Introduction
CHAPTER 1 INTRODUCTION

Bamboos are fast-growing arborescent grasses belonging to the family Poaceae, subfamily Bambusoideae, tribe Bambuseae (Chapman, 1996 & 1997). It is known as “Green Gold” because of its faster growth and multifarious uses. This green gold is sufficiently cheap and plentiful to meet the vast needs of human populace from the “child cradle to the dead man’s bier” that is why sometimes referred to as “poor man’s timber”. In nature, bamboos have a cosmopolitan distribution growing in the tropical, subtropical and temperate regions except Europe (Dransfield, 1992; Zhu et al., 1994; Nguyen, 2006). There are over 110 genera of bamboos with more than 1500 species all over the world (Subramaniam, 1998, Orhnberger and Goerrings, 1985). The large diversity of species allows it to grow in any part of the world (except Polar Regions) and to tolerate the climatic exigencies. Different growth forms of bamboos such as trees, shrubs and climbers are found naturally (Prasad and Gadgil, 1981). It is observed as pure stands, mixed with other species and also cultivated in homesteads, farmlands and other Agroforestry systems. It is estimated that the bamboo stands occupy an area of 36 million hectares (ha) worldwide which is equivalent to 3.2 per cent of the total forest area. Bamboo occupies over one per cent of the tropical and subtropical forest area - over 22 million ha. Over 80 per cent of the total area covered by bamboo is located in Asia, 10 per cent in Africa and 10 per cent in America (Lobovikov et al., 2007).

Bamboos are known for its diverse uses and about 1500 uses have been documented (Rai and Chauhan, 1998). Another resource book has listed more than 5000 uses for bamboos as on today (http://www.bambootech.org/tmlink.asp?subsubid=71&subid=16&sname=mission&lid=229). Bamboo can substitute wood and is one among the strongest and oldest building materials ever used. Bamboo contributes substantially to the ecological, economic and social development. Ecologically, bamboo plays a critical role in the balance of oxygen and carbon dioxide in the atmosphere, lowers light intensity and protects against ultraviolet rays. It prevents soil erosion and creates an effective watershed by binding soil along fragile riverbanks, deforested areas and in
places prone to landslides. It is reported to grow in a wide range of soil conditions from perennially poor to perpetually rich and known to adapt soil moisture conditions from drought to drowning. It is an important species for landscape as bamboo provides shade, effective windbreak, and acoustical barrier and has aesthetic beauty (INBAR, 1997). Its immense potential as a bio-energy resource helps in the retention of carbon already sequestered in the fossil fuels such as coal, oil and gas and can save the vast natural forests. The inherent ability of different bamboo species to grow on difficult sites makes it one of the preferred crops for greening the wastelands and degraded sites improving soil moisture and resulting in carbon sequestration. Employment potential of bamboo is very high and the major work force involved is rural poor, especially women. Bamboo and its related industries provide income, food and housing to over 2.5 billion people in the developing regions. For example, in China bamboo and rattan factories employ 7.59 lakhs workers per year, half of them are women. About 432 million workdays are provided by bamboo sector annually in India (Adkoli, 1994) and about 40 million workdays are provided by bamboo sector in Thailand (Thammincha, 1996).

With the realization of the potential of bamboo, a number of international agencies such as Asia Pacific Centre for Transfer of Technology (APCTT), Food and Agricultural Organization (FAO), International Development Research Centre (IDRC), International Network for Bamboo and Rattan (INBAR), International Plant Genetic Resource Institute (IPGRI), International Tropical Timber Organization (ITTO), United Nations Development Program (UNDP), United Nations Industrial Development Organization (UNIDO), World Bank, etc. supported for research and development (R&D) projects in bamboo growing areas. China made tremendous progress in the bamboo sector by transfer of technology developed through R&D. But in India, although lot of information has been generated through R&D transfer of technology is still limited.

The progress achieved by China in short time, and the pressure from Northeast regions that are rich in bamboo resources and bamboo products contributed for a major change in the perception about the potential of bamboo in India also. To promote the sector, an
An integrated bamboo development programme was launched on World Environment Day - June 5, 1999 by the Prime Minister. Subsequently the Planning Commission, Government of India prepared an action plan to give maximum emphasis for promotion and development of bamboo during the 10th Five-year plan. Two bamboo missions were established by Government of India viz., National Mission on Bamboo Applications (NMBA) and the National Bamboo Mission (NBM) under Ministry of Science and Technology and Ministry of Agriculture and Co-operation respectively, to focus on the integrated development of the sector.

Global warming and its associated climate change is one of the greatest challenges of this millennium. Emission of carbon into the ecosystem due to industrial and technological advancement is one of the strongest causal factors of the global warming. It is estimated that the current average annual increase of carbon dioxide is about 1.5 μL L⁻¹, with a predicted doubling of pre industrial concentrations by the end of 21st century (IPCC, 2001a). As a result, Earth’s climate has changed and will continue to change in the future, regardless of potential mitigation actions, with consequent impacts and implications for development and growth (IPCC, 2007). Kyoto Protocol expresses the deep concern of scientific community on increasing carbon emission due to developmental activities. During recent years concern has also been growing among scientists and the general public about the possible impacts of future climate change on terrestrial ecosystems, especially with respect to plant growth, changes in biodiversity, distribution patterns of naturally growing tree species and the overall impact on carbon storage in the biosphere (Rasmussen et al., 2002).

Three common options viz. mitigative, adaptive and indirect are adopted to control global warming and the associated climate change. Mitigative option includes carbon dioxide sequestration and reduction of emission; the adaptive option includes adjustment in ways that reduce the negative impacts of temperature changes on the environment; and indirect options include controlling population growth or changing technologies. To contribute to reduction of Green House Gas (GHG) emissions, and to
partly offset deforestation, the Kyoto protocol explicitly considered reforestation and afforestation activities for carbon sequestration accounting (IPCC, 2007). The total global potential for afforestation and reforestation activities for the period 1995–2050 is estimated to be between 1.1 and 1.6 Pg C (1 Pg = Peta gram, $10^{15}$ g) per year, of which seventy per cent could occur in the tropics (IPCC, 2001a). United Nations Framework Convention on Climate Change (UNFCCC) has recognized the importance of plantation forestry as a GHG mitigation option, as well as the need to monitor, preserve and enhance terrestrial carbon stocks (Updegraff et al., 2004). Biomass production is an indication of the productivity of any plants and carbon capture is an indication of the reduction of atmospheric carbon dioxide which can mitigate the global warming.

Bamboos can play a major role in carbon sequestration due to vigorous growth and addition of biomass annually both above and below ground. The fastest-growing species may grow up to 1.2 m per day. This unique growing capacity makes bamboo a valuable sink for carbon storage. Bamboo which can act as great carbon sink have significant advantage over other biomass resources due to its species diversity, vigorous growth, early establishment, adaptability to various soil and climatic conditions, short harvesting period, sustainability in yield and multifarious uses. Hence, it may be regarded as the best among the biomass resources. Bamboo plantations can also play a major role in ‘carbon trading’ in a developing country like India (Jijeesh and Seethalakshmi, 2009). ‘Carbon trading’ which is also known as "cap and trade" is a method developed to reduce the carbon emissions which contribute to global warming. This will allow the developed countries to transfer the emission credits (carbon credit) to other countries that reduce their emission more than their national target under Kyoto protocol. Bamboos have the immense potential as the carbon credits and with the inclusion of bamboos in REDD (Reducing Emissions from Deforestation and Forest Degradation) and REDD+ the prosperity of bamboo will be elevated.

Litter is an important component of biomass in bamboo. The litter on the forest floor can act as an input-output system for nutrients (Das and Ramakrishnan, 1985). The rate at
which litter falls and subsequently decays regulate the energy flow, primary productivity and nutrient cycling in forest ecosystems (Waring and Schlesinger, 1985). Plant litter acts as a temporary sink for nutrients and functions as 'a slow release nutrient source' (White, 1988), thereby guaranteeing a permanent contribution of nutrients into the soil (Cuevas and Medina, 1988). It is estimated that litter nutrients released by litter decomposition make 70-90% of total nutrient requirement of plants (Waring and Schlesinger, 1985). Litter dynamics studies are very important in the nutrition budgeting on tropical ecosystems where vegetation depends on the recycling of the nutrients contained in the plant debris (Singh 1968; Prichett and Fisher, 1987). Litterfall plays a significant role in the nutrient cycling of the tropical ecosystems. As most of the bamboo plantations occur in the nutrient-poor soils, bamboo litter can play a major role in recuperation of the soil fertility in degraded areas.

Kerala is one among the major diversity centres of bamboo in the country and 22 species of bamboos under seven genera have been recorded. Bamboos are found in forest and non forest areas. The total standing crop of bamboo in homesteads was estimated as 13.61 million culms and its green weight was 0.331 million tonnes during 2004-2005, whereas, bamboo resource in the forest areas was estimated to be 2.63 million tonnes based on the satellite imagery, 1997 (Muraleedharan et al., 2007).

Of the 16 priority bamboo species identified by NMBA, carbon sequestration potential and litter dynamics of four species viz. Bambusa balcooa Roxb, B. bambos Voss, Ochlandra travancorica Benth and Thysostachys oliveri Gamble were studied during this investigation. B. bambos and O. travancorica are endemic to Kerala and the other two are exotic. Farmers are coming forward to cultivate bamboo in homesteads and they are looking for suitable species. B. bambos is not preferred much due to its thorny nature and congestion at base. B. balcooa is a better alternative since it is stronger than B. bambos and no thorns. A comparison of these two species is required for making a recommendation. In Kerala, there are more than one lakh traditional artisans who depend on O. travancorica (bamboo reed) as the raw material for weaving. Bamboo reed
is the major raw material for two industries viz., Hindustan Paper Corporation Ltd. Kottayam and Kerala State Bamboo Corporation Ltd. Angamaly. Bamboo reeds were available from forests only. Recently attempts are made to cultivate this species in non-forest areas. *T. oliveri* due to its small clump size, straight growth and branching only from top one-third of the culms is the most preferred species by farmers for growing in homesteads (Gnanaharan *et al.*, 2004). *B. balcooa* is used for structural construction, thatching, walling, roofing, handicrafts and for making novelty item. It is good for scaffolding, making ladders and also used for pulp, paper, rayon and agarbathi sticks (Seethalakshmi and Kumar, 1998). There are several uses for *B. bambos* and some of them are pulp (*Tewari et al.*, 1994) and panel products, handicrafts, scaffolding, thatching, roofing, baskets, mats, bows and arrows, furniture, floating timber and rafting, cooking utensils, fencing, fodder, medicine, etc. Young shoots are edible (Seethalakshmi and Kumar, 1998). It is a good bamboo for ladders and also used for pulp, paper, rayon and agarbathi sticks. Vitamins and minerals are obtained from leaves and rhizome. *B. bambos* is the one of the most important source of medicine phytochemicals widely experimented by scientists (Sanjita *et al.*, 2012).

*Ochlandra travancorica* is an ideal raw material for paper and rayon manufacture (Bhat and Viramani, 1961). Culms are used for mat and basket making (*Ayyanar et al.*, 2010), umbrella handles, fishing rods and handicrafts. According to Thomas and Sujatha (1992) it is very efficient in soil conservation. Culms of *T. oliveri* are in great demand for construction purposes in Myanmar; reinforcement for concrete slabs, poles, basketing and handicrafts (Ramyarangsi, 1990). Young shoot is commonly used in Thailand for edible purposes. The culms are also in good demand for pluckers and banana props.

There is not much information on growth and biomass production and thereby the carbon sequestration potential of these four species grown in non-forest areas. Hence the present study is formulated with the following two major and five specific objectives.
The major objectives were

1. To study biomass production and carbon sequestration potential of the selected bamboo species in Kerala and
2. To estimate the litter production and decomposition dynamics of these species

The specific objectives were to study

a) The clump and culm attributes of selected bamboo species viz. *Bambusa balcooa* Roxb, *B. bambos* Voss, *Ochlandra travancorica* Benth and *Thrysostachys oliveri* Gamble
b) The biomass accumulation and allocation in bamboo clumps
c) The carbon storage of bamboo clumps and soil under bamboo cover
d) The litter production and decomposition dynamics of bamboo species
e) The nutrient release pattern from the decomposing litter