CHAPTER - 2

REVIEW OF LITERATURE
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Home-gardens are ancient and widespread agroforestry systems (Christiany, 1990; Karyono, 1990; Okigbo, 1990; Millat-e-Mustafa, 1997) in the tropical and subtropical areas. Home-gardens are said to have been components of human subsistence strategies since the Neolithic period (Soleri & Cleveland, 1989). The importance of home gardens is evident across countries and societies. Different cultures and customs have different names for this homestead production system, for example, the Americas-dooryard gardens, Java, Indonesia- Pekarangan, Malaysia- Kebun, West Indies - Jardin Creoje, (Michon, 1983), N.Tanzania - Chagga homegarden (Fernandes et.al., 1984), Tropical America- Qeintal and Calmil (Budowski, 1990), Africa -Compound farms (Hahn, 1990), Mixed garden, house garden, kitchen garden (Nair, 1993), Northwest Tanzania- Kibanja (Rugalema et.al., 1994), Conuco in Cuba (Castineiras et.al., 2000). In Nepal, Home garden refers as Ghar Bagaincha (Shrestha et.al., 2002), Vuon nha in Vietnam (Trinh et. al., 2003) and Venezuela (Mulas et.al., 2004). In Manipuri it is generally called as "Ingkhol". Homegardens are generally accepted to be economically efficient, ecologically sound and biologically sustainable agroforestry systems (Fernandes & Nair, 1986; Torquebiau, 1992). Homegardens were developed and sustained by farmers in many regions in the past due to the fact that these were then the most beneficial forms of cultivation or land use, given the constraints and opportunities encountered by them (Santhakumar, 1996). Inventory of homegardens
in Kerala have been done by Kumar *et al.* (1994) and Santhakumar (1996). Agroforestry studies by Jose and Shanmugaratnam (1993) have also analysed the biostructure of homegardens, level of biodiversity and interaction between different components in homegardens. Santhakumar (1996) catalogued the factors affecting biodiversity in homegardens. The species diversity that exists in homegardens are claimed to have beneficial aspects in terms of pests and diseases (Altieri, 1995). The existence of a higher level of biodiversity in homegardens could be reckoned as a result of more intentional choices made by the cultivars and farmer families in certain historical periods (Santhakumar, 1996). Kumar *et al.* (1994) noted that in Kerala as holding size increased, floristic diversity and density were reduced. Jose and Shanmugaratnam (1993) found the homegardens of Kerala to have holding size and percentage canopy cover inversely related. Homegarden diversity is especially notable in areas where there is a high degree of socioeconomic and socio-cultural variability such as North-East India (Ramakrishnan, 1992). Technical measurements of species diversity in homegardens were carried out by Brieley (1985). From an ecological and land use perspective, home gardens involve the management of multipurpose trees, shrubs, annual and perennial agricultural crops, herbs, spices, medicinal plants, fish ponds and animals on the same land unit, in a spatial arrangement or on a temporal sequence (Eyzaguirre & Linares, 2004).

**Homegardens: Structure and Diversity**

Tropical homegardens are characterized by vegetation layers (stories), imitating the tropical forest structure. The top storey consists of a canopy of tall trees which reduces radiation and mechanical impact of rainfall, creates a relatively constant
micro-climate in the lower layers and through leaf fall contributes to the
maintenance of soil fertility. The lower layer features staple food and fruit
production (e.g. banana, mango, papaya, etc.) followed by bush level growth (e.g.
cassava, maize, peppers, etc.) in the third layer. In-ground and ground-covering
species (roots and tubers and others) form the last layer, while climbing species
transverse the lower stories (Fernandes & Nair, 1986; Ninez, 1987). Despite the
fact that the spatial arrangement of the species seems to lack order and pattern,
compatible species are often mixed (Fernandes & Nair, 1986). Moreover, spatial
arrangement in these systems often reflects their functional adaptation in a
multitude of factors including utilization of plant-symbiotic relationships through
mixed cropping (Ninez, 1987). The structure and composition of homegardens
differ across sites depending on the ecological setting and socioeconomic functions
within different household economies (Wiersum, 1982; Christanty, 1985;
Fernandes & Nair, 1986; Soemarwoto & Conway, 1991). Plant associations are
groups of plant species chosen to complement each other in fulfilling a range of
functions (Christanty, 1990). The position of plants is related to their use, for
example Gliessman (1990) observed that in Latin America trees are concentrated
to the back of the house, annual food crops were concentrated towards the front of
the house in full sunlight, ornamentals are clustered round the path and walls of the
house in beds and containers, while animal pens are behind the house in the shade
of trees and chickens roam freely. Christanty (1990) found that vegetables and
spices used daily were located near the house as were crops with high water
requirements, whilst crops with high nutrient requirements were planted close to
animal pens and garbage dumps. Fernandes and Nair, (1986) recorded that vertical
structure of homegardens is composed of 2-5 canopy layers. Homegardens are characterized by high species diversity and usually 3-4 vertical canopy strata, which results in intimate plant associations (Nair, 1993). Despite species choices being related to environmental factors, socio-economic factors, dietary habits and market demands, there is remarkable similarity in gardens of various places (Fernandes & Nair, 1986). In spite of the very small average size of the management units, homegardens are characterized by high species diversity and usually 3-4 vertical canopy strata, which results in intimate plant associations. The layered canopy configurations and combination of compatible species are the most conspicuous characteristics of all homegardens. Contrary to the appearance of random arrangement, the gardens are usually carefully structured systems with every component having a specific place and function. The Javanese pekarangan is a clean and carefully tended system surrounding the house, where plants of different heights and architectural types, though not planted in an orderly manner, optimally occupy the available space both horizontally and vertically (Wiersum, 1982; Soemarwoto & Soemarwoto, 1984). The homegardens in the Pacific Islands present a more clearly defined arrangement of species following the orientation and relief characteristics of the watershed. The West African compound farms (Okafor & Fernandes, 1987) are characterized by a four-layer canopy dominated by a large number of tall indigenous fruit trees. An architectural analysis of the canopy reveals a relatively higher percentage of canopy distribution in the upper strata. The most conspicuous characteristics of all homegardens are their layered canopy arrangements and admixture of compatible species, with each component occupying a specific place and function (Nair, 1993). Most homestead systems
consist of an herbaceous layer near the ground and a tree layer at higher levels. The herbaceous layer can be partitioned into two, with the lower layer consisting of vegetable and medicinal plants; and the upper layer composed of food plants such as cassava (*Manihot esculenta*), papaya (*Carica papaya*), banana (*Musa* spp.), yam (*Dioscorea esculenta*), and other vegetables and tubers. The tree layer usually has two levels as well, with the lower tree level consisting of medium-sized trees (10 to 20 m high) and fully-grown timber and fruit trees occupying the uppermost layer (more than 25 m high). Fruit trees, some of which could continue vertical development, could occupy an intermediate layer (3 to 10 m high). Small and marginal farmers rely on homegardens as a risk aversion strategy (Jose & Shanmugaratnum, 1993). Homegardens represent an important repository of genetic diversity (Kumar *et al.*1994). The number of species found in homegardens varies greatly, and figures in the literature often do not specify if the figures refer to total number of species found in a sample of homegardens or to a single plot (Hoogerbrugge & Fresco, 1993). Soemarwoto (1987) documented in a West Javan village 219 plant species in the dry season, 272 plant species in the wet season with an average of 56 plant species per garden. Rico-Gray *et al.*, (1990) found 301 plant species in homegardens of the Yucatan, Mexico. Padoch and De Jong (1991) noted 168 plant species in 21 homegardens in Santa Rosa, Amazonia with 18-74 plant species in each garden; 65 plant species occurred in only 1 garden with no species present in every garden. Kumar *et al.*, (1994) found 127 woody species in homegardens of Kerala, 32 of which were exotic. Millat-E-Mustafa *et al.* (1996) recorded 92 perennial species in 80 Bangladeshi homegardens. In the lowlands of Mexico 'huerto familiares' or 'solares' contain a mix of indigenous and
exotic plant species in the town of Xuilub, 404 plant species were found in homegardens, whilst only 1,120 species are known in the whole state. Shastri et al. (2002) recorded 68 tree species in homegarden of Karnataka with greater number of fruit and vegetable. (Das and Das, 2005) reported 87 tree species in homegarden of tea garden communities of Barak valley, Northeast India. Similarly, Haripriya Devi (2004) reported 42 tree species in Meitei homegardens at Singerband and Linthoingambi Devi (2004) 36 tree species at Rajubari in Cachar district of Assam. Tynsong and Tiwari (2010) reported 197 plant species (70 trees, 41 shrubs, 50 herbs, 23 climbers and 13 epiphytes) from the homegardens of Meghalaya.

Christanty (1990) found the homegardens of Bangladesh to range from 30-700 m$^2$ with an average of 200 m$^2$. Kumar et al. (1994) recorded an average of 0.43 ha in Kerala homegardens and 0.6ha was recorded by Rugalema et al. (1994) in N.W.Tanzania and 0.75ha in Nigeria (Hahn, 1990), Perera et al.(1991) recorded the size of Kandyan homegardens in Sri Lankan ranging from 0.05 to 2.50 ha. The average size of West Java Homegarden was 0.0229ha (Soemarwoto, 1987) and the size of Santa Rosa Homegarden in Amazon varied from 0.0067 to 0.7322 ha (Padoch & de Jong, 1991). The size ranged from 0.07 ha to approximately 0.78 ha, with an average of 0.20 ha in the traditional meitei homegardens in Barak Valley, Assam, India (N.L.Devi, 2004). Das and Das (2005) reported the size range from 0.02 to 1.20 ha with an average of 0.30 ha in Barak valley, Southern Assam, India.

In Sri Lanka 30-40% of the cultivated area is Homegarden, this figure is 20% in Java (Hoogerbrugge & Fresco,1993).The area under Homegarden in Java has increased from 1.398million ha in 19933 to 1.554 million ha in 1980 (Soemarwoto,
Management zones in homegardens have been documented by Brieley (1985). Mendez et al. (2001) noted that location of zones in most homegardens in Nicaragua was deliberate, and the number of zones per homegarden ranged from two and six. Farming systems based on diversity also provide a range of products with multiple uses, including varied food and other products, fuel, medicines and construction material (FAO, 1998). Mendez et al. (2001) recorded a total of 324 plant species with nine different plant uses in homegardens of Nicaragua.

José and Shanmugaratnam (1993) noted that labour is major input in homegardens. The role of tree leaf litter in the contribution to soil fertility has been documented by Sinclair and Walker (1999). Socially, homegardens act as a status symbol and strengthen community links through the sharing of produce (Christanty, 1990). Fernandez and Nair (1986) stated that homegardens could be a gene pool for breeding programmes. Homegardens also constitute a valuable part of the in situ conservation system (FAO, 1998). A baseline information on structure, composition and utilization of Kandyan homegarden was made by Perera et al. (1991). 12 species were identified as the “base” species assemblage in the Kandyan homegarden. They suggested that any importances to Kandyan forest gardens must be considered within the existing framework of physiognomy, use and management. This is because all benefits (ecological, economical and social) commonly linked to Kandyan forest gardens appear to depend on the unique nature of their physiognomy, utilization and management style. According to Coomes and Ban (2004), homegarden diversity is positively related to household land holdings.
(i.e., number of fields), suggesting that in Nuevo Triunfo—where most households depend fundamentally upon agriculture for sustenance—wealthier households tend to hold greater plant diversity in their gardens. This association between land wealth and home garden diversity arises because households with more agricultural fields are more likely to have different types of fields (e.g., swidden, transitional, orchards, forest fallow) and fields in distinct environments (e.g., uplands as well as lowland), raising total crop diversity in their farming portfolios. The final variable related to homegarden diversity is the number of plant species received from others. Households commonly exchange planting material—including seeds, cutting, and suckers—that are incorporated into the garden and add to plant diversity (Coomes & Ban, 2004).

**Phenology of Trees**

The phenology is the study of growth of buds, leaf flushing, anthesis, fruiting and leaf fall in relation to seasons or years with climatic factors (Okullo *et al.*, 2004). Lieth (1974) defined phenology as the study of (i) the rhythm of repetitive biological events, (ii) the biotic and abiotic causes of these events, and (iii) the relationship between phenophases (i.e. periods during which specific phenological events occur) for individual or different species. Charles Morren, a Belgian botanist introduced the word in French for phenology for the first time in 1853; but of course the history of phenology is much older, dating back to the time of hunters and gatherers. The aboriginals who have occupied the Australian continent for at least 50,000 years developed a deep understanding of the interrelationships between the environment and its influence on fauna and flora. Aboriginal calendars recognize between 5 and 10 seasons, each season defined by...
the changes in flora and fauna well as the strength of wind, amount of rain and
temperature (Keatley, 2000). Japan has the oldest existing (and still on-going)
phenological monitoring record. The flowering of cherry tree has been observed
and recorded for about 1300 years. A very old European time series of
phenological observations is the bud burst of horse-chestnut in Geneva, dating
back to 1808. A clear trend towards earlier appearance (0.24 days per year) was
detected becoming more pronounced since the beginning of the 20th century. This
coincides with the growth and industrial development of Geneva (Defila & Clot,
2001). The climatological and phenological records of the Marsham family in
Norwich, England, are another example of a very old European data series, as is
the newly published series of cherry flowering in Switzerland which dates back to
1721, and the grape harvest dates from France which go back to the middle Ages.
Carolus Linnaeus is looked upon as the father of modern phenological networks.
The first known phenological network was installed by him in Sweden in the
middle of the 18th century. In his work Philosophia Botanica he outlined methods
for compiling annual plant calendars of leaf opening, flowering, fruiting and leaf
fall, together with climatological observations “so as to show how areas differ
(Schnelle, 1955). Many of the “modern” phenological networks started in the
middle of the 19th century (e.g. in the Austrian Hungarian monarchy organized by
the NMS, in the US by the Smithonian Institute or by the Royal Society of
Canada). At the same time guidelines for phenological animal and plant
observations were published, for example, by Fritsch in the 2nd yearbook of the
newly founded K.K. Centralanstalt für Meteorologie und Erdmagnetismus, now
the NMS of Austria. In the early 1960s the International Phenological Gardens
were founded by Volkert and Schnelle. The idea was to plant clones of different
trees and bushes throughout Europe to study their phenological development and to
remove any influence of different genetic material (Chmielewski, 1996). In 1993
the Phenological Study Group of the International Society of Biometeorology
(ISB) started a new initiative called GPM (Global Phenological Monitoring) whose
main objectives are to form a global phenological backbone with a “standard
observation program”, to link 'local' phenological networks and to encourage
establishment and expansion of phenological networks throughout the world
(Hudson & Keatley, 2009). The European Phenology Network has been established
as platform for phenologists for data exchange, information and network activities.
The GLOBE Program (Global Learning and Observations to Benefit the
Environment) founded in 1998, recognized the value of phenological observations in
education and encourages students to take scientifically valid measurements in the
fields of atmosphere, hydrology, soils, and land cover/phenology combining
scientific research with education. In Australia the Macquarie University
developed a website which hopefully may serve as nucleus for a network to gather
and collate flowering and fruiting observations from observers around Australia
(Rice et al., 2001). Nevertheless one need to acknowledge that little in the way of
phenological networks are available in some countries, particularly in the Southern
Hemisphere. Phenological phases reflect, along with other environmental
conditions and genetic factors, the characteristics of the climate. Consequently,
long series of phenological observations may be used to detect climate variability
and/or climate change. The significant responses of life cycle events to global
changes have caused a strong increase in interest in phenological processes as an
indicator for climate change impacts. However, the actual timing of phenological events is also of importance for other issues in education, agriculture, human health, tourism and recreation, bio-diversity and ecology. Schnelle (1955) discussed the value of phenological observations and concluded that these inexpensive and useful ‘plant-instruments’ are integral instruments which respond to many meteorological and environmental factors. He concluded that the best method to analyse impacts on plants would be to ask the plants themselves. Sparks (2000) best summarises the value of phenological data as follows: “Historical data are a resource. They were collected at considerable effort in time and money. They do have value, and that value is too great to allow them to be left in obscurity or lost forever”. At the very minimum, they may give insight into possible repercussions of man induced global climate change and allow cautious forecasts of future timing of phenological events.

Plant development, and thus phenological phases, show great interannual variability and also large spatial differences. Individual (e.g. genes, age) and environmental factors (weather and climate conditions in the micro and macro-scale, soil-conditions, water supply, diseases, competition, etc.) influence plants. They can be viewed as integrative measurement devices for the environment. The seasonal cycle of plants however is influenced to the greatest extent by temperature, photoperiod and precipitation (Morellato & Haddad, 2000; Keatley, 2000). In particular, spring development in the Northern Hemisphere mid latitudes mainly depends on the temperature in winter and spring in the tropics and subtropics rainfall regime is predominant. Phenology is probably the simplest and most cost effective means of observing the effects of changes in temperature, and
consequently, phenology has become an important tool in global change research. The use of phenology as a biological indicator of climate change presupposes (1) precise quantitative analysis of changes in phenological time series, (2) a known relationship with temperature or (3) an analogous change in corresponding temperature series over time. Reported changes in plant phenology are quite uniform with numerous studies indicating that the onset of plant growth in the middle and higher latitudes of the northern hemisphere has become earlier in spring, the growing season has become longer and the breeding season starts earlier (Parmesan & Galbraith, 2004; European Environment Agency, 2004; Sparks & Menzel, 2002; Koch, 2000).

Phenology is perhaps the simplest way by which to track changes in the behaviour of species. Various indications of shifts in plant and animal phenology have already been reported for the boreal and temperate zones of the northern hemisphere (Menzel & Estrella, 2001). Phenological observations are necessary ground truth for satellite data. Northern hemispheric CO2 data and NDVI time series show in a coarse resolution an enhanced activity of vegetation and an earlier beginning of the growing season for Europe, for the 1970 to 1994 and 1981 to 1991 periods, respectively (Keeling et al., 1996; Myneni et al., 1997). Phenological studies in Europe and North America generally confirm these findings by similar shifts of different phenological phases (Menzel & Estrella, 2001) and link them to changed climate conditions during the last decades. The main difficulty in comparing phenological trends based on the ground observations with remote sensing-derived measures, as described e.g. by Schwartz (1998), is that the satellite 'Spring Green Wave' represents species averaged information over large and
diverse spatial areas, whereas phonomological events are traditionally determined on
the individual species-level and for discrete sites only. Phenological information is
important in monitoring all aspects of ecosystems (Lechowicz, 2001) and is
essential to understanding the dynamics of plant communities, which of course
impact animal populations as well. Much of today’s interest in monitoring stems
from the impact of climate change on human society, both directly and through
changes in the natural ecosystem. Once correlations are determined between the
timing of both observed plants and commercially important organisms such as
crops or pest insects, considerable money can be saved in sectors such as
agriculture and forestry. Phenology data can support decision making in fields as
diverse as medicine (pollen warnings for allergy sufferers), forensic studies,
tourism, and wildlife management. These data also are also needed as input to
models of future plant distribution (Chuine & Beaubien, 2001).

Phenology studies vary with respect to the size of the observation area, the
number of observers, the duration of time observed, the type and number of
species, and the selection of phenophases. They can be divided into three basic
types: the snapshot study, where many observers survey phenology over a large
area at one point in time; the intensive study, where one or a small number of
observers survey a small area over a period of one or more growing seasons; and
the extensive study, which involves a network of observers who survey a large area
over a period of years (Beaubien, 1991).

Thousands of years of phenology records exist in the Orient, and one or
more centuries of data exist for several countries in Europe. Phenological surveys
are active in most of Europe, often based in agro-meteorological government
departments. The UK and the Netherlands are currently reactivating networks of observers for their ‘Nature’s Calendar’ programs, with great success in volunteer recruitment. Germany uses rapidly reported data to issue bulletins to farmers to forecast plant diseases, irrigation needs, and fertilization timing. Their precise phonological growth models add so much to agricultural efficiency that millions of dollars are saved annually in preventing crop diseases (Deutscher Wetterdienst, 1995). Plant phenologies are the result of interactions of biotic and climatic factors that, through natural selection, determine the most efficient timing for growth and reproduction (Van Schaik et al., 1993). Biotic factors include morphological and physiological adaptations of plants (Borchert, 1983), as well as the behaviour of pollinators and seed dispersers (Van Schaik et al., 1993). Climatic factors include photoperiod (Wright and Van Schaik, 1994), temperature (Arroyo et al., 1981), and rainfall (Opler et al., 1976). While phenological patterns may be due to several factors (Lieth, 1974), understanding phenology in relation to climate is an important first step. Since climatic variables are often highly intercorrelated, testing their influence on phenology requires, firstly, finding significant correlations of phenology with climatic variables (Smith-Ramírez & Armesto, 1994; Morellato et al., 2000) then, secondly, controlling for interactions among these variables so that the most parsimonious model of the influence of climate on phenology can be derived. Different plant species within a community may share phenological patterns to varying degrees for a variety of reasons. For example, being subject to the same climatic regimes, plant species may share patterns independently of their morphological and physiological adaptations. Also, different species may show similar patterns in phenology because of close phylogeny
(Wright & Calderon, 1995). On the other hand, different life-forms may respond differently to climatic factors because of morphological and physiological adaptations reflecting different ways in which water and nutrients are sequestered and utilized (Sarmiento & Monasterio, 1983; Smith-Ramirez and Armesto, 1994). These various considerations have been studied for trees and shrubs in seasonal forests in Latin America (Frankie et.al., 1974; Morellato et.al., 1989; Opler et.al., 1980), but community-wide patterns with a variety of life-forms, including lianas and epiphytes, are still relatively poorly understood (Croat, 1975; Morellato & Leitão Filho, 1996).

Plant periodicity pattern reflect annual distribution of specific kinds of available food resources (pollen, nectar, and fruit seed resources). Phenological events influence the feeding, movement patterns, and sociability of insects, birds and mammals. In community analysis, data on major periodicity pattern can be broken down into several minor flower and fruit resource pattern. These resource patterns may be used by zoologists for investigating animal periodicities. Recently, phenological studies of tropical plants have been subjects of various workers (Bhat, 1992; Fuller, 1990; Justiniano & Frediricksen, 2002; Falcao & Clement, 2002). Knowledge of phenological pattern and how these are influenced by environmental factors is important for the prediction of the potential effects of climate change on vegetation (Lieth, 1974). Huxley (1996) highlighted the paucity of research concerning the importance of tree phenology in agroforestry systems, despite its potentials impact on under storey crops. The phenological studies are important from the point of view of the conservation of tree genetic resource and forestry management as well as for a better understanding of the ecological
adaptations of plant species and community level interactions. The plant animal interaction in the community is based on the knowledge of seasonal production of plant parts. The general phenological aspects of leafing, flowering and fruiting in tropical tree species are fairly known (Borchert, 1983; Daubermire, 1972; Frankie et al., 1974; Opler et al., 1980; Putz, 1979; Singh & Singh, 1992; Sun et al., 1996).

Okullo et al. (2004) suggested that observations on the phenology of tree crops with multipurpose uses are needed, as phenological events have many practical implications for agroforestry, such as assisting in the prediction of flowering, fruiting and seed maturation in individual trees and can also relate to a tree’s ability to capture environmental resources successfully. The knowledge of phenology of plant has helped to understand the influence of phenological events on feeding movement patterns, and sociality of insects, birds and mammals (Foster, 1983; Leigh & Windsor, 1982; Prasad 1983; Wada, 1983; Appanah, 1985; Coates-Estrada & Estrada, 1986). The two most compelling grounds to undertake such studies in tropical regions are that, they would greatly enhance our understanding of how the organism phase their phenological events in time and space, which in turn helps in a better appraisal of functioning of the ecosystem not only in tropics but elsewhere in temperate condition. In order to achieve this goal, an ideal phenological study should include as many species of the community as possible, should be based on a long-term basis and should be quantitative in nature (Prasad & Hegde, 1986). Emphasis on the need of quantitative phenological study was made by Singh and Kushwaha (2005a) in a review article. Four major leaf phenological functional types, characterized by specific combinations of phenological features, seasonal variation in stem water status (SWS), and structural
properties affecting tree water relations have been recognized in dry tropical forests as follows: (i) Leaf exchanging (ii) Brevideciduous (iii) Deciduous (iv) Deciduous stem succulent. While the studies on phenology in North Eastern India (Boojh & Ramakrishnan, 1982; Shukla & Ramakrishnan, 1982; Shukla & Ramakrishnan, 1984; Kikkim & Yadava, 2001) and in Himalayas (Ralhan et al., 1985a,b) do shed light on foliage dynamics and its relation to successional status of a given species. Studies related to the phenology of homegarden trees are scarce. Homegarden trees enjoy more favorable condition for reproduction – presumably from better indigenous management and protection, and less competition (Okullo et al., 2004). The various physiologically active sites, or sinks, within a plant (vascular cambium, leaves and leaf buds, flower and flower buds, and fruits) may compete for water, nutrients and metabolites (Alvim, 1964; Wareing & Patrick, 1975). An outcome of such internal competition may be the partitioning in time of a plant's function. Almost all tropical environments vary seasonally in temperature, humidity, rainfall, wind speed and day length, although the amplitude of the variation may be small (Richards, 1952). All of these factors are known to play a role, alone or in combination in triggering phenological changes in tropical plants (Longman & Jenik, 1987).

Nine phenological events (phases) of tree, they are i) leaf buds ii) mature leaves iii) abscission of leaves iv) flower buds v) fruit buds vi) anthesis of flower vii) abscission of flowers viii) maturation of fruits ix) abscission of fruits (Prasad & Hegde, 1986). The detailed phenological study was made in Vitellaria paradoxa, an important savanna parkland species in Uganda by Okullo et al.
The study revealed the pattern of leafing and leaf loss, flowering and fruiting as unimodal although the rainfall was bimodal.

Homegardens: Traditional knowledge and management

Homegardens are cared primarily by women; they are more likely to be developed among matriarchal societies, typical of Central Java thirty years ago. In Tegal on the northern Coast, for example, a homegarden could not be sold without the consent of the wife, similarly, well developed homegardens are found in the matriarchal society of West Sumatra and among the Acehnese of Sumatra but not among the patriarchal Batak people, also of North Sumatra (Penny & Ginting, 1984). Homegardens are also essential to the transmission of knowledge across generations. For example, among the Maya in highland Guatemala, “Women educate children through the chores of the garden. They teach how to use farm tools, what plants need to thrive, and how to manage crops, especially through weeding and harvesting” (Keys, 1999). Local knowledge is "Gendered" (Warren, 1998) because men and women have different and often complimentary economically productive roles. There are at least four main types of gendered difference in local knowledge system; women and men having different knowledge about similar things; having knowledge of different things; having different ways of organizing knowledge; and having different ways of preserving and transmitting knowledge (Norem et al., 1989). Rugalema et al. (1994) found that in homegarden of N.W.Tanzanian, women did twice the number of hour’s work than men.

Sustainable use of biodiversity mentioned in article 10 of the Convention on Biological Diversity (CBD) emphasizes the important of gender analysis in biodiversity management. The gender division of right, responsibility, works and
knowledge is taken as a point of departure to examine and explained the multiple role of women and men as resource users managers, where men are preferentially drawn into cash crop production, local wages labour, and the urban work force, women are increasingly responsible for the used and maintenance of complex rural landscapes and the plant and animal life support. Less information is available on the gender role of biodiversity (Ramakrishnan *et al.*, 1996; Adamo & Horvoka. 1998; Haripriya, 2004; Das & Das, 2005).

In a preliminary study carried out in Nepal under IDRC (International Development Research Centre) programme on gender issues in biodiversity management, it was indicated that Wet Terraced fields were classified as a male domain while homegardens were considered as female domain by the three ethnic groups among the Lepchas, however among the Nagas swidden areas are a female domain (FAO, 1998). Women's particular responsibility for the management of home gardens has been extensively documented in other parts of the world (Boncodin & Vega, 1999). It has been observed that in the hill and mountain regions of Nepal, women play an important role in the management as well as benefit sharing from home gardens, due to their responsibility in ensuring household food security. The gender role, however, also depend on the ethnic and cultural background as in the terai community where men have been found to play an equally important role in the management and introduction of new diversity in the home gardens (Subedi, *et al.*, 2003). However, in depth understanding of the importance and influence of gender to the management of home gardens is lacking. Another objective of the CBD is to ensure the “fair and equitable sharing of the benefits” from the use of biological diversity (CBD, 1992). This cannot be
addressed at all without considering the importance of women and gender relations in biodiversity management at the local level, and the presence of gender inequalities and gender bias in local, regional, national, and international systems that develop norms and regulations around biodiversity conservation. There is still often a failure to even acknowledge the importance of women or gender relations in the literature and in policy documents dealing with biodiversity conservation; even where acknowledgement is made, such as in the Convention on Biodiversity, it is recognised that "much more still needs to be done in relation to increasing the participation of women in the work of the Convention" (UNEP, 2000).

**Growth of trees**

Growth forms an important component for sustainable utilization tree products. Studies on tree growth as such are very limited (Gourlet-Fleury & Houllier, 2000; Alder *et al.*, 2002). It is important to mention that diameter increment of a given tree varies considerably over its life span due to competitive, biotic and geometric factors. There is a general tendency for mean growth rate to increase with a typical species size (Alder *et al.*, 2002). There is less information on the growth of trees in agroforestry systems (Lott *et al.*, 2000; Yamada & Gholz, 2002). Richards (1959) discussed the application of growth functions viz. monomolecular, logistic, gompertz, von Bertalanffy’s extended form etc. for plant data. The use of sigmoidal growth models viz. logistic, gompertz etc. has been discussed by Gore and Paranjpe (2002) for describing the growth of single species population. Non-linear statistical models were used to describe the growth of *Melocanna baccifera*, a fast growing bamboo species in Barak Valley, Assam. The
estimated model parameters were treated as a summary of the growth pattern (Das et. al., 2006).