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# MULTISTORIED AGROFORESTRY: AN ALTERNATIVE AVENUES FOR MAXIMIZATION OF AGRICULTURAL LAND USES

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## ABSTRACT

The population of the world is increasing rapidly and the rate of increase is very high in developing countries like Bangladesh. Bangladesh only 8.16 million hectares of arable land is one of the most densely populated countries of the world struggling hard to feed her more than 140 million people. Population has become doubled in the last 30 years and population density is now 860 persons per square kilometer (BBS, 2008). The arable land is shrinking @ 86000 ha every year. The current food deficit of around 2 million tons is likely to be increased further with decreasing land: man ratio. It is said that, a country needs 25% of forest land of its total area for ecological stability and sustainability. Unfortunately, Bangladesh is endowed with only 13.6% of unevenly distributed forests. Substantial depletion of forest resources has occurred in the last few decades, and now it is reduced to less than 0.02 ha person$^{-1}$, which is the one of the lowest ratios in the world. So to combat this alarming situation, it is urgently necessary to think about a joint production system that could be needed for population-food-nutrition balance, to fulfill the demand of fuel wood and timber, and finally conserve biodiversity. Multistoried agroforestry system may fulfill those purposes. Multistoried agroforestry system combines several (2-5) vertical strata with high species diversity. However, multistoried agroforestry system is more complicated than monocropping of trees or annual crops. So, multistoried agroforestry systems require careful planning. Planning helps to avoid problems, minimize risks, and maximize benefits in crop combinations. The need of each crop to be planted should be fully understood, as well as the effect of each species on the other species in the system. This paper introduces key planning issues that should be considered include species selection, spacing, scheduling, and management of multistoried agroforestry systems.

**Key words:** *Agricultural land, land uses, multistoried, agroforestry systems, trees.*

## INTRODUCTION

The arable land is reducing rapidly across the world due to high population growth and establishment of new industries, houses and other infrastructures. In Bangladesh perspective, the situation is very worse, where arable land is shrinking @ 86000 ha every year (BBS, 2008). Bangladesh has only 8.16 million hectares of arable land is one of the most densely populated countries of the world struggling hard to feed her more than 140 million people. The current food deficit is likely to be increased further with decreasing land: man ratio. Again, the fruit consumption in the country is only 35 g day$^{-1}$ capita$^{-1}$, which is far behind the necessity of 85 g. Incase of vegetables, per head utilization is 80 g that is also at the back of 200 g day$^{-1}$. Moreover, most of the people of our country can not afford to buy even average requirements of vegetables or fruits due to its unavailability and high price. Socio-economic, the consequence of this event is, therefore, widespread malnutrition throughout the country. Again, forestry plays an important role in maintaining environmental equilibrium and socio-economic development of the people. It is said that, a country needs 25% of forest land of its total area for ecological stability and sustainability. Unfortunately, Bangladesh is endowed with only 13.6% of unevenly distributed forests (BBS.2008). Due to rapid growth of population there is a tremendous pressure on the forest

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lands. About 7300 ha of forest land has been lost due to transformation to agricultural land, aquaculture, homesteads and other purposes. Substantial depletion of forest resources has occurred in the last few decades, and now it is reduced to less than 0.02 ha person$^{-1}$, which is the one of the lowest ratios in the world (BBS, 2008). Under these alarming situations, agricultural

production as well as forest resources must be increased by using modern or new techniques. Multistoried agroforestry system is one of them. Incorporation of fruits, vegetables, spices and some medicinal plants in multistoried agroforestry system can be an effective and compatible element in Agroforestry system. There are about 20.0 million homesteads in the country which comprises about 0.3 million hectares of lands and most of the vegetables produced and consumed in the country are coming from these homesteads (BBS, 2008). These areas are also increasing due to construction of new houses for the ever increasing population. Traditionally farmers grow different types of crops in association with trees in their homesteads, where productivity of crops is low due to inadequate knowledge about the appropriate combinations and management techniques. From time immemorial, a large number of diversified tree species are grown in the homesteads and recently many exotic species are included. Besides homesteads and adjacent land, one-eighth of the land surface area of Bangladesh consists of hills and valleys that also offer potentials for year round fruits, vegetable and forest trees production under Multistoried Agroforestry systems. But farmers used to face the problems of growing crops after 4-5 years of tree plantations and even some times failed to grow under stored crops under and around these. In Agroforestry systems, the basic growth resources viz. light, water and nutrient become the determinative factor for inevitable competition for the crops species grown in association of trees, resulting marked depletion in the productivity of under storied crops.

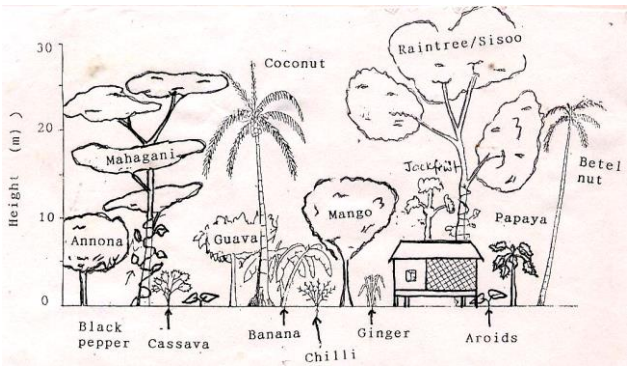


Figure 1. Schematic model of multi-storied system in homestead

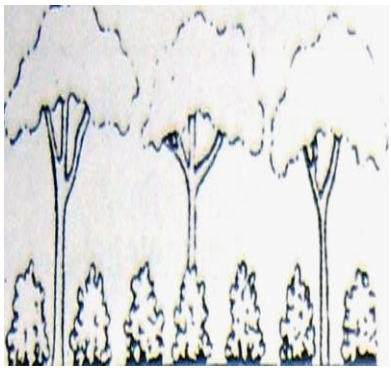

Figure 2. Tree crops with single understory crop

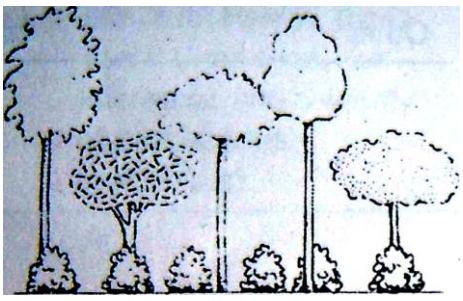

Figure 3. Multiple tree crops with understory crop

Figure 4. Multi-species, multistoried system understory crop

There are many kinds of multistoried production systems. They range from simple systems consisting of one species on the overstory and one in the understory (Fig. 2), to complex systems with many layers of trees, shrubs, and herbaceous plants stacked together (Fig. 3 and 4) (Staver, 1999).

However, for identifying the compatible tree crop combinations, particularly under storey species i.e., different crops should be screened out in terms of their adaptability and yield under different shade levels created by the upper storey tree species. For practitioners, researching potential multistoried crops, especially shade-tolerant trees, shrubs, and vines used as under story crops should be known. Some planning issues such as spacing, scheduling, crop selection, their management should be understood. For this purpose, the paper deals on these issues related to multistoried agroforestry systems in view of proper utilization of homesteads, hilly areas or other shady places and to increase the production of fruits, vegetables, spices and timber trees.

**What are multistoried agroforestry systems?**

Multistoried agroforestry systems are characterized by high species diversity and usually 2-5 vertical canopy strata, thus indicating the intimacy of plant associations. Schematic presentations of canopy configurations of multistoried agroforestry systems models have been presented in

**Why do farmers practice multistoried agroforestry systems?**

Some farmers prefer not to devote their resources entirely to a single, long-term tree crop such an orchard or timber stand. Instead, they diversify their planting, utilizing the area between the tree crops to cultivate under story crops. Some benefits of multistoried agroforestry systems may include:

A. maximizing use of agricultural land and light with multiple crops and hence more biological production;
B. diversified agriculture products, such as, vegetables, fruits, spices, fodder, forage, fuel-wood, medicinal plants and timber can be obtained from different layers of the same piece of land at a time; more constant source of income and less capital investment;
C. protection from heavy loss in a given time period caused by failure in one component, due to success with other components;
D. effective utilization of laborers; including participation of different family members at different times, and
E. mutual biological benefits gained from interactions among different vertical strata.

Moreover, in multistoried agroforestry system, the trees in different layers harvest sunlight at different canopy strata and they also harvest soil nutrient from different soil layers by different root strata. Environmental protection also results from multistoried plant configuration, although it is often an effect of the multistoried home garden system and seldom a motivation for adopting the practices. Furthermore, adequate production of fruits and vegetables under trees will help serve nutritional needs to the poor people.

**Scope of multistoried agroforestry systems in Bangladesh**

There is golden opportunity for multistoried agroforestry in Bangladesh. In Bangladesh at present there are about 20 million homesteads, where multistoried systems could be applied. Fruit specially mango and litchi orchard in northwest part of Bangladesh could be brought under this system which will provide continuous cash flow. Jackfruit orchard in the Madhupur, Gazipur areas of Bangladesh and in the forest plantation of Chittagong Hill Tracts, Sylhet where banana, pineapple, cassava, aroids could be grown.

**Some promising multistoried agroforestry models for Bangladesh condition**

The experimental multistoried agroforestry system at the Horticulture farm of the Bangladesh Agricultural University produced a good indication of multistoried agroforestry systems in three layered canopy configuration. Recently the department has demonstrated the beneficial effects of three multistoried agroforestry models like coconut based, mango based and sissoo based multistoried agroforestry system, in terms of return per unit area (Fig . 6, 7 & 8).

**Coconut based multistoried agroforestry system**

It is a three layered garden (Fig. 5) consisted of coconut at the top layer, guava and lemon at the middle layer; and the vegetables, spices and the medicinal plants are at the ground layer. Coconut + guava based multistoried agroforestry system and coconut + lemon based multistoried agroforestry system allowed, respectively 42 to 46% and 53 to 58% sunlight for the growth of vegetables, spices and medicinal plants (Bari, 2009). The upper layer occupied by coconut was thirty years old and the spacing of plantation was 8m x 8m. As the middle or second layer plant, guava and lemon both were five years old and were in full bearing condition. Spacing between guava and / or lemon and between rows was 3m × 3m. This system is economically viable.

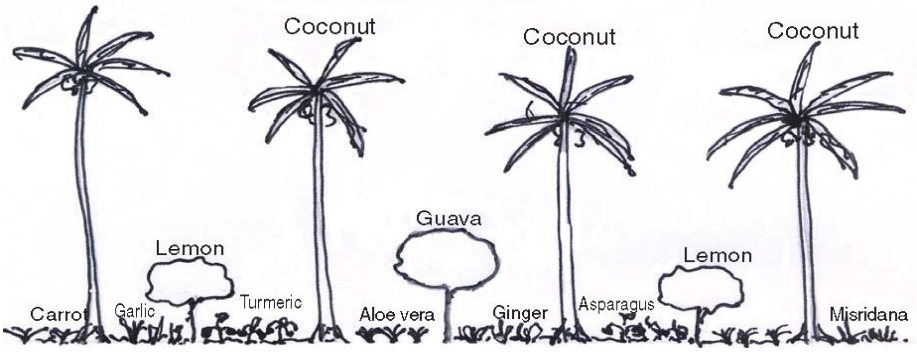


Figure 5. Schematic presentation of Coconut based multistoried agroforestry system

**Mango based multistoried agroforestry system**

It is also a three layered garden (Fig. 6) consisted of mango at the top layer, guava at the middle layer; and the vegetable, spices and the medicinal plants were at the ground layer. Mango+guava based multistoried agroforestry system allowed 19 to 23% sunlight for the growth of vegetables, spices and medicinal plants (Bari, 2009) . The upper layer occupied by mango tree was thirty two years old and the spacing of plantation was 8m x 8m. As the middle or second layer plant, guava was five years old and was in full bearing condition. Spacing of guava plantation was 3m × 3m. These three storied system have also given positive economic return per unit area.

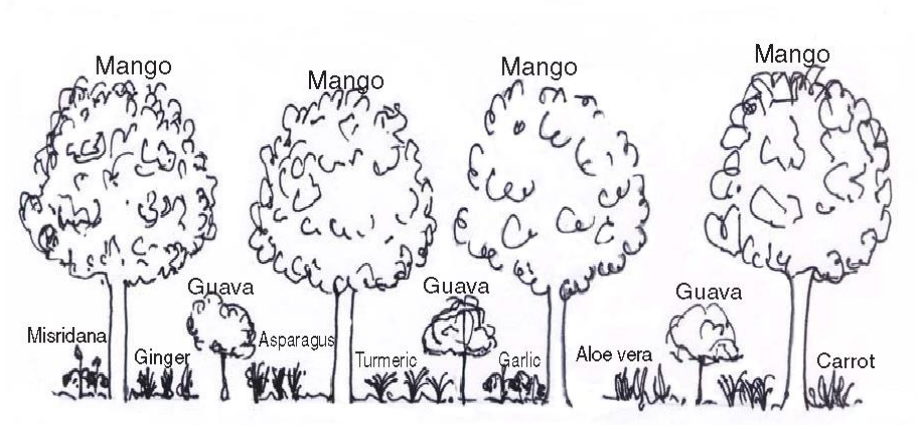


Figure 6. Schematic presentation of Mango based multistoried agroforestry system

**Sissoo based multistoried agroforestry system**

It was also a three layered garden (Fig. 7) consisted of sissoo at the top layer, guava and lemon at the middle layer; and the vegetables, spices and the medicinal plants are at the ground layer. Sissoo+ guava based agroforestry system and sissoo +lemon based agroforestry system allowed, respectively 49 to 54% and 63 to 69% sunlight for the growth of vegetables, spices and medicinal plants (Bari, 2009). The upper layer occupied by sissoo, a good multipurpose and deciduous tree. The age of sissoo tree was eight years and the spacing of plantation was 6m x 6m. As the middle or second layer plant, guava and lemon both were five years old and were in full bearing condition. Spacing between guava and / or lemon and between rows was 3m × 3m. It was interesting to note

that the economic analyses showed total net return of the multistoried agroforestry systems becomes higher than that of the monocropping of vegetables, spices and medicinal plants. So, integration of vegetables, spices and medicinal plants as ground layer crops in mango based multistoried agroforestry system is clearly preferred agroforestry system.

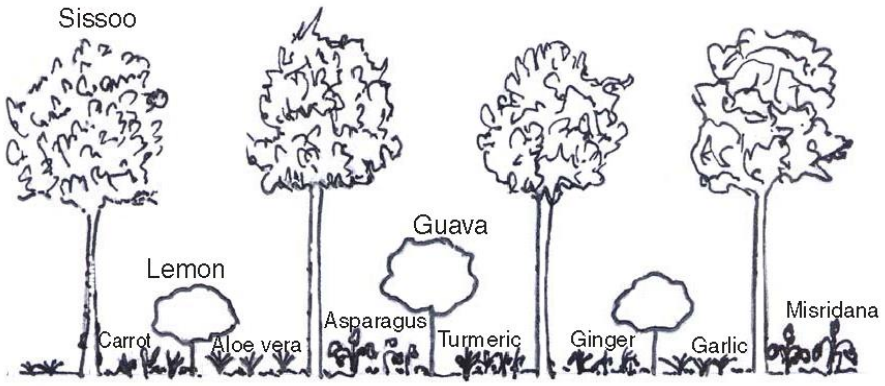


Figure 7. Schematic presentation of Sissoo based multistoried agroforestry system

**Some planning issues**

For practicing multistoried agroforestry systems require careful planning. The needs of the species to be planted should be well understood, as well as the effect of each species on the other species in the system. Careful planning helps to avoid problems, minimize risks, and maximize returns from crop combinations. Key issues in planning multistoried agroforestry systems are briefly mentioned below-

**Upper strata species selection-** The trees that make up upper strata play the key role in creating the ground story environment. When planning a multistoried agroforestry system, the upperstory trees are a crucial element. The most influential factors are tree canopy shape, canopy foliage type, and tree spacing. The trees which have narrow and columnar form/shape of canopies are suitable for multistoried agroforestry systems. In some cases other types of tree canopy may be considered by proper pruning management. Some type of tree foliage create dappled sunlight or light shade; others create a thick canopy dense, heavy shade beneath. Although groundstory crops can tolerate some degree of shade, some light must be available in order for the crops to be productive. The type of foliage should be considered along with canopy shape/tree form, to determine the spacing needed to create an optimal groundstory environment for the crop. The spacing of the upperstory trees is also important in creating the groundstory environment. Compared to single-species monoculture of timber or fruit trees, multistoried agroforestry systems normally involve a reduced number of trees per unit land. The number of trees in multistoried agroforestry systems per unit land is usually 25-50% less than the monoculture of forestry or orchard trees. The species growth rate, form, rooting patterns, and other factors should be taken into account when planning multistoried agroforestry systems to provide the most favorable environment for the groundstory crops as well as to minimize competition for water, light, and nutrients.

**Groundstory crop selection-** In planning to practice the multistoried agroforestry systems, groundstory crops selection is a very important consideration. When selecting species, growth and rooting habits should be understood so plants are compatible and not overly competitive. Groundstory crops should be integrated in ways that maximize light, space and nutrients. According to Wadsworth (1997) in case of multistoried agroforestry systems, groundstory crops should

- tolerate partial shaded
- exploit, at least partially, different soil horizons than the upperstory trees
- be shorter than the upperstory trees when mature
- be less susceptible than the upperstory trees to diseases they may have in common, and
- not involve damage to the upperstory trees during cultivation or harvest groundstory crops

**Microclimatic effects-** As the upperstory trees mature, the groundstory environment will become shadier, cooler, and more humid. One of important considerations in planning for multistoried agroforestry system is the rate at which the groundstory environment changes. The challenge is to predict when the optimum environmental conditions will occur and how long they will last (Arakaki, 2000).The duration of favorable environmental conditions influences expectations of optimum output from groundstory crops. The rate of change should be taken into account for selection and spacing of upperstory and groundstory crops. Determining the time frame for optimum environmental conditions also affects the groundstory planning schedule. For example, if groundstory crops thrives in shade but cannot tolerate full sun, then they should not be planted until the upperstory trees have grown enough to provide sufficient shade. As upperstory trees continue to mature, the groundstory conditions can be maintained by pruning and thinning the upperstory trees. Determining the net benefits of maintaining a set environmental condition by pruning and thinning will help in decision making (Arakaki, 2000).

**Major constraints and possible solutions of multistoried agroforestry systems:**

There are some limitations of multistoried agroforestry systems. This are-

- Shortage of scientific study and information about tree/groundstory crop interactions.
- Lack of economic data about the trade-offs of mixed cropping systems.
- Risk for unpredicted competition or allelopathic effects.
- Greater complexity in management of multiple species and multiple products.
- Potential damage to upperstory from harvest of the groundstory, or vice-versa.
- Increased challenges of marketing diversified products.

With adequate research and good planning, many of these limitations can be overcome to effectively integrate groundstory crops with tree crops.

**Extent of multistoried agroforestry systems to farmer level adoption:** To ensure more effective and efficient transfer of the multistoried agroforestry systems technology to the farmers, the following parameters merit should be considered-

- Consultation with the local Government so that the multistoried agroforestry systems is in line with the Government agricultural extension program.
- The farmer chosen as nucleus should not only own the land but also till his own land and willing to convert his land from monocropping into multistoried agroforestry systems.
- The land chosen as demonstration plot should be currently used for monocropping of fruit or forest trees rather than the fallow lands. The nucleus farmers should be given training course stepwise on the multistoried agroforestry systems; each step followed with demonstration by the team to show what to do and then ask the farmers to do themselves to complete the work.
- All the family members should be encouraged to participate in the multistoried agroforestry systems to develop sense of belonging, so that when the head of the family attending social function, the other member of the family will take the responsibility of the multistoried agroforestry systems activity.
- The farmers participate in the demo plot should be chosen from the existing farmer groups, or to from a new one, if no farmer group is exist.
- Meeting between the team and the farmers should be carried out regularly to discuss various matters that have arisen and to seek solution that are to beneficial to the farmers.
- The participating farmers should be given incentive in the form of saplings, seeds, fertilizers and manures and shared half of the income from selling of the multistoried products.
- Local custom and tradition should be observed to avoid inconveniences to the farmers and the surroundings.
- Appoint contact person to bridge the gap between the farmers and the team.
- Each team should bear in mind that its presence is to solve the farmer's problems rather than to solve the team problem; the farmer has the knowledge and the team has the science; the team belong to the farmers in stead of the farmers belong to the team.

- The team should ask the GO and NGO to visit the multistoried agroforestry systems and meet the farmers, so that the GO and NGO will help to spread the idea of multistoried agroforestry systems.
- Whenever appropriate, mass media (newspaper, radio, TV reporters) are also invited to make documentation and report about the farmer activities through their particular mass media.

## CONCLUSIONS

To maximize the uses of agricultural land as well as to get fruits, fuel wood, timber, various agricultural products and, to bring back equilibrium in the ecosystem, agricultural conservation, establishment of multistoried agroforestry systems in the homesteads and/or orchard, is inevitable. The development model should be applied in the orchards of mango/litchi (in North-west region) and jackfruit in Eastern region and forest plantation in forest areas of Bangladesh. These multistoried agroforestry systems may also be introduced in the high and medium high land of the northern part of Bangladesh.

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