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Invited Review Article

Development of fruit tree based agroforestry systems for degraded lands – a review

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Abstract

Fruit crops are major components of various agroforestry systems (AFS) recommended for degraded lands. Many fruit trees are highly suitable for AFS under varied agroclimatic conditions. Early workers recognized the importance of fruit trees in popularizing fodder production systems among farmers. Initial roles of fruits crops in various AFS were subsidiary because main function of these systems was to enhance fodder production. However, fruits proved to be the primary product for farmers. The first and foremost activity to establish fruit trees in AFS was to identify suitable species. The main basis of species selection is to follow the fruit trees being grown by farmers. Bushes like jharber *(Ziziphus nummularia)* and caronda *(Carissa carandas)* are more suitable for cultivation in the natural/sown pasture of anjan (*Cenchrus ciliaris)* in Bundelkhand region where soil is sandy loam, shallow and underlain by murram layer. Tree species like ber *(Z. mauritiana), jharber*, etc. can be used for lopping fodder in the tropics. The criteria for MPTS selection may be summarized in the following five steps: (i) Suitability to local edaphic and agroclimatic conditions, (ii) Potential for tree management practices, (iii) Purpose of tree plantation, (iv) Adaptability to the agrarian system, and (v) Socio-economic considerations. Various aspects of hortipastoral system like, tree spacing, growth and productivity of the system, rooting system, nutritive value of tree leaf fodder and impact of climate change were undertaken by various workers. In another approach, native jharber shrubs were budded with improved cultivars of ber, like, Umran and Banarasi Kadaka. The system proved to be a successful low input hortipastoral system for degraded lands. Owing to its popularity among farmers, hortipastoral system was recognized as a separate AFS. Fruit tree based AFS for humid, semiarid and arid climatic regions, like, Agrihorticulture (Crops + Fruit trees), Hortipastoral (Fruit trees + Pasture/Animals), Agrihortisilviculture (Crops + Fruit Trees + MPTS) were identified as potential AFS for sustainable development. Based on long term trials, it has been established that fruit trees when grown with fodder grasses and legumes gave good system productivity. Fruit based AFS, being site specific, need to be developed according to the local agroclimatic conditions and farmers requirements. Emphasis should be there on developing a few generic technologies and leaving ample scope for individual farmer to innovate.

Key words : Ber budding, Degraded lands, Economic analysis, Employment generation. Hortipastoral systems, MPTS, Species selection

Introduction

The demographic pressure to produce food (fruits), fibre and fodder from degraded lands has highlighted the importance of crops that can survive on such lands, and produce more under severe climatic constraints. These crops produce higher when they are grown under some system (agroforestry systems, AFS). Patil (1980) identified research needs of AFS and grouped them in four sections. Among these sections, Section I "System synthesis, crop geometry and modeling of forage crops and grazing lands" included system synthesis for hortipastoral/pastoral/ hortiforage systems. In Section, II "Stratification of research on forages on the basis of natural problems", accent was on identifying fruit crops for AFS for arid zone, temperate zone, humid region and semiarid. Many fruit trees are naturally suitable for AFS under varied agroclimatic conditions. Therefore, the initial definition of agroforestry by King and Chandeler (1978) "Sustainable land management system ..... cultural practices of local population" envisaged the following products from fruit trees component in an AFS:

- Small timber for household, agricultural implements
- Fodder and feed for cattle
- Food in form of fruit, nuts, berries, roots, mushrooms, *etc.*

- Gum resin, honey, medicinal herbs, tannins, dyes, *etc.*
- Self-employment and income through a series of agricultural activities, like lac cultivation, silk rearing, basket making, bee keeping, sales of firewood, supply of raw material for handmade paper, *etc.*
- Building and conserving natural resources (sustainable land uses).

One of the limitations of Initial AFS was that the area taken for the system was a major loss to farmers, especially when there was no other place to take their animals (Patil and Pathak, 1980). This was one of the reasons why adoption rate of various AFS by farmers was low despite severe fodder shortage during summer months. Early pioneer workers recognized the potential roles of fruit trees in popularizing AFS based fodder production systems among farmers (Patil, 1980). Many horticulturists also picked up the idea, and started working on it (Pareek and Chadha, 1993; Pathak, 1993, 1999; Pathak and Pathak, 2000; Saroj *et al.,* 1994).

Since many fruit trees fulfill the above requirements and farmers were traditionally growing them in their fields, they form an integral component of any sustainable AFS.

Early research attempts

Initial roles of fruits crops in various AFS were subsidiary because main responsibility of AFS was to enhance fodder production. Therefore, fodder and fuel wood were the primary products and fruits were accepted as secondary products. Accordingly, early research attempts were mainly confined to species selection and observation on their effect on main crop.

Species selection : Appropriate selection of suitable plants is the most important factor for successful production from AFS. Many workers tried various methods of fruit tree selection. Initially one factor was considered for species selection, later on, more than one factors were adopted at a time.

Survey of existing plantation : The main basis of species selection was to follow the fruit trees being grown by farmers. During a survey of tree species distribution based farmers' fields, Ziziphus spp were found to be most prominently distributed on red and black soil on farm bunds in semiarid parts of India (Tewari and Sharma,1990). Later on, Hegde (1993) identified jack fruit (*Artocarpus heterophyllus* aonla (*Emblica officinalis*), mango (*Mangifera indica*), drumstick (*Moringa oleifera*), jamun (*Syzygium cuminii*), tamarind (*Tamarindus indica*) and ber (*Ziziphus mauritiana*) as important fruit tree species for AFS and recommended collecting their germplasm. Though, mango, guava (*Psidium guajava*), custard apple (*Anona squamosa*), wood apple (*Feronia elephantum*), ber were traditionally associated with Kanchas (several hundred years old practice of natural and cultivated silvipastoral and Savannahs of Deccan), Chinnamani (1990) suggested introduction of more multipurpose tree species (MPTS).

Based on soil type : Deb Roy *et al.* (1980) observed that bushes like *jharber (Ziziphus nummularia)* and *Caronda* were more suitable for cultivation in the natural/sown pasture of anjan (*Cenchrus ciliaris)* of Bundelkhand (BKD) region where soil is sandy loam, shallow and underlain by murram layer. Manikar (1981) recommended mulberry (*Morus alba*) on kabar (black and low land) soils. Muthana (1981) made specific recommendation for suitable fruit species for forage-forest practices for BKD region. He recommended jharber specifically for desert region, while mulberry, lasora *(Cordia myxa)* and drumstick were other suitable species. Deb Roy and Patil (1981) identified jharber as a suitable species for energy plantation in culturable wasteland in BKD region. Pathak and Roy (1992) recognized ber, jackfruit and mango as fodder trees having multiple uses, while their fruits were considered as secondary products. Jharber was recommended for year-round fodder, while ber was recommended for fodder in summer months.

Based on climate : Singh and Roy (1991) identified the following species under various climatic conditions: (i) Drought like conditions - Ker (*Capparis decidua*), Pilu (*Salvadora oleoides,)* Goudi (*Cordia gharof)* and jharber*;* (ii) Rainfed conditions – ber, guava, caronda, Pomegranate (*Punica granatum*), custard apple*)* (iii) Irrigated conditions – *Aonla* fig (*Ficus carica)*, Phalsa (*Grewia subinequalis),* date palm *(Phoenix dactilifera),* lime *(Citrus aurantifolia),* papaya *(Carica papaya)* and sweet orange.

Based on management/usage : Hegde (1990) suggested that fruit tree species like ber and jharber can be used for lopping fodder in the tropics.

Based on multiple factors

Later on, more complex methods, using many criteria, were used for species selection. Tiwari and Sharma (1990) tried to combine some of the above factors in species selection by evolving a subjective Superiority Index (0-30) by combining Utility Index (0-10), Adoptability Index (0-10) and Productivity Index (0-10). On Superiority Index, ber scored 25, jackfruit scored 24 and jharber

scored 18 points. Singh and Roy (1994) in the review of MPTS, suggested suitable fruit trees considering climate (different rainfall), edaphic (different soil types) conditions and different farming systems. Sharma and Mishra (1999) advocated participatory selection of tree species for AFS. The criteria for MPTS selection were categorized into five groups: (i). Suitability to local edaphic and agroclimatic conditions, (ii) Potential for tree management practices, (iii) Purpose of tree plantation, (iv) Adaptability to the agrarian system, and (v) Socio-economic considerations. They recommended that involvement of farmers at various stages of MPTS selection could enhance chances of success of the plantation.

Tree spacing : Optimum density of fruit trees in AFS was among the first few research areas investigated. Sharma *et al.* (1980) raised various species of *Ziziphus* at four spacings. Maximum dry forage yield was obtained at 210 pl/ha, while there was no significant effect of tree density on forage yield in *Z. rotundifolia.*

Growth and production of tree component : Some basic studies like growth of fruit tree in a AFS in semiarid and arid region was undertaken (Jambhole *et al*., 1993b). Among various fruit trees like bael (*Aegel marmelos*), custard apple, jackfruit and jamun, maximum growth was observed in Jamun. Raturi and Hiwale (1993) recorded total production from a ber based hortipastoral system in Godra (Gujarat). Production from the system was 4.9 t/ha fruit, of 0.22 t /h fire wood, 5.5 t/ha with grasses (anjan) and 3.89 t/ha legume (Stylo). Kumar *et al.* (2003) tried to establish effect of fertilizers on production of the system. They observed higher fruit production with application of nitrogen in aonla based hortipastoral system in BKD Region.

Fodder quality : With the use of fruit tree leaf as animal fodder, their nutritive quality also required investigation. Roy and Pathak (1994) compared leaf crude protein in ber (8.6%) and jharber (10.5%). Singh and Osman (1995) measured crude protein in the leaf fodder of some popular tree species, like, ber (8.6%), bael (15.1%), gouda (15.1%), mahua (*Madhuca indica*,15%), khirni (*Manilkara hexandra,* 9.5%), jamun (8.8%) and jharber (11.5%). These studies proved versatile nature of fruit trees.

Root system : In AFS, trees and annual crops compete for above ground and below ground resources. For better understanding of below ground competition for nutrients and water. Patil *et al.* (1994) studied root system of ber in response to different pit size. They compared between transplanted seedlings and *in situ* seed sowing. The study indicated better development of all the root parameters of the plants raised in larger size pits. Root biomass was more than the shoot biomass in seeded stands. Seed sowing *in situ* or seedling planting in proper size pits may avoid competition for soil moisture and nutrients between tress and crops/grasses in AFS.

Comparison with other MPTS : Growth of fruit trees and their effect on production of annuals were compared with other MPTS. Initial plant growth of *ber* in first three years was intermediate between babul (*Acacia nilotica)* and Kabuli kikar (*Prosopis juliflora*) (Upadhayay and Mertia, 1991). Tree growth of MPTS, including jamun and aonla, was distinctly better under agrisilvicultural system as compared to sole trees. Grain yield was more in aonla (with Casuarina and Eucalyptus) as compared to other MPTS (Deb Roy and Gill, 1991).

Climatic change : In some recent publications, the effect of climate change on productivity of fruit crops was also studied. Kumar *et al.,* (2005) studied the effect of rainfall distribution on productivity of ber fruit, leaf fodder, fuel wood, and fruit quality. Early rainfall (May-August) had favourable response while >500 mm rainfall during September caused detrimental effect on fruit productivity. Early onset and early withdrawal on monsoon enhanced fruit quality

Field application

Hazra and Singh (1994) used shrub caronda, among other tree species, to rehabilitate wasteland at Gaharawa watershed in Jhansi (UP). Chinnamani (1994) used jharber as one of the tree species to rehabilitate Chambal ravines in central India. Here the emphasis was more on leaf fodder rather than fruit yield.

In another approach, native jharber plants were budded with improved cultivars to enhance their productivity. Tiwari and Sharma (1993) applied the approach of rejuvenation of existing tree species like jharber and ber. They were headed back and budded with improved cutlivars. Plants with thicker collar diameter produced faster growth after budding on jharber rather than on ber. Among improved ber cultivar budded on jharber, Umran had better growth than Banarsi Kadaka. Budding jujube *cv* banarasi kadaka on jharber produced 10-12 kg fruits/tree in the 4th year in a trial at NRC Agroforestry, Jhansi (Deb Roy,1994). The system was recommended to establish ber based AFS where natural plants of jharber are found. The system was later on demonstrated successfully and applied to farmers' fields in Ambabai village (Jhansi, UP) under National Wasteland Development Board funded project during 1992-94. It has proved to be a successful low input AFS for degraded lands.

System perspective

Owning to its popularity among farmers, Singh and Roy (1991) recognized hortipasture as a separate AFS. Now workers started considering cultivation of fruit trees as a part of the system. Jambhole *et al.* (1993a) Induced jujube as tree component with pasture grasses in evaluation of various silvipasture models in scarcity areas of Maharashtra. In their compilation of agroforestry options for degraded lands of Asia Pacific region, Pathak and Roy (1994) identified fruit tree based AFS for humid, semiarid and arid climate of the region. Deb Roy (1994) identified Agri-horticulture (crops + fruit trees); Hortipasture (fruit trees + pasture/animals), Agri-horti-silviculture (crops + fruit trees + MPTS) as potential AFS for sustainable development. Fruit tree based AFS like Silvihorticulture, Agrihorticulture and Serihorticulture were among nine agroforestry interventions recommended for North East hill region of India (Dhyani and Chauhan, 1995). Chinnamani (1990) suggested the following hortipastoral combination as a new AF intervention: (i) Ber + anjan tree (*Hardwickia binata)* + grass/legume, (ii) Custard apple + babul + *Israeli babul* + *kala siris* + grass/legume, (ii) Mango + Custard apple + grass/legume, (iii) Ber + grass/ legume/ Siratro, and (iv) Custard apple + grass/ legume/ Siratro. Considering shortage of farming land, Khan *et al.* (2001) found some niche areas for fruit trees. In a simultaneous 'on farm' and 'on station' trial, both fruit trees and fodder crops were raised on farm bunds. Effect of different fodder crops on survival and growth of fruit trees was negligible, while the combination of caronda + Napier Bajra Hybrid + *Stylosanthes* produced more forage yield.

A rainfed system involving jujube, aonla, subabool (*Leucaena luecocephala*), urd, til pigeon pea in central India produced reasonable fruit production of aonla *cv*. Kanchan (14 kg/tree), aonla *cv.* Narendra-7 (13 kg/tree), jujube *cv* Banarasi Kadaka (9-14 kg/tree) and jujube *cv* gola (20 kg/tree) in the 3rd/4th years (Deb Roy, 1994). He also reported success of pomegranate in the system involving subabool, urd, til *etc.*

Long-term trials were conducted at IGFRI, Jhansi to develop hortipastoral systems under rainfed and partially irrigated conditions. Their growth and productivity was recorded. Ber plants showed a steady growth with age. During first five years, the plant growth was not affected significantly by cultivation of fodder crops. Trees started yielding fruits from 3rd year onward and the yield increased from 5.37 (3rd year) to 6.55 t ha^{-1} (8th year). The fruit yield was not affected significantly by growing intercrops in the inter-space. Other workers also obtained similar trends of production. Raturi and Hiwale (1993) obtained fruit yield of 1.61 and 4.9 t ha^{-1} in the 1st and 3rd year respectively on Horti-silvi-pasture system at Godhra (Gujarat, India). Singh and Osman (1995) harvested 919 kg fruit ha^{-1} under ber based Hortipastoral system at Hyderabad. Pasture production showed a general trend of increase in dry matter yield up to 4th-5th year. The fodder production was 4.59, 3.23 and 4.27 DM t ha^{-1} in buffel, stylo and mixed pasture respectively. The maximum fodder production was obtained when anjan and stylo were grown together as mix crop. Average fodder production of stylo was lower when grown with ber, however, the production of anjan and mix crop was more when grown with ber. Raturi and Hiwale (1993) harvested green fodder of 5.5 and 3.89 t ha^{-1} of anjan and stylo respectively in ber orchard. Singh and Osman (1995) observed similar results. They obtained production of 5.98 DM t ha^{-1} stylo and 6.77 DM t ha^{-1} of anjan in custard apple. Ber plants when grown with anjan and stylo as intercrops, gave maximum system productivity. While in the hortipastoral system under partial irrigation, Kinnow plants showed a steady growth during first five years. It started producing fruits from 3rd year onward. The fruit production was nominal (2.56 to 3.86 tha^{-1}) in the first year, which increased to 6.42-8.21 t ha^{-1} in 4th year. Pasture production was low in the first year (2.09 to 3.18 DM t ha^{-1}). There was continuous increase in pasture production in first three years. It ranged between 4.95 to 7.38 DM t ha^{-1} in the third year. Thereafter, there was a decline in pasture production in all treatment combinations. Kinnow based hortipastoral system under partial irrigation gave maximum productivity when tree, grass and legume components were grown together (Sharma, 2004).

In a recent review of horticulture based cropping system for arid region, Awasthi and Pareek (2008), have found cropping system approach integrating suitable under and ground storey crops with the hardy fruits trees as remunerative providing food, fruit, fuel, fodder to the poor farmers. They attempted to identify the most suitable fruit and fodder trees, crops, vegetables, grasses, forages *etc.* along with the cropping system models such as horti-agri, horti-pastoral and horti-agri-pastoral system for different locations. Growing of vegetable crops, pearl millet, moth bean, cluster bean, and gram between trees of khejri, boradi, lasora and ker is a prevalent traditional practice in the arid region. They suggested ber, aonla and khejri based horti-agri systems. Among horti-pastoral systems, various combinations of fruit trees (ber, jharber, boradi, lasora, aonla, Kinnow, guava and custard apple) and pasture (anjan, sevan and stylo) were suggested for arid and semi-arid regions. For horti-agri-pastoral system, livestock oriented systems such as khejri-ber-grass or ber-pilu-lana or aonla-ber-grass, aonla-drumstick-cluster

bean could provide fodder from grasses, top feed from khejri, ber, pilu, lana and drumstick, beside the edible fruits of ber and aonla, pods of khejri and drumstick. They recommended partial shift from the existing high input requiring rotation to low input requiring system for sustainable management of arid lands and for enhancing the economic viability of the cropping system.

Economics

Sharma and Diwakar (1989) estimated economics of ber and anjan at Samdhari in western Rajasthan by method of discounting. The benefits accrued in the first year were less than the cost of production due to gestation period of the system. Second year onwards, the benefits accrued were substantially higher than production costs. The costs were positively related with the yield of forage and its seed production throughout the life of the system except for the first year. The economic parameters delineated clearly, the economic soundness of the system even at higher costs (25%). Later period benefits of the systems also indicated further validity and economic soundness of the system. Therefore, the system may be adopted on large scale under the similar agro-climatic conditions. Sharma and Saran (1999) studied economics employment generation potential of *in situ* ber budding programme. Gross returns to the farmers from 1 ha and with a tree density of 170 per hectare were estimated at Rs.1,913/- and Rs.3,826/- during first and second years respectively. The gross returns increased to Rs.11,116/-, Rs.17,850/- and Rs.20,400/- in the 3rd, 4th and 5th years respectively. The net profit was around Rs.9,000/- 4th year onward. It provided a long term source of income to farmers at very little initial and maintenance cost in the subsequent years. With its sustained profitability, the programme provided for good employment generation potential for rural poor especially women.

Conclusion

Hortipastoral systems, being site specific, need to be developed according to the location and farmers' requirements. They are also governed by the priority of farmers to use resources for the system. Therefore, emphasis should be there on developing a few generic technologies and leaving ample scope for the individual farmers to innovate.

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