Economic rationale of traditional agroforestry systems: a case-study of *Ficus* trees in semiarid agro-ecosystems of Karnataka, southern India

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**ABSTRACT**

In Mandya district of southern dry agroclimatic zone of Karnataka, trees of the genus *Ficus* are abundant in rainfed agro-ecosystems with field crops like millets, maize, pulses and oilseeds. Economic values of this traditional agroforestry system were compared with alternative high-input systems using data collected from farmers’ interviews, group discussions and field walks held in 18 villages in Mandya. Data on annual farming costs and returns were used for a preliminary income comparison of various agricultural systems prevalent in Mandya. For further comparison with *Ficus* agroforestry, alternative systems were selected based on existing cropping pattern and farmers’ preferences. Financial (including all paid up costs and benefits) and economic (including opportunity costs of land, family labour, external agricultural inputs and benefit of *in situ* litter nutrient input from trees) benefit-cost analyses were conducted for assessing relative profitability of farming systems. Among the different systems compared, irrigated agroforestry systems with high-value trees emerged to be the most profitable. Among rainfed systems *Ficus* agroforestry had higher financial net present value (NPV), while economically *Eucalyptus* plantation had higher NPV due to less labour requirements. The implications of these results in judging a socioeconomically optimal land use for Mandya are discussed further.

**KEYWORDS** Benefit cost analysis; financial analysis; economic analysis; net present value; surrogate valuation; opportunity cost; optimal land use

1. Introduction

Agroforestry systems with scattered trees in croplands have traditionally played a pivotal role in sustaining rural livelihoods in arid and semi-arid zones of the world. In Mandya district of southern dry agro-climatic zone of Karnataka state, trees of the genus *Ficus* are integral components of rainfed agro-ecosystems with field crops like millets, maize, pulses and oil seeds. *Ficus benghalensis* L. is the major species of *Ficus* grown in these agroforestry systems, followed by *F. religiosa* L., *F. amplissima* Sm., *F. virens* Aiton, *F. racemosa* L., *F. mysorensis* var. *pubescens* Roth, etc. (Dhanya et al. 2012). *Ficus* trees provide direct benefits such as fodder, firewood, small timber for household uses and shade during agricultural operations besides...
crucial ecosystem services such as supporting soil fertility and local biodiversity (see Dhanya et al. 2012 for a detailed description of the system structure and benefits). However, preliminary surveys conducted in Mandya revealed that Ficus agroforestry systems, though perceived to be ecologically superior, are increasingly abandoned in pursuit of higher short term returns from intensive agricultural systems. Availability of assured irrigation water supplies, promotion of fast growing exotic trees and spread of intensive monocultures have accelerated the decline of indigenous low input systems (Dhanya 2011).

The contrast between private and social returns from traditional agroforestry and alternative land uses has been illustrated by several researchers including Sangha and Jalota (2005), Rasul (2009), Poppenborg et al. (2012) etc. Net financial returns to farmers from agroforestry in most contexts are less than the net returns from other unsustainable land uses while just the reverse in case of social returns (Pearce & Mourato 2004). To design appropriate strategies that encourage sustainable land uses, it is therefore important to recognise the economic value of services/disservices generated by alternative agricultural practices (Rasul 2009). In this context, the economic values of the traditional Ficus agroforestry system in Mandya was compared vis-a-vis the intensive systems with a view to judge a socioeconomically optimal land use option for the study area.

2. Methodology

2.1. Study area

Mandya, the third smallest district of Karnataka consists of seven taluks (subdivisions) with a total population of 1,808,680 as per 2011 census (location map in Figure 1). The district comprises plain lands, spanning an area of 4961 km² between 76° 19’ and 72° 20’ North latitude and 12° 13’ and 13° 04’ East longitude with an elevation of 757–909 m above mean sea level and a mean annual normal rainfall of 700 mm. The major crops grown include finger millet or ragi (Eleusine coracana (L.) Gaertn.), paddy (Oryza sativa L.), sorghum or jowar (Sorghum bicolor (L.) Moench), horse gram (Macrotyloma uniflorum (Lam.) Verdc.), cow pea (Vigna unguiculata (L.) Walp.), sugarcane (Saccharum officinarum L.), mulberry (Morus alba L.), groundnut (Arachis hypogaea L.), castor (Ricinus communis L.), sesame (Sesamum indicum L.) and maize (Zea mays L.). Mandya district had been predominantly dependent on rainfed

Figure 1. Location map of Mandya district. Source: This image was created by Mr. Kiran M at the GIS laboratory of Ashoka Trust for Research in Ecology and Environment, Bangalore, India exclusively for the purpose of this research.
agriculture until irrigation facilities became available through construction of Krishnarajasagar (KRS) dam across river Cauvery in 1932 and consequent spread of canals, which triggered large scale conversion from dryland crops to intensively managed paddy and sugarcane crops as well as introduction of double cropping system (Government of Karnataka 2009). Concurrently, native species such as *Ficus* and neem (*Azadirachta indica* A. Juss.) which had been maintained as scattered trees in farmlands were replaced by fast growing exotic species such as Casuarina (*Casuarina equisetifolia* L.), *Eucalyptus* spp. and silver oak (*Grevillea robusta* A. Cunn. ex R. Br.), high-value timber species such as teak (*Tectona grandis* L.) and horticultural species such as coconut (*Cocos nucifera* L.). Highly irrigated taluks of Mandya (Maddur, Mandya, Malavalli and Srirangapattana) now have extensive patches of sugarcane, paddy, vegetables, mulberry etc. along with fast growing/high-value trees on bunds, while the remaining relatively unirrigated taluks (Pandavapura, Nagamangala and Krishnarajpet) have large swathes under dryland farming with scattered native trees. However of late, farmers in these areas are also switching to irrigated systems by extracting ground water using borewells and pumpsets for which institutional credit is easily available and power supply is subsidised or often free.

### 2.2. Primary socio-economic surveys

To garner information on agricultural/agroforestry systems in Mandya, primary surveys were conducted during 2009–2011 in a two-stage stratified sampling process in which villages were selected at 1% intensity from each taluk of Mandya and 9–13 farmers were surveyed from each village, taking care to include *Ficus* growers (farmers with any species of *Ficus* deliberately retained in farmland), farmers without *Ficus* but other agroforestry species and those without any trees in farmlands. As there was no pre-existing data on the number of farmers growing *Ficus* or other tree species in Mandya, the population size for the study could not be accurately estimated. A sample size of around 200, fairly large enough for various statistical analyses was therefore pre-determined for the study. Since no information was available on the spatial distribution of trees, it was decided to extensively sample villages from all the seven taluks of Mandya so as to cover as many villages as possible with *Ficus* trees in the district. The final sample size was 210 farmers from 18 villages of Mandya, which included 147 *Ficus* growers, 33 non-*Ficus* tree growers and 30 tree non-growers. Semi-structured questionnaires (pretested and suitably modified) were administered for collecting details of household, land, agriculture (inputs, production, consumption etc.), livestock, credit availed and farmers’ preference for various crops and trees. Additionally, around 15–20 farmers were assembled for village level group discussions on trends in agricultural/agroforestry practices in each village. Field walks were undertaken to assess the cropping pattern and for biometric observations (total height, girth at breast height, clear bole height and crown diameter) on tree species grown in field. Secondary data were collected from government offices, markets etc. to supplement primary data.

### 2.3. Preliminary financial analysis

During the field surveys, farmers were sampled from three distinct categories: *Ficus* growers, non-*Ficus* tree growers and tree non-growers. Observations on cropping practices during surveys later facilitated further detailed understanding and categorisation of different
farming systems in Mandya based on the presence or absence of irrigation and type of tree species into (i) dry land agroforestry with *Ficus* and fast growing trees, (ii) dry land agroforestry with only *Ficus* trees, (iii) dry land agroforestry with only fast growing trees, (iv) irrigated agroforestry with *Ficus* and fast growing/high-value trees (v) irrigated agroforestry with fast growing/high-value trees and (vi) irrigated agriculture without any tree. For a preliminary understanding of profitability of these farming systems, data on farming costs and returns collected from farmers falling under each category were averaged and compared.

2.4. **Comparison of Ficus agroforestry with alternative systems**

Benefit-cost analysis (BCA) procedure was used for comparing the traditional agroforestry system with alternative high-input systems. BCA is a tool that allows to understand whether or not a given change will improve the welfare of specific households as well as the overall economy (Purushothaman 2005). The different steps followed for BCA are outlined in the following sections.

2.4.1. **Selection of specific sub-systems (tree–crop combinations)**

From the broad categories of farming systems identified in the preliminary income analysis, specific subsystems (tree–crop combinations) were selected for further detailed analysis based on the following criteria;

(a) Existing cropping pattern: Data on crops grown in the previous cropping season, collected through individual farmer surveys were analysed to shortlist the major crops in irrigated and dryland farming systems in Mandya.

(b) Preference for trees: Ranking given by each farmer for preferred tree species in irrigated land and dryland were scored (score of 1 for rank 1, 0.5 for rank 2, 0.25 for rank 3 and so on) and scores assigned by 210 farmers were added to arrive at a composite preference score for each tree species.

(c) Compatibility with borewell irrigation: Only those systems were selected which could be a potential alternative to *Ficus* system in drylands, either in purely rainfed or in a borewell irrigated scenario as canal irrigation could not be obtained at farmers’ will.

2.4.2. **Quantification and valuation of costs and benefits associated with selected sub-systems**

Costs identified and quantified in each of the selected system include, labour and material inputs for planting, cultivation, protection and harvest of crops and trees and loss of yield due to diseases, pests and droughts. Direct benefits including food grains, straw, vegetables, timber, pulp wood, fuel wood and fodder leaves were considered. While crop inputs and outputs and biomass yield of *Ficus* (timber, firewood and fodder) were quantified based on primary data collected through surveys, biomass yields (timber, pulpwood, firewood and fodder) of trees other than *Ficus* were based on published works on the concerned species. Biomass outputs were valued at farmgate or nearest market price collected during survey.

Additionally to capture the value of ecological services from trees, the indirect benefit of nutrient addition to soil from tree litterfall was also taken into account for agroforestry land uses. For *Ficus* systems, litter nutrients were quantified through primary field experiments for litterfall measurement and nutrient estimation (see Dhanya 2011 for details) and for
non-\textit{Ficus} systems relevant secondary data was made use of. Monetary value was assigned to litter nutrients following the surrogate valuation technique in which the value of nutrients returned to soil through litterfall was computed in relation to the market price of chemical fertilisers obtained through market surveys (Chopra et al. 1997; Sangha & Jalota 2005). Farmer interviews in Mandya revealed that woody biomass of \textit{Ficus} was primarily used as fuelwood and carbon accumulated thus returns to atmosphere quickly. Since long term storage of carbon is not achieved in this land use, social benefit of carbon sequestered in above ground biomass was not accounted for in the study. Estimation of below ground carbon sequestration required exploration of soil up to 1 m depth (Nair et al. 2010), while monetisation of biodiversity services required detailed taxonomic and quantification exercises. Estimation of these services could not be undertaken and hence these social benefits were not incorporated in the analysis.

\subsection*{2.4.3. BCA of selected farming systems}

Financial and economic BCAs were conducted to assess the net benefits of selected agricultural systems in the present study. Financial analysis accounts for all paid up costs incurred by farmer and cash benefits accrued, while economic analysis measures the impact of land use on farm household as a whole, including the shadow prices of inputs and benefits not accounted for in financial analysis. Thus, differences between financial and economic BCA in the present study are in terms of the opportunity costs of land, labour, external agricultural inputs (chemical fertilisers and electricity for irrigation pumpsets) and \textit{in situ} inputs in the form of nutrients added to soil through litterfall from trees (Table 1).

Net present values (NPV) and benefit-cost (B: C) ratios, derived from BCA were used to analyse the relative profitability of the selected farming systems. NPV determines the present value of net benefits by discounting the streams of benefits and costs back to the base year (Rasul 2009). Equation (1) gives NPV as the sum of discounted net benefits

\begin{equation}
\text{NPV} = \sum_{t=0}^{T} \frac{(B_t - C_t)}{(1 + r)^t}
\end{equation}

where $B_t$ is the benefits accrued over the years, $C_t$ is costs incurred over the years, $r$ is the discount rate and $t$ the time period (Nair 1993).

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Costs and benefits} & \textbf{Financial BCA} & \textbf{Economic BCA} \\
\hline
\textbf{Land} & Direct (cash) & Direct and indirect (cash and noncash) \\
& No financial costs as land is owner operated & Opportunity cost of land in terms of prevailing lease rates \\
\hline
\textbf{Labour} & Hired labour monetised at actual wage rate & All labour including family labour priced at prevailing wage rate to reflect opportunity cost \\
\hline
\textbf{External inputs} & Actual paid up cost, which include subsidies for chemical fertilisers and electricity for pumpsets & Input prices without subsidy \\
\hline
\textbf{In situ inputs (litter nutrients)} & No cash implication & Benefits include replacement cost of nutrients in terms of market rates of N, P and K \\
\hline
\end{tabular}
\caption{Comparison of financial and economic benefit cost analysis of small farmer operated farming systems in Mandya.}
\end{table}
Costs and benefits were evaluated for a time period of 20 years, fixed on the basis of average harvesting age of *Ficus* trees as revealed by primary surveys. Interest rate for agricultural credit was considered indicative of discount rate (Rasul 2009). In Mandya during the study period, agricultural credit rates ranged from 3% (crop loans from Primary Agricultural Co-operative Societies) to 14.75% (for term loans usually covering capital costs for farm mechanisation, irrigation etc.). A discount rate of 3% was therefore used for rainfed farmers based on recent evidences that poor farmers often act to reduce consumption and preserve their assets in the face of risks such as drought and famine and hence have low discount rates (Moseley 2001; Gray & Moseley 2005). For irrigated land uses a higher discount rate of 13% was used considering the enterprising nature of these farmers and their preference for immediate returns. A medium rate of 7% was applied for both irrigated and rainfed land uses as a common rate for comparison.

Assuming that the land will continue under the concerned land use into perpetuity, liquidation value was calculated using Equations (3) and (4). In economic BCA, this liquidation value is added to the net benefits of the end year and then discounted.

\[
\text{LV for perennial systems} = \frac{\text{Net benefits in the end year}}{(1 + r)^{20} - 1} \tag{3}
\]

\[
\text{LV for annual systems} = \frac{\text{Net benefits in the end year}}{r} \tag{4}
\]

Incremental NPVs [Equation (4)] were computed to measure the incremental discounted net benefits from alternative farming systems relative to *Ficus* agroforestry. This indicated whether farmer would consider any non-*Ficus* system superior to *Ficus* agroforestry.

\[
\text{Incremental NPV} = \{\text{NPV (non – *Ficus* system)} – \text{NPV (*Ficus* system)}\} \tag{5}
\]

Benefits and costs were valued at constant prices prevailing in 2009 and the annual net benefit flows discounted to find the present value of land-use over a period of 20 years, using Equation (1). Details of the figures used for the BCA and details of the BCA calculations are available in annex 1 (see supplemental file).

3. Results and discussion

3.1. Preliminary income analysis of farming systems in Mandya

Results of the preliminary income analysis showed that irrigated farming systems were financially superior to rainfed systems, despite high-input costs (Table 2). Farmers practising irrigated agroforestry with high-value trees such as teak, silver oak etc. incurred the highest total labour and material costs for agriculture annually, but at the same time accrued the highest total annual agricultural income, net income and net income per ha, due to substantial timber value of trees and high value of associated crops. Farmers who grow both
Table 2. Preliminary financial analysis of farming systems in Mandya.

| Farming system                                                                 | Number of farmers sampled | Meanland area (ha) | Total income | Total costs | Total costs/ha | Net income | Net income/ha | Rank (based on net income/ha) |
|--------------------------------------------------------------------------------|----------------------------|--------------------|--------------|-------------|---------------|------------|---------------|-----------------------------|
| Dryland agroforestry with *Ficus* and fast growing trees                       | 59                         | 1.64               | 24989        | 15660       | 9549          | 9329       | 5703          | 5                           |
| Dryland agroforestry with only *Ficus* trees                                   | 70                         | 1.15               | 28913        | 14450       | 12565         | 14464      | 12577         | 4                           |
| Dry land agriculture with only fast growing trees                             | 6                          | 0.72               | 8712         | 6736        | 9355          | 1976       | 2737          | 6                           |
| Irrigated agroforestry with *Ficus* and fast growing/high-value trees         | 18                         | 1.50               | 83157        | 28578       | 19052         | 54580      | 36386         | 2                           |
| Irrigated agroforestry with only fast growing/high-value trees                | 27                         | 1.24               | 92060        | 36491       | 29428         | 55569      | 44963         | 1                           |
| Irrigated agriculture without any trees                                       | 30                         | 0.83               | 41714        | 23130       | 27867         | 18585      | 22281         | 3                           |

Notes: Costs and income figures are average values for farmers practising particular farming system in INRs./annum. 1 US$ ~ 65 INR.
Ficus and high-value trees had the next highest returns which indicated loss in potential monetary benefits when high-value trees were replaced by Ficus. Monocultures had the least returns among irrigated land uses, but higher per ha input costs compared to agroforestry with both Ficus and high-value trees. Lower returns are due to higher crop losses and vulnerability to price variations in monoculture systems producing mostly cash crops.

Among dryland uses, Ficus agroforestry was the best in terms of total annual income and net income per ha albeit higher costs, inclusive of value of family labour. Rainfed agroforestry with fast growing trees such as Eucalyptus, in combination or not with Ficus ranked low in profitability due to incompatibility of such trees with crops, leading to loss of annual returns from crops. However, only labour (including family labour) and material costs incurred by farmers annually were considered for this analysis and capital costs for irrigation, constructing bunds etc. were not included. Intensive agroforestry systems are feasible in dryland areas without access to irrigation canals only if farmers have the potential to meet capital costs for irrigation by installing borewell and pumpsets. But for farmers who are not able to bear such costs, dryland agroforestry with Ficus trees remains the best option in terms of profitability.

### 3.2. BCA of farming systems

Specific tree–crop combinations were selected for BCA based on existing cropping patterns and farmers’ preference for crops and trees. In drylands of Mandya the major crops cultivated were finger millet (grown by 79% of farmers surveyed), horse gram (50%), sorghum (16%), cow pea (15%), sesame (12%) and groundnut (6%), while in irrigated areas the major crops were paddy (grown by 50% of farmers surveyed), vegetables (35%), sugarcane (27%) and mulberry (7%). Preferences of farmers for trees (converted into scores based on ranking given by farmer), show that Ficus spp. and neem are highly preferred in unirrigated lands, while in irrigated areas high-value timber species such as teak and horticultural species such as

![Figure 2. Tree species preferred by farmers in dryland and irrigated lands of Mandya.](image)
Table 3. Farming systems selected for BCA and their costs and benefits.

| System                                           | Cropping season | Crops                                      | Trees                                           | Costs                                                                 | Benefits                                                                                           |
|--------------------------------------------------|-----------------|--------------------------------------------|------------------------------------------------|----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Agri-silviculture: Rainfed *Ficus* agroforestry (DF) | Kharif (Monsoon cropping) | Summer Sesame and horse gram Finger millet inter-cropped with sorghum, field beans and cow pea | Scattered *F. benghalensis* trees Tree density – 16/ha Rotation – 20 years | Labour and material inputs for planting, cultivation and harvest of trees and crops, yield loss due to drought (20%), yield loss due to tree canopy (20%) | Food grains, fodder from trees and crops, fire wood, small timber and indirect use benefit of litter nutrients |
| Plantation: Rainfed *Eucalyptus* hybrid (EU)       | Perennial       | Nil                                        | *Eucalyptus* hybrid Tree density – 2777/ha Four rotations in 20 years | Labour and material inputs for planting, watch and ward, thinning, pruning, harvest of trees | Pulpwood, fuelwood, stakes for tomato cultivation                                                  |
| Agri-silviculture: Borewell irrigated mulberry with teak (*Tectona grandis*) (MT) | Perennial       | Mulberry Line planting of *Tectona grandis* on bunds and boundaries Density – 160 /ha Rotation – 20 years | Installing and maintaining borewell irrigation, labour and material inputs for planting, management and harvest of tree, material and labour inputs for planting, management and harvest of mulberry | Mulberry leaves, fuel from mulberry, timber from teak, fuel wood from teak prunings and indirect use benefit of teak litter nutrients |                                                                                  |
| Agri-horticulture: Borewell irrigated paddy, finger millet and vegetables with coconut trees (PC) | Kharif          | Summer Finger millet (Short duration variety: INDAF – 9) Finger millet (Medium duration variety: Jaya) Rotations of vegetables – Tomato (variety Abhijit) and pumpkin (variety CO-1) | Line planting of coconut trees on boundaries Tree density – 40/ha | Installing and maintaining borewell irrigation, labour and material inputs for protection, planting, cultivation of crops and tree, harvest of crops and tree products, yield loss due to drought, pests and diseases | Food grains and fodder from crops, vegetables for sales, fruits, fuel etc. from coconut trees |
| Monoculture: Borewell irrigated Sugarcane (SC)     | Annual          | Monoculture of sugarcane (CO-62175) Nil | Installing and maintaining borewell irrigation, labour and material inputs for planting, cultivation and harvest | Sugarcane for market |                                                                                                     |
as coconut are preferred (Figure 2). Based on prevailing practices and preferences for crops and trees and also considering compatibility of each crop and tree with borewell irrigation, alternative non-\textit{Ficus} systems were selected for comparison with \textit{Ficus} based agroforestry, whose costs and benefits are outlined in Table 3.

### 3.2.1. Financial NPVs

Financial analysis of discounted costs and benefits under the five farming systems demonstrated that irrigated agroforestry systems is the most profitable among the land uses compared (Table 4). Borewell irrigated agri-silviculture system of mulberry with teak (MT) yielded the highest NPV and B: C ratios. Wood benefits from teak accounted for high returns from the system by virtue of high prices in local markets. In intensively managed agroforestry systems, survival rate of teak was as high as 90\% and the growth was also found to be better due to annual soil working (Shukla & Viswanath 2014). Besides, mulberry leaves have strong local markets in Mandya and gives annual returns on sales or can be alternatively used for sericulture as an additional income source. Thus, this system has the twin benefits of intermediate returns and a final large accrual of benefit from teak timber making it attractive in both short term and long term perspectives.

Irrigated agri-horticulture system of rice and finger millet with coconut trees on boundaries had the second highest NPVs and B: C ratios. Though the NPV was considerably less than that of mulberry + teak agri-silviculture, this system had the advantage of supporting food security of the farm household. Additionally, rotations of vegetables would serve the cash needs also. B: C ratio increased with increase in discount rate to 13\%, which suggest that this system is desirable for farmers preferring immediate returns due to annual benefits accrued from both trees and crops. In fact at higher discount rates B: C ratio is higher than the irrigated agroforestry system with teak.

Sugarcane monoculture had the lowest NPV and B: C ratios among all irrigated systems, though financially better than unirrigated systems. B: C ratio was lower compared to \textit{Ficus} agroforestry due to lower returns in proportion to the costs incurred. Sugarcane cultivation has been a highly preferred land use in Mandya since the spread of canal irrigation, earning the district the sobriquet ‘sugar bowl of Karnataka’. But sugarcane is highly vulnerable to pests and diseases and requires huge amount of chemical inputs and labour. Additionally, the production is solely market oriented and highly susceptible to price variations.

Among rainfed land uses \textit{Ficus} agroforestry with millets, pulses and legumes produced highest NPV at 3 and 7\% discount rates. \textit{Eucalyptus} plantations had slightly lower NPVs, probably due to absence of annual returns. But in terms of B: C ratios \textit{Eucalyptus} plantations emerged as a more cost-effective option, since after initial planting, costs are non-existent other than for final harvest. However when B: C ratios and NPVs are not in agreement, the

| System | Irrigation | NPV (INRs. in lakhs) | B: C ratio | Ranking (on NPV at 7%) |
|--------|------------|---------------------|------------|------------------------|
|        |            | 3% | 7% | 13% | 3% | 7% | 13% |                       |
| DF     | No         | 2.40 | 1.67 | – | 2.40 | 2.31 | – | 4 | |
| EU     | No         | 2.37 | 1.64 | – | 5.93 | 5.35 | – | 5 | |
| MT     | Borewell   | – | 15.25 | 8.84 | – | 5.94 | 4.58 | 1 | |
| PC     | Borewell   | – | 11.13 | 7.49 | – | 5.13 | 5.21 | 2 | |
| SC     | Borewell   | – | 5.73 | 3.60 | – | 1.90 | 1.80 | 3 | |
NPV criterion is usually given preference (Gittinger 1984), making *Ficus* agroforestry, a financially better option. Besides, compatibility of *Ficus* with staple food crops of Mandya finger millet and sorghum, has conferred this traditional land use a key role in catering to nutritional requirements of subsistence farming communities. Thus, *Ficus* agroforestry could be a more socially desirable land use compared to *Eucalyptus* plantations for drylands of Mandya. The results of financial analysis thus reinforce the finding of preliminary income analysis that for rainfed farmers without monetary resources for securing borewell irrigation facilities, *Ficus* agroforestry is a financially attractive proposition.

### 3.2.3. Economic NPVs

In economic analysis including land rent and shadow prices for family labour, external agricultural inputs and litter nutrient benefits, all farming systems yielded lower NPVs compared to financial NPVs (Table 5). *Ficus* has a very low NPV of Rs. 0.20 lakhs at 3% discount rate which makes it viable for sustainable farmers who view agriculture as means of subsistence, rather than a source of surplus cash income. But as discount rate goes up to 7%, this enterprise produced negative NPV indicating its non-viability at higher discount rates. B: C ratios plunged below one for *Ficus* agroforestry at both discount rates in economic analysis. Low/ negative NPVs and economically unviable B: C ratios are due to monetisation of family labour. *Ficus* agroforestry is labour intensive compared to *Eucalyptus* and depends on household labour for most of the agricultural operations.

Unirrigated *Eucalyptus* plantations gave better economic NPVs compared to *Ficus* agroforestry due to virtual absence of all labour and material costs other than at the time of tree planting and harvest. These activities mostly utilise hired labour and hence profitability of *Eucalyptus* plantation does not diminish in economic analysis. The profitability of irrigated land uses remains unchallenged in economic NPVs and B: C ratios also, with agri-silviculture system (MT) generating best economic returns, followed by agri-horticulture system (PC) and monoculture of sugarcane (SC). Economic NPV for PC is only half of its financial NPV at both discount rates owing to high-family labour requirements in this system. B: C ratio of irrigated land uses MT and PC declined drastically and approached that of SC in economic analysis because of higher costs including shadow prices for land, family labour, chemical nutrient inputs, electricity for irrigation pumpsets etc. Sugarcane's profitability in terms of B: C ratio did not vary much in economic analysis due to heavy dependence on hired labour for agricultural operations compared to household labour, which already had been accounted for in financial analysis.

### 3.2.4. Incremental NPVs

Incremental financial and economic NPVs at 7% discount rate were the highest for MT followed by PC and SC (Figure 3). *Eucalyptus* had negative financial incremental NPV, which

**Table 5. Economic BCA estimates of selected farming systems at different discount rates.**

| System | Irrigation | NPV (INRs. in lakhs) | B: C ratio | Ranking (on NPV at 7%) |
|--------|------------|----------------------|------------|-----------------------|
|        |            | 3%       | 7%       | 13%       | 3%       | 7%       | 13%       |            |
| DF     | No         | 0.20     | -0.14    | -         | 0.97     | 0.93     | -         | 5          |
| EU     | No         | 1.13     | 0.68     | -         | 1.60     | 1.50     | -         | 4          |
| MT     | Borewell   | -        | 10.50    | 4.98      | -        | 2.10     | 1.76      | 1          |
| PC     | Borewell   | -        | 4.60     | 2.61      | -        | 1.50     | 1.39      | 2          |
| SC     | Borewell   | -        | 2.17     | 1.23      | -        | 1.21     | 1.18      | 3          |
turned positive when shadow prices for non-traded inputs—land and family labour were included in economic NPV, owing to low household labour inputs required for this system compared to *Ficus* agroforestry.

Results of economic BCA thus show that if farmers have the required financial and physical resource (ground water table at extractable levels) endowments to acquire irrigation facilities, high-value agri-silviculture and agri-horticulture systems are financially and economically desirable. *Ficus* agroforestry is economically preferable in drylands, when alternative employment opportunities are less or nonexistent and consequently family labour has very low opportunity costs. In presence of strong labour markets *Eucalyptus* plantation turns out to be a more economically desirable option in drylands of Mandy. It makes economic sense for farmers facing labour constraints to take up *Eucalyptus* plantations if alternative better options are not available, as this system seems to benefit from lower labour requirements. Sharma (1993) also illustrated a similar trend of *Eucalyptus* plantations emerging more profitable than alley-cropped systems of *Eucalyptus* in economic analysis due to higher socio-economic costs for additional operations and inputs in agroforestry.

Primary survey shows that there are 263 person days per year available per family for surplus employment in Mandy. Hence opportunity costs for family labour are not significant in the current scenario in Mandy, which implies that practising *Ficus* agroforestry makes economic sense in addition to providing food security, economic stability and ecological sustainability. Low input sustenance systems could be socio-economically desirable in spite of low financial profits where labour has low opportunity costs (Chayanov 1966). But when policy measures increase the opportunity costs of labour; implementation of rural employment guarantee schemes for instance, practices like *Eucalyptus* plantations that are low on labour requirements becomes economically rewarding. Though a full-fledged social BCA was not attempted in the present study, economic BCA included the social cost of state subsidies for agro-chemicals and electricity that translated as avoided costs for farmer.
However, economic BCA excluded social benefits of carbon storage or biodiversity services and hence could be indicative of a lower bound estimate of social NPV of the agricultural systems compared.

4. Conclusions

The two unirrigated land use options compared in the present study, *Ficus* agroforestry and *Eucalyptus* plantation showed varying economic profitability, contingent on the availability of labour markets. In spite of lower economic NPVs it may be argued that *Ficus* agroforestry is a more socially desirable system, considering its low requirement of external inputs, resilience to risks such as water scarcity, pests and diseases and contribution to food security in addition to environmental benefits and economic desirability when household labour has low opportunity costs. More importantly, *Ficus* agroforestry is a more socially desirable system, considering its low requirement of external inputs, resilience to risks such as water scarcity, pests and diseases and contribution to food security in addition to environmental benefits and economic desirability when household labour has low opportunity costs. More importantly, *Ficus* trees are highly preferred by farmers in rainfed areas (Figure 2) and this per se is indicative of the social acceptability of this land use. A similar argument was made by Purushothaman (2005), in dry deciduous forest peripheries where millet based agroforestry system had lower NPVs compared to tree plantations but enjoyed higher stakeholder preference. Value assessment of exotic species like *Eucalyptus* based upon short-term gains from wood has suggested that exotic plantations are more profitable (Sangha & Jalota 2005). But long term sustainability concerns of such species including impacts on ecological functions such as water usage, understorey ground cover and allelopathic effects are to be accounted for a rationale judgement of land use reflecting all social costs and benefits (Shiva & Bandopadhyay 1987; Jalota & Kohli 1996; Sangha et al. 2000; Singh & Singh 2003).

Though results of economic analyses in the present study *prima facie* suggest that irrigated systems are more profitable, such generalisations may not be meaningful unless various trade-offs (vulnerability to risk at high-income level versus economic stability at low income level, ecological services versus disservices etc.) are rigorously analysed. Development of irrigation has generally been seen in terms of the positive benefits it provides through enabling the expansion and intensification of agriculture. However, this ignores the negative effects such as soil salinisation, depletion of ground water and salt water intrusion besides equity issues and loss of resilience of agricultural systems from high input use associated with irrigated agriculture (Perrings 1995, Kerr 1996; Urama 2005). Additional risks arise from drastic fluctuations in prices of irrigated crops such as sugarcane which are linked to the global market. Between April 2003 and January 2007, 57 farmer suicides have been reported from Mandya district (Assadi 2008), many of which are due to the indebtedness from cumulative crop loss caused by irrigation failure. Low input self-sustaining systems such as *Ficus* agroforestry may at least be able to maintain the current levels of income the farmers have, without making them vulnerable to increasing market risks and resource constraints encountered in irrigated agriculture. The need of the hour is to recognise such indigenous systems through appropriate policy incentives.

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