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Review

Fruit-based agroforestry systems for food security and higher profitability

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ABSTRACT

The fruit-based agroforestry system comprises of a combination of perennial (fruit trees) and annual plant species as different components in the same piece of land arranged in a geometry that facilitates maximum utilization of space in four dimensions (length, width, height and depth) leading to maximum economic productivity of the system. This agroforestry system contributes products as well as services some of which have economic potential as cash crops and are also highly adaptable and applicable to a wide area and range of physical and social conditions worldwide. Because of the relatively short juvenile (pre-production) phase of fruit trees, fruits have high market value of their products and the contribution of fruits to household dietary and nutrition hence this system enjoys high popularity among resource limited producers worldwide and provides the subsistence to farmers and appreciable amount of economic returns even under unfavourable agro-ecological situations. This system has diverse products (fruits, vegetables, spices etc) which are available year-round in systems like home gardens and not only contribute to food security during the lean seasons but also ensure food diversity.

Keywords: Agroforestry; productivity; spatial arrangement; agri-silviculture; home garden

INTRODUCTION

Fruit tree-based agroforestry involves intentional simultaneous association of annual or perennial crops with perennial fruit producing trees on the same farm unit. Because of the relatively short juvenile (pre-production) phase of fruit trees, high market value of their products and the contribution of fruits to household dietary

needs, fruit tree-based agroforestry enjoys high popularity among resource limited producers worldwide (Bellow 2004). Most examples of fruit tree-based agroforestry systems have developed over long periods of time in response to interactions between agro-ecological conditions, plant diversity and farmer resources and needs. Because of this the system performance at any given location will depend to a great extent on several site specific features. Nevertheless the system performance also follows some general characteristics such as their potential benefits and limitations that are applicable over wider regions. An understanding of such general characteristics of these systems is helpful for adaptation and extension of the system to other highland areas with similar production environments.

Fruit-based agroforestry system can be defined as a planting system comprising combinations of plants with various morpho-phenological features to maximize the natural resource use efficiency and enhanced total factor productivity (Dhakar et al 2013). The system comprises a combination of perennial and annual plant species as different components in the same piece of land arranged in a geometry that facilitates maximum utilization of space in four dimensions (length, width, height and depth) leading to maximum economic productivity of the system. Fruit trees yield valuable bye-products like fodder, fuel wood etc through their annual prunings and fruits which are supposed to improve and maintain good health of human beings.

Agri-horticulture system or horti-pastoral system is one form of agroforestry where the tree component is a fruit tree. Agroforestry is a collective term for systems of land use in which woody plants (trees and shrubs) are deliberately combined on the same land management unit with herbaceous crops in some form of spatial arrangement. The fruit-based system can be placed in a broader agroforestry classification structure described by Nair (1990) and is generally described as an agri-silviculture production oriented system used on sloping lands in a highland moist tropical ecological zone. The fruit-based system is not uniform but rather is made up of many different practices or subsystems. An important step in understanding the spread and possible impacts of the fruit-based cropping system is to classify and describe the subsystems in use.

Fruit-based agroforestry for food security

This system has diverse products (fruits, vegetables, spices etc) which are available year round in systems such as home gardens and not only contribute to food security during the lean seasons but also ensure food diversity (Kumar and Nair 2004). It is a source of mineral nutrients for improving household nutritional security especially for at-risk populations (eg women and children). Because of the relatively short juvenile (pre-production) phase of fruit trees, fruits have high market value of their products and the contribution of fruits to household dietary and nutrition

hence this system enjoys high popularity among resource limited producers worldwide (Bellow 2004)

In Kenya fruit trees are intercropped with all types of short term crops such as beans, peas, potatoes, maize, millet, exotic and indigenous vegetables when they are still young as a way of attaining food security and income before the trees mature (Ouma and Jeruto 2010). Most crops can now be intercropped including fruit trees and therefore farmers with small pieces of land should no longer worry. From the perspective of wildlife management, fruits have many advantages as food source compared to many other food sources. Fruits are easy to find and capture and are high in energy such as sugars and/or lipids (Snow 1971, Morton 1973, Stiles 1980, Stiles 1993, Borowicz and Stephenson 1985, Johnson et al 1985, Willson 1986, Borowicz 1988, White 1989, Bairlein 1990). In addition many fruits are available during autumn and winter when energy demand of wildlife is high and other food sources such as insects are generally less abundant (Morton 1973, Thompson and Willson 1979). In fruit-based agroforestry, Jackfruit trees not only provide suitable ecology for the under-storey crops but also produce other basic requirements of the growers such as food, fodder, fuel-wood and timber. The average annual net returns of the traditional agri-silvicultural practices were found much higher than the agriculture (Abedin and Quddus 1991)

Biodiversity in eastern Madagascar is threatened by slash and burn agriculture which is resulting in species extinction, land and soil degradation and rural impoverishment. Athno-botanical study was undertaken to determine the domestication potential of indigenous fruit tree species as components of agroforestry systems. Four major selection criteria were used: nutritional and income needs of the population, diversification of the agro-ecosystem and protection of plant and animal diversity. At three sites Andasibe, Masoala and Ranomafana, in the humid primary forest region of eastern Madagascar a total of 150 wild fruit species from 82 genera and 42 families of which 85 per cent were indigenous and 92 per cent of woody habit were identified. In contrast to most of the deforested areas in Madagascar the rural population in these areas possesses an intimate knowledge of indigenous plant resources. Most of the indigenous fruits are collected from the forest but for a few species domestication is initiated by managing naturally established species or by planting individual trees in agricultural fields. Wild fruits supplement the daily diet, substitute for exotic fruits, gain importance during periods of food shortage and are most appreciated by children. Commercialization of wild fruits is mainly undertaken by the poorer sections of the population. Gender related differences in knowledge and preferences on species were identified and related to the respective household responsibilities. A list of the 26

priority species was established based on the preferences of children, women and men at the three sites. Local, fruit-eating lemur species are also highly dependent on indigenous fruit trees and are crucial for successful regeneration of forest vegetation (Styger et al 1999)

Fruit-based agroforestry systems for higher profitability

Agroforestry system contributes products as well as services some of which have economic potential as a cash crop and is also highly adaptable and applicable to a wide area and range of physical and social conditions worldwide (Nair 1984). In the highlands of northern Thailand 62.4 per cent of fruit tree plantings were actively intercropped with annual crops (Withrow -Robinson et al 1999). In Bhopal region of central India fruit tree-based systems were found to have higher benefit:cost ratio (ie 2.7) than agroforestry-based on non-fruit trees (ie 1.8). When cash crop systems were assessed fruit tree-based agroforestry had B:C ratios of 2.9 versus 1.8 for timber and cash crops (Bellow 2004). Fruit tree-based agroforestry systems in the north temperate zone are able to provide the public environmental services better than monoculture annuals or intensively managed orchards. Apple accounts for 60 per cent of the temperate region's fruit production. It is the world's second largest fruit crop, after oranges (Dhakar et al 2013). Jackfruit, a multipurpose tree species is of great importance for its fruit, timber, fodder and fuel wood. It is the national fruit of Bangladesh which is consumed by all classes of rural people; it is native to the country (Rashid et al 1987). Competition for nutrients and moisture has been identified as potential limitation in some tropical agroforestry systems (Ong et al 1991) but has not been reported in subtropical highlands or fruit tree-based systems. An important step in understanding the spread and possible impacts of the fruit-based cropping system is to classify and describe the subsystems in use. To ensure high returns from the underutilized and stressed lands and improve the soil characteristics, perennial fruit plant-based production systems have been found successful under semi-arid and dry land conditions (Roche 1987).

Agroforestry system not only assures diversification but also provides higher economic returns in comparison to monocropping. Agri-hort-silvicultiure system comprising of peach (*Prunus persica*) and *Morus alba* with wheat-soybean and lentil-blackgram cropping sequences can be better option for higher monetary benefits than agri-sliviculture system integrating wheat-soybean with *Grewia optiva* (Thakur 2003). The two medicinal plants *Andrographis paniculata* and *Stevia rebaundiana* thrive well under plum-based agroforestry system. Growth, yield and physiological attributes of medicinal plants were positively affected by application of different doses of organic

manures. Kumar (2011) suggested that growing of *S rebaundiana* under plum-based agroforestry system is economically more profitable. The financial returns of the apple-based agroforestry system in Kullu district of Himachal Pradesh with the integration of different annual crops viz pea, tomato and bean were highest from intercropping apple with tomato which had total benefit from both components amounting to Rs 1577489.08/ha followed by apple + pea intercropping and apple + bean association with total net benefit from both the components of Rs 1330199 and 1170583/ha respectively. Increase in net benefit from the system was 1.5, 1.27 and 1.12 times higher with apple + tomato, apple + pea and apple + bean respectively over the net benefit from apple alone.

Palsaniya et al (2012) reported that tree height, collar diameter and canopy spread were slightly higher in L-49 followed by Lalit, Allahabad Safeda and Sweta. In general the growth attributes were marginally higher in L-49 and minimum in Sweta. The height of L-49 (265 cm) was 12.8, 17.3 and 28 per cent higher than Lalit, Allahabad Safeda and Sweta respectively. Similarly the canopy spread of L-49 was 18.7, 23.3 and 30 per cent higher than Lalit, Allahabad Safeda and Sweta respectively. The collar diameter was maximum in L-49 (6.6 cm) and minimum in Sweta. The fruit yield kg/tree as well as kg/ha was higher in Allahabad Safeda followed by L-49, Lalit and Sweta. Allahabad Safeda produced 1170 kg fruits/ha at five year age which was higher by 8, 20.6 and 21 per cent over L-49, Lalit and Sweta respectively. Since same crop was raised in all the guava varieties with uniform package of practices therefore there was no impact of crop on growth of guava varieties. The present variability in growth and yield may be attributed to inherent genetic variability in these varieties. Allahabad Safeda was more suitable and economical followed by Sweta for agri-horticulture system in the region of Jhansi, UP.

The fruit yield of mango was significantly improved by intercrop combinations as compared to sole mango tree. The fruit yield ranged between 1.89 and 5.31 tons/ha with cowpea–Toria, 1.26 and 12.50 tons/ha with sesame–Toria, 1.75 and 14.58 tons/ha with pigeon pea, 1.63 and 14.94 tons/ha with black gram–Toria, 1.15 and 13.79 tons/ha with okra–Toria and 1.02 and 13.97 tons/ha in sole mango respectively during 1999-2005. The mean fruit yields were harvested 7.02, 6.26, 6.50, 6.59, 6.02 and 5.76 tons/ha with cowpea–Toria, sesame–toria, pigeon pea, black gram–Toria, and okra–Toria and sole mango tree respectively during first phase (1999-2005). In the second phase of the study the data on mango fruit yield revealed that mean maximum fruit yield (13.71 tons/ha) was obtained in the turmeric block while in colocasia block mean maximum yield was higher (13.00 tons/ha) compared to sole mango tree (11.86 tons/ha). Mango

fruit yield during 2006-2010 ranged from 4.75 to 18.44 tons/ha in association with turmeric followed by 3.90-17.53 tons/ha with colocasia. In control the mean fruit yield was 3.21-15.65 tons/ha. Fruit yield of mango increased with increasing age of the tree but occurrence of frost (sub-zero temperature) in the month of January 2003, 2008 and 2010 when minimum temperature was recorded as low as -1.0, -3.8 and -1.0°C respectively had reduced the fruit yield by 57.4 to 74.9 per cent over mean of 7 years of fruiting (1999-2005) among all agri-horticultural models during first phase whereas 65.5-72.9 per cent and 10.4–16.2 per cent as compared to mean of 5 years (2006-2010) in 2008 and 2010 during second phase respectively. The study was conducted at Central Soil and Water Conservation Research and Training Institute, Research Farm, Selakui, Dehradun, Uttarakhand, India from 1995 to 2010 under the subtropical foothill zone of the northwestern Himalaya (Rathore et al 2013).

Under sapota/mango-teak-based agroforestry system for peninsular India, a multi-component agroforestry system with sapota as the base crop, teak in the sapota line and agricultural crop in the interspace was developed for high rainfall areas having irrigation facilities. Demonstrations were initiated during 1996 in two farmers' fields at village Kyarakoppa, district Dharwad. Sapota was planted at a recommended spacing of 10 × 10 m in rows across the slope. Three teak plants were planted at a distance of 3 x 2 x 2 x 3 m in between two sapota trees. Field crops viz horse gram, Jowar and Bajra were grown in the interspaces of sapota + teak alleys. Sapota crop served as an insurance against failure of field crops. The same technology was adopted by another farmer with a modification ie sapota being replaced by mango. Fruit bearing in sapota and mango started from the seventh and eighth year respectively. Presently the sapota is yielding 30 to 40 kg/plant which fetches Rs 22000 to 25000/ha. The fruit yield from mango is 30-50 kg/plant that fetches Rs 36000 to 60000/ha. Income generated from field crops in both the cases is about Rs 2500 to 3500/ha.

Value estimation of teak reveals that each teak pole costs about Rs 120. With age the crown size of perennial component (sapota/mango and teak) increased and consequently of field crops were not in cultivation from 2007 onwards. The system generated employment to an extent of 180 mandays per year. Socio-economic status of the farmers improved as farmer is earning on an average of Rs 23500/ha/year with sapota and Rs 48000/ha/year with mango-based system as against Rs 3000/ha/year only during initial period from the same land (Anon 2012).

In Manipuri valley, agri-silvi-horti agroforestry system is highly remunerative and preferred by the farmers. Among the tribal farmers crops like paddy, mustard, sugarcane, soybean, beans, vegetables

Table 1. Agro-climatic regions/zones in India with preferred fruit trees

Agro-climatic region/zone	States	Fruit trees preferred
Western Himalayan region	Himachal Pradesh, Jammu & Kashmir, Uttarakhand	Apple, cherry, strawberry, peach, plum, kiwi, apricot, almond, walnut
Eastern Himalayan region	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, West Bengal	Orange, lemon, banana, Kagzi lime, pineapple, papaya, cherry
Lower Gangetic plain region	West Bengal	Litchi, mango, guava
Middle Gangetic plain region	Uttar Pradesh, Bihar	Litchi, papaya, mango, guava and Jamun
Upper Gangetic plain region	Uttar Pradesh	Mango, papaya, guava, peach, Jamun, aonla
Trans-Gangetic plain region	Delhi, Haryana, Punjab, Rajasthan	Kinnow, guava, aonla, mango
Eastern plateau and hills region	Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Orissa, West Bengal	Mandarin, mango, guava, Aonla, lac, lemon, pomegranate, custard apple,papaya
Central plateau and hill region	Madhya Pradesh, Rajasthan, Uttar Pradesh	Aonla, ber, mango, mandarin
Western plateau and hill region	Madhya Pradesh, Maharashtra	Mandarin, lemon, Malta, pomegranate, papaya, banana, grapes, mango
Southern plateau and hill region	Andhra Pradesh, Karnataka, Tamil Nadu	Mango, banana, grapes, guava, sapota, citrus
East coast plains and hill region	Andhra Pradesh, Orissa, Pondicherry, Tamil Nadu	Cashew nut, mango, sapota, banana, custard apple, pineapple
West coast plains and Ghat region	Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu	Cashew nut, mango, citrus
Gujarat plains and hill region	Gujarat, Dadra & Nagar Haveli, Daman & Diu	Sapota, banana, guava, dates, mango, grapes
Western dry region	Rajasthan	Ber, pomegranate, kinnow, Mausambi
Island region	Andman & Nicobar Islands	Papaya, mango, sapota.

Source: Final Report, Working Group on Agro-Climatic Zonal Planning including Agriculture Development in northeastern India for XI Five Year Plan (2007-12)

(mainly pumpkin or potato), walnut, cherry, banana, guava, etc are grown. In this region forest tree species are grown to produce wood and leaves for fodder in combination with high income horticultural crops like pineapple. In a study at Langoi Hill, Lamphelpat pineapple was grown with *Eucalyptus tetricornis*, *E citridora*, *Leucaena leucocephala* and *Parkia roxburghii*. This study shows that the trees

do not have any shade effect on the yield of pineapple. Pineapple with *P roxburghii* agroforestry system gave the highest yield of pineapple (Anon 1990).

Agri-horti systems can be used to improve economic condition of the farmers. In the northeast region, peach-based agri-horti systems were evaluated on class II lands. Both annual and companion crops were grown. The net returns doubled when turmeric was grown with peach. Mixed cropping is preferred over pure crops in rainfed condition as risk of failure of crop is minimized. If annual crop fails, tree crop can provide some income. In Sikkim among the tree species grown with large cardamom, *Alnus napalensis* is the predominant. This shade tree is important as it also serves as a major source of fuel, fodder and timber to the farming communities. From tree cardamom combination about 140 kg dry capsule yield of the spice alone can be obtained which gives high returns with minimum inputs.

Mandarin, *Citrus reticulata* is another commercial fruit crop in Sikkim. Mandarin orchards are intensively intercropped with many species of cereal, pulse and vegetable crops. Ginger is the most remunerative intercrop in Sikkim. Singh and Pradhan (1989) observed that various intercrops with mandarin can yield 609 kg/ha (ginger), 149 kg/ha (black gram and rice bean) which fetches higher returns then sole cropping alone.

Locations having comparatively better soil conditions and facilities of supplemental irrigation, litchi-based models with guava as filler crop can be grown with intercropping of French bean and cowpea during initial eight years. At locations having no supplemental irrigation with sloppy land, mango + Gamhar (*Gmelina arborea)* + *Stylosanthes hamata* (Gass) model will be more effective. On the highest part of watersheds having gravelly land or coarse soil formations, aonla-based system can be most effective (Dhakar et al 2013)

CONCLUSION

Fruit-based agroforestry is a source of mineral nutrients for improving household nutritional security. It is a very good option for minimization of crop failure risk at a farm due to anomaly of weather. It yields valuable bi-products like fodder and fuelwood through annual pruning apart from fruits. It is a self-sustainable system where solar energy can be harvested at different heights, soil resources can be efficiently used and cropping intensity is increased. Fruit-based multitier cropping systems were found to be effective alternatives to the traditional monocropping system for increasing the profitability under rainfed as well as irrigated upland conditions of the eastern plateau and hill region. This also provides the subsistence to farmers and appreciable amount of economic return even under unfavourable agro-ecological situations.

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