People believe that regular cutting of bamboos promotes good growth, and if not harvested regularly, the bamboo population decreases.

Bamboo is used in Nepal in 180 different ways, the most visible ones being basketing, housing and scaffolding (Poudyal 1991). Bamboos provide a large proportion of renewable material for building, paper, animal fodder and vegetable and cottage industries in many areas of the Terai and mid-hills. While traditional uses continue to consume large quantities of bamboos, new uses are also being developed. Bamboo is a major agroforestry crop widely planted in farms and vacant lands on the periphery of settlements. Most of the households in the rural areas have their own bamboo stands (Anon 1996a). In the eastern Terai region of Nepal, there are a large number of bamboo farms with an area ranging from 1.25 to 2.5 ha each. In the lowlands, natural stands are mixed with deciduous subtropical forest vegetation. The weaving bamboos are the most popular species with about 70 % of the farmers growing them on their farms and homesteads. About 66 % of the bamboos grown are for commercial purposes. Entire culms are used as rafters, pillars and fence posts, while split culms are used for panels or further split for weaving baskets and other articles. Bamboos also find use in making furniture and a host of domestic items. Bamboo-based enterprises are an important source of employment for both the rural and urban workforce. It is estimated that the sector accounts for employment generation of more than 100,000 workdays per annum (Anon 1996a). Out of the estimated 15 % contribution to the national GDP by the forestry sector, bamboo contributes 1–2 %. Estimates show that the annual bamboo production is a little over

3 million culms, of which 2.64 million culms are consumed locally. Young culms are harvested for string making and weaving of bamboo articles. Mature culms are used mostly for construction and furniture making. Most of the bamboo products—such as mats, basketry, household accessories and implements—are manufactured by the farmers and artisans and sold in local markets. The local market, though strong, does not receive products from all regions owing to lack of transportation network and a well-established marketing system. Bamboo is also being increasingly used in rural construction and for making water tanks, tubs, bus stands, etc.

Bamboo fodder plays a significant role in Nepal as one of the main sources of fodder in late winter (Anon 1995b). Over 30 bamboo species are extensively used as fodder. Cattle graze on *Drepanostachyum intermedia*, *Thamnocalamus* spp. and *Arundinaria racemosa* growing at higher elevations in natural forests. Vitaly important for Nepal is the use of bamboos in rehabilitating riverside degraded lands. In Nepal, bamboo plantation has been highly preferred by local community to reduce the impact of landslide (Paudel and Kafle 2012). Investigations are going on in combining mechanical structures and bamboo planting to divert and control river flow in different parts of the country. The use of bamboo strip-based brush dams to replace iron mesh wires is also being tested by different government and nongovernment organizations.

1.6 Pakistan

Pakistan is bordered by Afghanistan to the northwest and Iran to the west, while China borders the country in the north and India to the east. Pakistan lies in the temperate zone. The climate is mostly semi-arid, but arid in the south, characterized by hot summers and cool or cold winters and wide variations between extremes of temperature at given locations—the average daily low of 2 °C in January to an average daily high of 46 °C in June. Half of the annual rainfall occurs in July and August, averaging about 255 mm in each of those 2 months. The remainder of the year has significantly less rain, amounting to about 50 mm/month. Hailstorms are common in the spring.

The arid climate of Pakistan does not favour the natural occurrence of bamboos. No published reports are available on the bamboos of Pakistan. The natural distribution of bamboos in the Indian subcontinent is very scanty towards the western part. It appears from the description of Gamble (1896) that it is likely that a few clumps of *B. bambos* and *D. strictus* may exist near the Indian boarder of Punjab. Bamboos are of limited diversity in Pakistan. Three species grow naturally in Pakistan. *Arundinaria falcata* is in the northwest Himalayas at 1200–2000 m. It occurs in the undergrowth in forests of oak, firs and mixed trees, usually on northern slopes or in ravines. It is part of a wider gene pool through the Himalayas. It is used for making baskets, mats and pipes. *Bambusa bambos* is rare in the Ravi river eastwards. It is absent in the hills. This species is extensively used for construction. *Dendrocalamus strictus* is found in Punjab and Kashmir. It is found also in mixed

vegetation on Margalla hills surrounding Islamabad. It is used for construction and a variety of purposes. This forms part of a gene pool extending across India and usually growing below 1200 m. In Pakistan, the bamboo resources are shrinking.

Efforts were made in the 1980s to introduce different species of bamboos from Bangladesh, China, Sri Lanka and Thailand into Pakistan. Some of them are well adapted to climatic conditions of Punjab. In 1980, about a dozen propagules of *B. vulgaris* and *B. tulda* were taken from Chittagong, Bangladesh, Forest Research Institute and four from Thailand and China and then planted in the Punjab of Pakistan (Banik 2000). Some of the species in this regard are *Dendrocalamus giganteus*, *Dendrocalamus strictus*, *Bambusa bambos*, *Bambusa tulda*, *Dendrocalamus hamiltonii*, *Bambusa vulgaris* and *Dendrocalamus longispatus*, and the ornamental species *Phyllostachys aurea* survived and grew well in some pilot plantation plots. Some bamboo species may be grown ornamentally in the urban homesteads, parks and gardens. Bamboo plantations have been raised on good agricultural lands in Sargodha, Jhang, Khushab and Mandi Bahauddin districts of Punjab province in Pakistan. Most of these plantations are on 0.5 acres of lands. In Chunian subdivision of Kasur district, small farmers have also successfully established small bamboo groves of 4–10 acres area. Bamboo plantation area increases or decreases with the market demand in the domestic as well as in the Middle East markets. *Dendrocalamus strictus*, *Bambusa bambos*, *Bambusa tulda* and *Dendrocalamus hamiltonii* are the major species grown on private farmlands.

1.7 Sri Lanka

It is an island in the Indian Ocean, located between five and ten north latitude in southeast of India. It has a total area of 65,610 km², with 64,740 km² of land and 870 km² of water.

The climate can be described as tropical and quite hot. Its global position endows the country with year-round warm weather, moderated by ocean winds and considerable moisture. The mean temperature ranges from a low of 16 °C in Nuwara Eliya in the Central Highlands (where frost may occur for several days in the winter) to a high of 32 °C in Trincomalee on the northeast coast, where temperature may reach 38 °C. The average yearly temperature for the country as a whole ranges from 28 to 30 °C. January is the coolest month, especially in the highlands, where overnight temperatures may fall to 5 °C. May, the hottest period, precedes the summer monsoon rains. The rainfall pattern is influenced by the monsoon winds of the Indian Ocean and Bay of Bengal. The mountain slopes and the south-western sector of the island receive heavy rains. Some of the windward slopes receive up to 2500 mm of rain per month.

Sri Lanka possesses only ten bamboo species according to a recent revision of the group (Soderstrom and Ellis 1988). Of the ten species, *Bambusa bambos* and *Dendrocalamus cinctus* are confined to the dry zone of the country (annual rainfall of less than 1000 mm). A third species, *Ochlandra stridula*, is found extensively in

the wet lowlands of the south-western region (2000–5000 mm annual rainfall). The natural habitat of most of the bamboo species is the forest understorey. The bamboo flora of Sri Lanka may be said to approach very nearly to that of the hills of the Western Ghats of Southern India (Gamble 1896). *Dendrocalamus cinctus* and *Arundinaria scandens* are confined to windswept mountain tops, and *A. densifolia* (*Chimonobambusa densifolia*) prefers wet places and grows in marshes at elevations of 2300 m among montane grasslands. A new endemic genus *Davidsea* has also been reported from Sri Lanka (Zoysa Neela de et al. 1988). About 20 bamboo species are supposed to have been introduced into Sri Lanka of which seven are cultivated. Among them, the yellow variety of *Bambusa vulgaris* is most widely cultivated, particularly in the rural areas of the wet low and mid-country and in the vicinity of waterways in the dry zone. *Dendrocalamus giganteus* is cultivated on a small scale in the wet highlands, whereas *Dendrocalamus asper* and *Dendrocalamus membranaceus* are found in the intermediate highlands. During 1964, *Dendrocalamus strictus* was introduced to Sri Lanka, and a few pilot plantations were established in the dry zones (Vivekanandan 1987). Two species of bamboo cultivated for their ornamental value are *Bambusa glaucescens* (synonyms *B. multiplex*, *B. nana*) and the recently introduced *Thyrsostachys siamensis*. The former is found in most parts of the country, while the latter is currently restricted to urban areas. Most of the above-mentioned bamboo species are found in the three Botanic Gardens of the country.

The usage of bamboo in Sri Lanka is largely in the handicraft industry and in the housing and construction sector. Bamboo handicrafts form a traditional cottage industry in the country, employing about 20% of the people working in the handicraft sector. *Ochlandra stridula* and the introduced *Bambusa vulgaris* are exclusively used in housing and cottage industries (Zoysa Neela de et al. 1988). The supply of *O. stridula* and *D. giganteus* is fast decreasing, while *B. vulgaris*, which is cultivated, is still available in reasonable quantities. The farmers mainly cultivate *B. vulgaris* because of high demand in the construction and housing sectors. The price of 9 m long bamboo culm was rupees 30 in 1988–1989. In early 1995, the price increased to Indian rupees 80–120, and nowadays, it has gone up to rupees 175–200 (2014). Of the people involved in the bamboo sector, 77% are engaged in collecting and processing raw materials mainly from forest sources, while 11.5% produce bamboo-based products, and the remaining 12% includes 9% in trade and marketing area and only 3% involved in resource production (nursery, plantation raising and management). About 79% of the people, who harvest bamboos, process and utilize these themselves (Anon 1994). It is reported that a great number of people are dependent on the existing bamboo resource, particularly *O. stridula* in the natural forests.

From time immemorial, bamboo has played a vital role in the lifestyle of rural areas of South Asian countries. The extensive cultivation of different bamboo species in almost every rural holding throughout the length and breadth of these countries indicates the importance of this plant in the socio-economic life. The uses of bamboo in rural housing and agricultural implements are so common that a homestead in the rural area cannot be conceived without bamboo. Since unknown past

farmers in the region have been growing various bamboos in their homesteads through selection from the wilderness. Through experience, field trial and wisdom, people identified suitable phenotypes or varieties in a number of bamboo species in respect to specific utilization. Considering ecologic and socio-economic aspects, some of these were finally domesticated by the people in the region. In addition, some species have been introduced to enhance the productivity, market opportunity and industrial demand. In the South Asian region, the distribution of wet months ranges from 2 to 7 months yearly, with about 1200–4000 mm of annual rain fall. In some areas, the day temperature may even reach 44 °C during the dry season, during April to May, and may drop to –0 to 10 °C in the cool dry season, from December to January. However, the average temperature of the whole region ranges from 25 to 34 °C. The region has many rivers and fertile flat lands where rural people have been traditionally growing bamboo as one of the MPTs in their homesteads and farms. On the hills, indigenous people are also living with the bamboos for food, housing and most of the livelihood activities. Thus, all countries in the region have enormous potentiality of raising extensive bamboo plantation and opportunity for industrialization of bamboo and can provide maximum employment opportunity to the rural community which would upgrade the status of this plant as cash crop, and all the country in the region would be benefitted.

Accordingly, people in this South Asia region started selecting and prioritizing some bamboo species out of the more than 300 naturally grown or cultivated species. Among those selected majorities are common in all the countries of the region. However, some of the prioritized local bamboo species are not considered in the priority list of global context.

Chapter 2

Some Priority Bamboo Species for South Asian Region

To a botanist bamboo is a grass even though apparently it doesn't look like it. Bamboo is a member of the Bambusoideae, a subfamily of the grasses. The subfamily is markedly diverse both in reproductive and vegetative characters. To talk of the habits of bamboos, and of the management of bamboo plants in general, has little meaning and is of no practical use. 'Each species has its own peculiarities and its own requirements...and without a reliable guide, the study of bamboos...would be hopeless' (Brandis 1899).

For centuries, bamboo has been used in fishing, papermaking, landscape gardening, handicrafts, fine arts, food, fodder, building, weapons and hundreds of other things. Some cultures are based on bamboo; the shoots provide a large portion of their food, and the culms are used for building housing and for making products that are sold as their only form of income. Bamboo has long been used in handicrafts and as the raw material for thousands of objects used in daily life and in the pursuit of a livelihood. The qualities of bamboo have been, and are, celebrated in paintings, drawings and verse. The pulp of bamboo is well suited to making fine papers of many varieties and adaptations. In India, Bangladesh and many other countries, bamboo pulp is blended with shorter weaker pulps for making wrappings and fine papers. High-grade bamboo pulp can be, and is, used in its pure state for making coated and uncoated book and magazine papers. The high length-to-diameter ratio of bamboo pulps gives it a special versatility in the papermaking process. *Bambusa vulgaris* and *Melocanna baccifera* rank very high in performance in South Asian countries both in the field and mill though most papers come from other species because of larger and more accessible stands. Two of such species are *Dendrocalamus strictus* and *Bambusa bambos* (syn. *Bambusa arundinacea*). And the people of South Asia region are bestowed with all the four species of bamboos and receiving benefit.

A total of 1482 species of bamboo under 119 genera have been described from different continents of the globe (BPG 2012). Major species richness is found in Asia Pacific and South America while least in Africa, except in Europe which has no native species. The major genera found in Asian countries include *Arundinaria*,

Bambusa, *Cephalostachyum*, *Dendrocalamus*, *Dinochloa*, *Gigantochloa*, *Melocanna*, *Ochlandra* and *Schizostachyum*. In temperate Asia, as in China, Korea and Japan, *Phyllostachys* and *Sasa* are common. From the tropical moist, primeval forests to the cool mountain foothills, bamboo is a natural partner to humans in all walks of life that to live without it is scarcely imaginable. Out of such huge number of bamboo species growing in the wilderness, only a few have been domesticated and cultivated in different parts of the world. People of each country identified their species on the basis of climatic suitability, social importance and utilization need.

In order to enhance production, especially against a background of over-exploitation, International Network for Bamboo and Rattan (INBAR)'s research networking requires a much sharper focus on a limited number of high-priority species. The INBAR in cooperation with the International Plant Genetic Resources Institute, formerly the International Board for Plant Genetic Resources (IPGRI), canvassed a number of experts (where author was also a member) from different parts of the world to choose priority bamboo species. Experts met together in expert consultation meeting in 1993 and also in 1994 for sharing information, established criteria for choosing species, and the expert group agreed upon groups of bamboo species—as those meriting focused research and wider use (Banik 1995).

From the beginning, it was recognized that a consensus on the major priorities for regional and international action would, of necessity, not include many of the other species which are used locally, many of which are the subject of research by national programmes. It is stressed that research on these should continue to receive attention from national, regionally or sub-regionally important species.

Accordingly, the following 20 taxa of bamboos are accorded high priority for international action, and a document entitled 'Priority species of bamboo and rattan' was published jointly by IPGRI and INBAR in 1998 (Rao et al 1998).

1. *Bambusa balcooa* Roxb.
2. *B. bambos* (L.) Voss
3. *B. blumeana* J A and J H Schultes
4. *B. polymorpha* Munro
5. *B. textilis* McClure
6. *B. tulda* Roxb.
7. *B. vulgaris* Schrad. ex Wendl.
8. *Cephalostachyum pergracile* Munro
9. *Dendrocalamus asper* (Schultes f.) Backer ex Heyne
10. *D. giganteus* Wallich ex Munro
11. *D. latiflorus* Munro
12. *D. strictus* (Roxb.) Nees
13. *Gigantochloa apus* J A and J.H. Schultes
14. *G. levis* (Blanco) Merrill
15. *G. pseudoarundinacea* (Steud.) Widjaja
16. *Guadua angustifolia* Kunth
17. *Melocanna baccifera* (Roxb.) Kurz
18. *Ochlandra* Thw. (spp.)—a number of species