Arable cropping enterprise in dryland areas of arid and semiarid India is often unremunerative due to aberrations of monsoon like late onset, prolonged dry spell, early withdrawal and unequal distribution of rainfall (Gill et al., 1998). Hence an integrated approach of land management in rain fed area is essential for efficient utilization of natural resources, to meet the requirements of farmers without deteriorating the land productivity and also to stabilize the income (Gill and Roy, 1998). One of the need based alternate land use system in the rainfed semiarid tropical region is replacing the traditional farming system with tree based cropping system i.e., agroforestry, which acts as a sustainable land management system especially in dryland areas. This recognition is due to the fact that the combined returns from the tree and crops grown in agroforestry are of great practical advantage to the semiarid rainfed farmer (Singh et al., 1999).

Generally trees with the age advancement tend to suppress the growth and yield of associated crops due to canopy spread. This suppression is attributed to both above and below ground competition (Geiger et al., 1994). To regulate the shade in agroforestry system, trees are usually pruned during the cropping period to avoid the competition on light (Gillespie, 1989). Inclusion of nitrogen fixing trees (NFTs) like *Hardwickia binata* (Anjan), *Faidherbia albida* (African Babul), *Dalbergia sissoo* (Shisham), *Leucaena leucocephala* (Subabul) etc. in an agroforestry system offers immense possibility of supplementing a part of nitrogen requirement of the associated crops besides enriching the site through addition of organic matter and helps to cater the basic needs of poor farmers in drylands (Gaddanakeri, 1993).

Land use according to its capability

There are eight well-recognized land capability classes. Classes I, II, III and IV lands are fit for all agricultural uses as per need. Classes V, VI, VII, and VIII are not suitable for agriculture. Land use according to its capability is set out in Table 1.

Alley cropping

Alley cropping also known as hedgerow intercropping, involves rising of food crops in alleys formed by hedgerows of trees or shrubs. The primary purpose of alley cropping is to maintain or increase crop yields by improvement of soil and microclimate (Yamoah, 1991). During the rainy season, the hedgerows are usually cut to about one metre at planting of crops and kept pruned to reduce competition with crops (Kang et al., 1985). In the semiarid regions of India, the main benefit of alley cropping is fodder production during the dry season because mulching in alleys with
hedgerow pruning does not consistently increase crop production (Singh et al., 1987). Success in alley cropping depends on alley width and height of hedgerows. Alley width of 5-6 m and alley height of 0.50-1 m has been found to be effective in most of the food crops (Kalaghatagi and Nadagoudar, 2002).

**Competitive Interaction in alley cropping system:**

Pandey et al. (2001) in Chattisgarh revealed that the reduction in above ground biomass was 55-60%; growth rate by 42-55% and crop yield by 71-72% due to above ground competition when Linum ustissimum was alley cropped with Leucaena leucocephala.

Shanmugavelu and Francis (2001) at Tamilnadu observed that yields of pigeonpea, soybean, turmeric and ginger in pure stands were higher than those in intercropped stands with Bamboosa bamboos which was attributed to the competition occurring in the root systems of agricultural crops. Panneerselvam (2003) reported that at all the growth stages of crop growth leaf area index, dry matter production and crop growth rate were significantly more under sole sunflower over intercropping with neem and melia. Srinivasrao (2000) observed significantly higher growth parameters yield attributes and pod yield of groundnut in alley cropping systems involving Dalbergia sissoo, Leucaena leucocephala and Albizia lebbeck over sole cropping of groundnut.

**Complementary Interaction in alley cropping system:**

Toky and Bisht (1992) reported that Leucaena and maize alley cropping was encouraging and yield levels were maintained at reasonable level with no additional input on sandy soils. Tomar et al., (1992) at Hyderabad revealed that in kharif castor growth parameters like plant height, dry matter production, crop growth rate, leaf area, leaf area index were significantly higher under Faidherbia albida alley cropping system over sole cropping. This is attributed to the leaf fall of the tree species during the cropping period thereby reducing the shade effect on the intercrop. Devaranavadgi et al. (2003) observed that Hardwickia binata has better compatibility with arable crops like rabi sorghum when grown in agri-silviculture system due to minimum crown diameter. Similarily Bheemaiah and Subrahmanyam (2002) studied intercropping of sunflower with Hardwickia binata and reported that growth characters like plant height, leaf number, leaf area and dry matter production and yield were significantly higher under intercropped sunflower over sole crop. Likewise Gill (2000) reported that seed yield of chickpea was the highest when grown as intercrop in Madhuca latifolia, Acacia cupressiformis and Hardwickia binata and the yield was increased with increasing distance from the tree component. Growing of castor and sorghum for two consecutive years under two years old nitrogen fixing trees (NFTs) showed 23% and 13% increase in yield of castor and sorghum respectively under Faidherbia albida as compared to respective sole crops (Osman and Rao, 1988).

**TABLE 1. Suitable farming systems for different classes (Singh and Korwar, 1986)**

<table>
<thead>
<tr>
<th>Land use capability classes</th>
<th>Suitable farming system</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Crop production (Intensive cultivation)</td>
</tr>
<tr>
<td>II and III</td>
<td>Moderately intensively cultivated – alley cropping, agro- horti, agri- silviculture.</td>
</tr>
<tr>
<td>IV</td>
<td>Restricted cultivation – Ley farming</td>
</tr>
<tr>
<td>V and VI</td>
<td>Horti / silvi- pastoral system</td>
</tr>
<tr>
<td>VII</td>
<td>Low density long – rotation tree plantations</td>
</tr>
<tr>
<td>VIII</td>
<td>Recreation, Wildlife, Watershed protection</td>
</tr>
</tbody>
</table>
Management of agri silvicultural system

The component interaction is a potentially valuable tool for the management of agro forestry systems. An understanding of where and how interactions are occur in the systems help us to undertake desired management techniques for optimizing crop production (Mureithi et al., 1992). Component interaction refers to the influence of on component of a system on the performance of other components as well as system as a whole (Rao et al., 1990). The major positive effects are Shading trees (Stress reduction), Biomass contribution and Soil water and conservation and negative effects are Light competition, Nutrient competition, Moisture competition and Allelopathy (Nair, 1985).

Choice of tree species

The desirable characteristics of agroforestry trees when associated with annual or perennial crops have been analyzed in terms of goods and services, growth habits, morphological and physiological features, methods of propagation, production of biomass, response to pruning, coppicing ability, litter decomposition, tolerance to fire, relationship to soil fertility and texture, capacity to fix nitrogen, efficiency of other micorrhizal, tolerance to pests and relationship with wildlife (Budowski, 1987). In general choice of trees is governed by climate, soil, topography, effect of annual crops, effect of site, purpose of plantation, agroforestry system, case of establishment, resistance to attack of pests and diseases (Salazar et al., 1993). Hazra (1995) reported that forage yields and seed yields of Trifolium alexandrum were found to be higher with Hardwickia binata than that of other trees viz., Acacia nilotica, Melia azaderach and Albizia lebbeck. Bengalgram intercropped with Faidherbia albida recorded 18 per cent higher yield as compared to Hardwickia binata. Soliappan et al. (2002) reported that sorghum, maize, blackgram and greengram crops produced higher grain yields in sesbania based agroforestry system than in neem and subabul based agroforestry systems due to competitive nature of neem and subabul compared to sesbania.

Spatial arrangement of trees

The competition between trees and crops in agroforestry systems can be reduced by modifying the spatial arrangement of trees, thus with this, higher productivity of agricultural crops can be obtained. The competition with crops increases linearly with increasing the tree population. Rao et al., (1990) observed reduction in the yields of sunflower, sesame and groundnut grown along with Casuarina equisetifolia and Leucaena leucocephala and the yield reduction in these arable crops were primarily attributed to reduction in light transmission. Samsuzzaman (2002) stated that in alley cropping system irrespective of the food crop, the decline in yield was more in narrow row widths (3.6 m) than in wider rows (7.8 m). Gill (1992) in a sandy loam soils with Leucaena leucocephala + sunflower/ sesame/ maize/ groundnut revealed that the yields of all these crops were reduced due to competition for moisture and light. Gaddanakari (1993) revealed that when sunflower crop was grown as intercrop in Leucaena leucocephala, the yields were decreased under close spacing of trees due to competition for light, moisture and nutrients.

Tree management

In agroforestry systems, trees interact negatively with agricultural crops at above ground and below ground interfaces for growth resources like light, water and nutrients. The above ground negative interactive effect of tree species is shading on understorey crops (Saradadevi, 2002). The magnitude of negative interactive effects of trees on crops at above and below ground interfaces can be reduced through coppicing, pollarding, lopping and pruning (Tilander and Bonzi, 1997). There are innumerable studies indicating that beneficial
TABLE 2. Need based alternate land use system (Singh et al., 1989)

<table>
<thead>
<tr>
<th>Food (Arable land) II and III</th>
<th>Fodder (Non-arable land) IV and V</th>
<th>Fuel/ Timber/ Fibre (Marginal degraded land) VI and VII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alley cropping</td>
<td>Horti-Pastoral Silvi - Pastoral</td>
<td>Tree farming</td>
</tr>
<tr>
<td>Agro-horticulture Intercropping with NFT's</td>
<td>Ley-farming</td>
<td>Timber cum fibre (TIMFIB)</td>
</tr>
</tbody>
</table>

effects of tree management on crop productivity in alley cropping system. Deb Roy et al., (1982) reported that leaf area index, dry matter production and crop growth rate of intercropped cowpea were lower in unpruned Albizia lebbeck over pruned one. Duguma et al. (1988) reported that the various pruning intensities of all hedgerow species had more pronounced effect on the grain yield of the alley cropped cowpea and maize and higher yields of arable crops were obtained with increasing pruning frequency and decreasing pruning height. Osman et al. (1998) reported that sorghum and cowpea grown with pruned trees of Leucaena leucocephala gave higher dry matter and leaf area index over unpruned trees.

Application of green manures

The use of hedgerow pruning for mulch or organic matter amendments to the soil is an integral part of agroforestry system. The tree-derived material increases the productivity of agricultural crops due to its following beneficial effects. It maintains and enhances soil organic matter (Tripathi and Hazra, 1997); Increase in soil physical properties (Radwanski and Wickens, 1981); Increase in nitrogen (Shankarnarayan et al., 1987); Increase in phosphorous (Palm, 1995); Increase in sulphur (Deb Roy and Gill, 1991); Conserving moisture (Subrahmanyan et al., 2001); Conserving soil (Bisaria et al., 1999) and by suppressing weed growth (Khadse and Bharad, 1996). Muthanna et al., (1985) reported that use of green leaf manure of Albizia leaves equivalent to 40 kg N ha\(^{-1}\) produced significantly higher growth parameters like leaf area, LAI, dry matter production, CGR and pod yield of groundnut under alley cropping over intercropping without green leaf manuring.

Fertilization

Historically fertilizer use in arid and semiarid agroforestry systems has been considered as a risky investment due to its unpredictable weather conditions. However, application of fertilizer in agroforestry system is an important aspect in order to obtain higher production of agricultural crops (Deb Roy et al., 1980). Karim et al., (1991) recorded higher yields of maize, cowpea and sweet potato grown under Leucaena leucocephala with the application of N fertilizer. Suresh and Rao (1999) revealed that yield of sorghum in alley cropping system involving nitrogen fixing trees was 88, 132 and 144 % higher with the application of 20, 40 and 60 kg N /ha respectively over control. Palada et al., (1992) reported that the mean yield of Amaranthus, Celosia, Okra and Tomato under Leucaena leucocephala alley increased by 36, 24, 4 and 20 % respectively with the application of fertilizers in combination with pruned material over no fertilizer. Pooran Chand et al. (2004) reported that application of 50% recommended dose of fertilizer (RDF) in conjunction with Azospirillum seed treatment recorded significantly higher seed yield followed by 25% N through FYM + phosphorus solubilizing bacteria. Akula and Reddy (1997) reported that the split application of 40 kg N ha\(^{-1}\) (20 kg N basal + 20 kg at 35 DAS) resulted in higher seed yield and nitrogen use efficiency (64%) of castor over control.

Influence of agri-silvicultural system on soil quality

Soil is one of the most important natural resources to suffer as a result of tree cutting. If it is not protected, its productivity
declines and it may become difficult to sustain the human and animal population even at its present level. Therefore, protection of this resource is important and an understanding of how this resource is influenced in alley cropping system is necessary (Jha et al., 2000). Many of the alley cropping system practiced in arid and semiarid tropics of India has the immense potential to maintain the soil fertility and to improve its productivity (Khan and Ehrenreich, 1994). Bheemaiah et al. (1992) reported that Faidherbia albida and Dalbergia sissoo trees besides enhancing the associated crop yields improved the soil physical properties and nutrient status. Ballakki and Badanur (1993) reported that the water infiltration rate and water retention characteristics of a Vertisol were increased and bulk density was decreased significantly with sorghum stubble alone or in combination with leucaena. Singh et al., (1982) observed that decrease in soil pH (7.6) and bulk density (1.56 g cm$^{-3}$) and increase in organic carbon (0.56%), EC (13.7 dSm$^{-1}$), available N (225 kg ha$^{-1}$), P (9.2 kg ha$^{-1}$) and K (235 kg ha$^{-1}$) under tree canopy of Hardwickia binata over without tree on rainfed Alisols. Anil Kumar et al. (1998) reported that soils under the canopies of Prosopis cineraria, Tecomella undullata, Faidherbia albida and Azadirachta indica were rich in organic carbon content, moisture availability and nutrient status (N, P and K) as compared to outside the tree canopies. Roy (1999) reported that nitrogen, phosphorus, potassium and calcium status of soil increased with increase in tree density of Hardwickia binata at Jhansi. Uday Burman et al. (2002) observed that Prosopis cineraria, Colophospermum mopane and Hardwickia binata recorded higher build up of amino acids, amino sugars, hydrolysable NH$_4$-N and total hydrolysable N over rest of the species studied.

Economic studies in agri-silvicultural systems

Economic evaluations are important in diagnosis and design of agri silvicultural technologies, working out B: C ratios and for rationalization of choice of technologies to be researched or disseminated for development (Kang et al., 1990). Malviya and Patel (1989) at Saurashtra reported that groundnut, green gram and blackgram with Leucaena leucocephala were more remunerative over their respective sole crops. Singh et al. (1989) recorded that alley cropped sorghum noticed two times higher income over sole sorghum; whereas the alley cropped pigeon pea recorded almost seven times higher income over sole pigeon pea. Bheemaiah et al. (1993) at Hyderabad on leucaena alley cropped with castor reported that with the increase in levels of nitrogen the net returns gradually increased up to 80 kg N ha$^{-1}$. Subrahmanyam et al. (1996) reported that sunflower and castor gave higher monetary returns under intercropping in young plantations of Dalbergia sissoo over sole cropping situation.

Srivastava (1988) observed that gross returns, net returns and benefit cost ratio of groundnut were maximum under leucaena and Dalbergia alley cropping systems. Bheemaiah et al., (1998) observed that sunflower intercropped with guava + curry leaf showed higher gross returns, net returns and benefit cost ratio than sole cropped sunflower. Bheemaiah et al., (1996) observed that the maximum gross and net monetary returns as well as benefit cost ratio of maize was obtained under wider tree spacing of 5.4 m x 3 m over closer tree spacings of 4.2 m x 3 m or 3 m x 3 m of Faidherbia albida. Devaranavadgi et al. (2005) reported that the highest and lowest net returns of Rs.10212 and Rs.4527 ha$^{-1}$ were recorded with Hardwickia binata + chickpea and Casia siamea + chickpea alley cropping systems respectively. Similar trend was observed with regard to benefit cost ratio.

Conclusion

Agroforestry is an ancient practice of growing trees and agricultural crops in intimate
combination with one another for the welfare of farm family. It has been in use for at least 1300 years. Agroforestry has great technical and economical potential to overcome the problems in the way of higher and sustained crop production and farm income. Agroforestry systems fulfill both production and service roles. Agri-silvicultural systems integrate the crops and the trees. Alley cropping is one such system in which crops are sown in alleys between rows of trees. *Leucaena leucocephala, Hardwickia binata, Gliricidia sepium, Faidherbia albida,* Dalbergia sissoo, *Casia siamea,* Prosopis cineraria and *Casuarina equisetifolia* are some of the potential and most widely used hedge tree species. The preferable alley width is 4-6 m. To avoid the competition between tree and crops the trees must be pruned at regular intervals, at 0.5 – 1.0 m above ground level, and the pruned dry matter can be used for mulch or animal meal. By adapting improved tree and crop management practices the productivity of the alley cropping system can be sustained.

REFERENCES