

Multifunctional agroforestry:

A new game-changer for attaining food security and environmental sustainability

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Agroforestry has witnessed challenges and changes every decade in the form of technology and marketing interventions. Although agroforestry is promoted for meeting food and nutritional security, it has become the need of the hour to promote multifunctional agroforestry with the main focus on small-scale farmers to provide income throughout the year. Keeping this in mind, a new circular-shaped multifunctional agroforestry was designed at Forest College and Research Institute, Mettupalayam, Tamil Nadu on 0.75 acres incorporating 25 tree species and 08 intercrops mainly to quantify ecosystem services, viz. provisioning services, regulating services, supporting services, and cultural services. In most of the agroforestry systems, the realistic values of supporting and cultural services are sidelined due to the utmost importance given to provisioning services. Therefore, this study has quantified ecosystem services and determined the holistic monetary value of multifunctional agroforestry for three years (2018–2021) as ₹374211.42.

Keywords: Family farming, Multifunctional agroforestry, Sustainability

Agroforestry is a prominent land-use strategy promoted for environmental, economic, and social benefits. It has always been in the limelight for its potential to provide food and nutritional security, reduce poverty and hunger, increase water quality, improve biodiversity, enhance soil health, and help address climate change issues. These benefits have been identified as a universal action in the UN 2030 sustainable development goals (SDGs). Out of 17 SDGs, 9 goals have been identified as potential options for which agroforestry-based ecosystem services are the major solution. However, since the inception of agroforestry, organized research has been focused on conventional Silvi-agri, Silvi-pasture, Silvi-horti systems, etc. It has also been noticed that, over the years, the importance of the study of indigenous agroforestry systems (AFS) like home gardens, shifting cultivation and taungya, khejri based agroforestry and alder based

systems which evolved without much intervention have also been side-lined. New concepts such as integrated farming systems, and urban and peri-urban agroforestry have emerged. In line with the newly emerged agroforestry systems, multifunctional agroforestry has gained significant attraction, especially in terms of multifaceted benefits, viz. wood or timber, fodder, vegetables, flowers, fruits, medicinal plants, etc.

Multifunctionality in agroforestry

The term multifunctionality was first introduced at Rio Earth Summit, in 1992. Further, the organization for economic cooperation and development (OECD) developed it in 1998. Since then, the term has gained importance in the future of agriculture and agroforestry development. Multifunctionality means the simultaneous provision of diverse outputs and consequent satisfaction of multiple demands



Field view and benefits reaped from multifunctional agroforestry

that have proven to strengthen livelihood of people and their sustainability. The concept of multifunctional agroforestry recognizes agroforestry as multiple output activity producing both commodity (tangible benefits) and non-commodity outputs (environmental and cultural services).

Need for multifunctional agroforestry

Currently, the area under agroforestry is 28.03 million hectares (mha) and it will be expanding shortly, which is estimated to be 53.32 mha in 2050. It is also estimated that the planet has to sustain around 9.8 million people by 2050. Therefore, the demand for food is expected to increase as population numbers grow. At the same time, climate change is taking a firmer hold, making farming more difficult and unpredictable for smallholder farmers, resulting in increased poverty and food insecurity. These small-scale farmers are the key to ensuring food security for many people living in poverty. Smallholders with less than 2 ha produce 70–80% of the world's food. They provide livelihoods to almost 2 billion women and men. Under such circumstances, multifunctional agroforestry will be a potential low hanging fruit to achieve food security and environmental sustainability

Criteria for selection

Keeping in view the innovations in agroforestry, the following factors were considered for selection of species in multifunctional agroforestry:

- The tree species favoured by farmers and adapted to suitable climatic and edaphic conditions were preferred
- Straight, medium to fast growing and species that allow light penetration for growth of intercrops.
- Species that provide short- and long-term income with potential economic and service benefits.
- The tree species with short to medium rotation were considered.
- Multiple tree species (fruits,

medicinal plants, tree borne oil seeds, timber, plywood, and fodder) were the option to cater multiple needs of the farmers.

- Prime importance was given to competition factors (water, nutrients and light). The multiple species leaf litter would also provide soil nutrients of varying properties on decomposition.

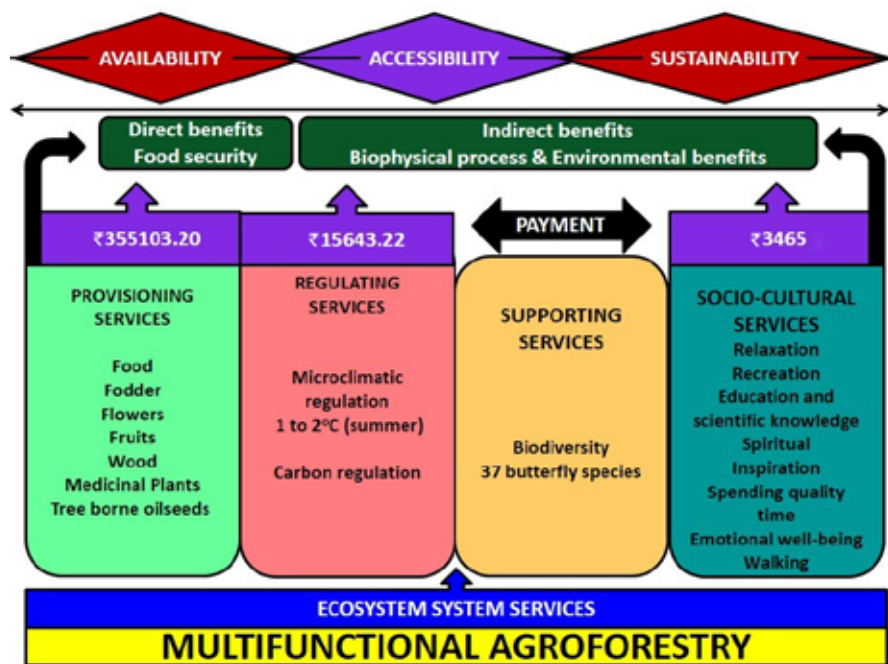
Design of multifunctional agroforestry model

Multifunctional agroforestry model (MFA) was developed at Forest College and Research Institute, Mettupalayam, Tamil Nadu, India especially designed on the concept of family farming and more specifically for small farmers. The designed MFA model comprises of 25 tree species and 08 intercrops covering 0.75 acre. It is designed in a circular shape and delineates

separate importance to each circle, viz. high valued tree circle, timber circle, plywood circle, medicinal plants, fruits circle and moringa circle. The entire multifunctional agroforestry is divided into four equal quadrats. The spacing between each circle is 5 m and each quadrat has different intercrops. Quadrat I is of flower block (*Jasminum grandiflorum*, *Jasminum officinale*), quadrat II is of vegetable block (crop selection differs for *kharif* and *rabi*), quadrat III comprises curry leaf (*Murraya koenigii*) and *Nerium oleander*, and quadrat IV is of fodder grass block, i.e. Guinea grass (*Megathyrsus maximus*) and *Desmanthus* (*Desmanthus virgatus*). The model is designed in such a way that, small farmers will be able to reap benefits and income from one or the other components round the year in the range of ₹450–900 per

Table 1. Categorization of species based on nature of ecosystem service in multifunctional agroforestry

Tree species	Spacing (m)	Number of trees/plant	Market price (₹)	Nature of service
<i>Moringa oleifera</i>	1 × 1	16	25	Food and fruit
<i>Murraya koenigii</i>	1 × 1	350	20	
<i>Aegle marmelos</i>	1 × 1	11	10	
<i>Psidium guajava</i> (L-49)	1.2 × 1.2	10	30	
<i>Annona squamosa</i> (APK-1)	1.8 × 1.8	10	70	
<i>Syzygium cumini</i>	2 × 2	10	-	
<i>Citrus limon</i>	2 × 2	6	-	
<i>Megathyrsus maximus</i> (CO-3)	0.8 × 0.8	Intercrop	2	Fodder
<i>Desmanthus virgatus</i>			3	
<i>Jasminum sambac</i> (Ramnad type)	1.2 × 1.2	72	215	Flower
<i>Jasminum grandiflorum</i> (CO-2)	0.8 × 2	104	220	
<i>Nerium oleander</i>	2.2 × 2.2	28	90	
<i>Terminalia arjuna</i>	1.8 × 1.8	11	10	Medicinal plants
<i>Justicia adhatoda</i>	1.8 × 1.8	11	10	
<i>Annona muricata</i>	1.8 × 1.8	11	-	
<i>Aegle marmelos</i>	2.0 × 2.0	11	10	
<i>Dalbergia latifolia</i> (DS 18)	3.5 × 3.5	12	-	High value timber
<i>Santalum album</i>	3.5 × 3.5	12	-	
<i>Pterocarpus santalinus</i> (TNRS 01)	3 × 3	12	-	
<i>Aquilaria malaccensis</i>	3 × 3	12	-	
<i>Tectona grandis</i> (MTP TK 07)	3 × 3	12	20000/t	Timber
<i>Swietenia macrophylla</i> (SM 20)	3 × 3	12	7000/t	
<i>Lagerstroemia lanceolata</i> (MTP 1)	3 × 3	12	8000/t	
<i>Gmelina arborea</i> (GA 08)	3 × 3	12	8000/t	
<i>Melia dubia</i> (MTP 2)	2.5 × 2.5	12	8500/t	Plywood
<i>Neolamarckia cadamba</i> (MTP 1)	2.5 × 2.5	12	6500/t	
<i>Toona ciliata</i> (TC 02)	2.5 × 2.5	12	8000/t	
<i>Acrocarpus fraxinifolius</i> (AF 07)	3.0 × 3.0	12	6000/t	
<i>Jatropha curcas</i> (JC 12; JC 13)	1 × 1	96	30	Tree borne oilseeds
<i>Calophyllum inophyllum</i>	1 × 1	5	-	
<i>Simarouba glauca</i> (MTP 1)	2 × 2	5	-	
<i>Pongamia pinnata</i>	2 × 2	10	-	
<i>Madhuca longifolia</i>	2 × 2	5	-	



Ecosystem service quantification from multifunctional agroforestry

day. This model not only provides monetary income but is also studied to quantify the services rendered by multiple sections (Table 1).

The main benefit of using a circular model of multifunctional agroforestry is that in a limited space, maximum number of tree, crop, fodder, flower and livestock components were included to cater both sustenance and economic farming. This design provides wide array of benefits economically (income throughout the year from multiple products such as wood, food, fodder, fruits, tree borne oilseeds), ecologically (carbon sequestration, habitat for biodiversity, soil and water conservation, nutrient cycling,

improving soil productivity and faunal activities) and sustainably (diversified production system that reduces risk associated with climatic vagaries and also reduces incidence of pest and diseases, breaks poverty and achieves food security in the long term).

Assessing ecosystem services

Agroforestry always aims at finding nature-based solutions and more specifically its external benefits can be broadly called ecosystem services. It is the direct and indirect contributions of an ecosystem to the human well-being. The Millennium Ecosystem Assessment (MEA) has indicated that approximately 60%, i.e. 15 out

of 24 ecosystem services are being degraded or unsustainably used as a result of agricultural management and other anthropogenic activities. MEA classified ecosystem services as provisioning services, regulating services, supporting services and cultural services. Since then, quantifying ecosystem services has gained significant attraction in agroforestry systems. However, studies on provisioning services and carbon regulation in agroforestry systems have been documented widely. Therefore, in this study, ecosystem services as a whole were quantified and economically valued (excluding establishment cost as services are only accounted) in the MFA model between 2018 and 2022.

Provisioning services: These are quantified as the tangible benefits of food, fodder, flowers, fruits, tree borne oilseeds, timber, plywood and moringa. The products were given monetary values based on the current price in market and an overall provisioning service generated from multifunctional agroforestry was ₹355103.20 at the end of three years.

Regulating services: These are the benefits obtained from the ecosystem that modulates the environment a favourable condition to live, viz. regulation of air, water and climate, soil fertility, carbon sequestration, pollination, flood control, pest, and disease regulation and water quality regulation. Agroforestry is known for improving the resilience of small farmers by moderating micro-

Table 2. Economic valuation of ecosystem services from multifunctional agroforestry

Ecosystem services	Service nature/ category	Nature of benefit	Valuation method	Economic valuation (₹)			
				I year	II year	III year	Total
Provisioning	Timber	Direct	Market price	-	28446.00		28446.00
	Food			-	27732.50	101305.00	129037.50
	Fruits			-		7180.00	7180.00
	Flowers			59000.40	117792.00	176792.40	
	Fodder			4788.00	7865.00	12653.00	
	Medicinal plants			-	692.00	692.00	
	Tree borne oilseeds			78.10	224.20	302.30	
Economic value of provisioning services from multifunctional agroforestry							355103.20
Regulating	Carbon stock	Indirect	Carbon price	-	-	15643.22	15643.22
Socio-cultural	Recreation		Willingness to pay	-	-	3465.00	3465.00
Total estimated economic value of ecosystem services from multifunctional agroforestry							374211.42

climatic conditions, improving productivity and mitigating climate in the long run. Similarly, the multifunctional agroforestry model has regulated the temperature to the tune of 1–2°C in summer. The vegetation composition in multifunctional agroforestry has ability to sequester 2.23 tonnes of carbon from 235 multi-utility trees and shrubs and 124 trees of tree borne oilseeds. The change in soil organic carbon stock over 3–4 years was 32.05 mg/ha. Reducing emissions from deforestation and forest degradation (REDD), a United Nations-based mechanism implemented a carbon market (an individual or company can sell carbon stored and receive an amount for every tonne of carbon sequestered). Therefore, revenue generated from the sale of carbon would be a supplementary benefit for the farmers. Henceforth, the total carbon revenue from the multifunctional agroforestry model (monetary benefits) were estimated as ₹2798.20 (vegetation) and ₹12845.02 (soil organic carbon).

Supporting services: These are the factors responsible for production of oxygen, habitat provision, soil

formation and nutrient cycling. Multifunctional agroforestry was able to produce oxygen of 5.92 tonnes from 0.75 acre. Moreover, the diversified vegetation complexity has attracted 37 different butterfly species during the migratory season which was counted based on the pollard walk method. Butterfly communities respond to both land-use type and management intensity, at local (field) and landscape level.

Cultural services: The physical, emotional and mental benefits generated by cultural services are subtle and intuitive in nature and the opinion differs with individual visitors which changes over a timespan. In other words, the non-immaterial benefits obtained from any ecosystem are referred as cultural services. The aesthetic and recreational benefits from multifunctional agroforestry were qualitatively surveyed through questionnaire methods by conducting awareness workshops (105 respondents from national and international experts, farmers and local people). Respondents' willingness to pay (WTP) depicted an average of ₹33 per visit for enjoying socio-cultural services

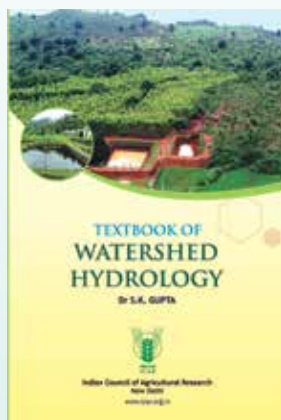
from a multifunctional agroforestry model. Holistically, in three years (2018–2021), the monetary value of ecosystem services from multifunctional agroforestry was ₹374211.42 (Table 2).

SUMMARY

There is accumulation of evidence on agroforestry supporting ecosystem services and attaining food security. However, paucity of evidences as a whole on multifunctional agroforestry for small holders and ecosystem services persists. In the era of environmental and ecological sustainability, agroforestry models are an alternative to traditional systems that offer various ecosystem services, alleviate poverty and ensure sustainable income rendering benefits to the society. Moreover, mainstreaming such multifunctional agroforestry in different regions of the country in a focussed way will help to meet the gaps and upscale multifunctional agroforestry in a coordinated manner.

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