



Identifying the Traditional and Existing Tree–Crop Combination of Agroforestry System in Southern Part of Chhattisgarh, India

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Authors' contributions

This work was carried out in collaboration among all authors. Author Kamesh gathered initial information, analysed the information and wrote the draft of the manuscript. Author SN designed the study and finalized the manuscript. Author BPS did the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The present study was conducted in Bastar district of Chhattisgarh to identify the traditional and existing agroforestry practices used by farmers. The data were collected through survey of field visits and filled out of pre-prepared questionnaires in four blocks of Bastar district, namely

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Jagdapur, Bastar, Tokapal and Bakawand. The survey revealed six different types of agroforestry system practices i.e., agrisilviculture, agrisilviculture, silviculture, agrisilvipastoral, silvicultipastoral, and agrisilvicultipastoral. Among these, 67% of farmers were practiced agrisilviculture-type agroforestry systems. Farmers in Bastar were found to use 29 different tree crops, 17 horticultural crops, 20 vegetable crops, and 11 agricultural crops in their fields.

Keywords: Agroforestry; bastar; cropping patterns; livelihood security; sustainability; tree-crop interaction.

1. INTRODUCTION

India, with a population of about 1.43 billion [1], faces immense pressure on food, water, land, and air quality [2,3], leading to the deterioration of natural resources. Deforestation for infrastructure, industrial expansion [4] and extensive agriculture disrupts environmental sustainability. Agroforestry enhances biodiversity by providing diverse plant species for fauna [5-8] and is a sustainable land use approach combining agricultural and woody components like home gardens, hedges, multistoried cropping, windbreaks, shelterbelts, border planting, and strip planting [9]. Agroforestry It defined as an agroforestry system is a collective land use where field crops are planted alongside trees and woody perennial plants [10,11]. It offers multifunctional benefits, including soil erosion control [12,13], organic matter enrichment [14], and shade, fodder, and biodiversity conservation [15-18]. A study showed agroforestry supports wild bees by providing food and nesting resources [19]. Several problems are facing that the natural resources, i.e., water erosion; soil erosion, landslides, deposition of air pollutants, and biotic pressure, but agroforestry can help against these problems in different ways, such as recharge groundwater, improve soil health by providing soil nutrients, and help to reduce air pollution by absorbing air pollutants on the leaves through providing large leaf area [20]. Agroforestry system selection depends on factors like farm topography, soil properties [21], agro-climatic features, labor, irrigation, and farm size etc. [21-23]. Different types of agroforestry systems practiced in India include agrisilviculture (crops + trees), silvipastoral (livestock + trees), agrisilviculture (crops + horticulture + trees), agrisilvipastoral (crops + livestock + trees), agrisilvicultipastoral (crops + horticulture + livestock + trees), and silviculture (horticulture + trees) [24-26].

The study was conducted in Bastar, Chhattisgarh, known for its world famous

traditional tribal culture and hand-made art crafts [27]. Bastar covers 403,003 hectares, with 20.83% forest, 17.63% uncultivated land, 10.69% agricultural land, and 5.10% wasteland [28]. The area is falling under the Tropical Moist Deciduous forest type specially dominated by Sal trees (*Shorea robusta* Roth), and other species *Bauhinia variegata* (L.) Benth, *Tectona grandis* L.f., *Pterocarpus marsupium* Roxburgh, *Terminalia elliptica* Willd, *Anogeissus latifolia* (DC.) Wallich ex Guil. Et Perr., *Madhuca indica* J.F. Gmel., *Diospyros melanoxylon* Roxb., *Embilica officinalis* Gaertn., *Cleistanthus collinus* (Roxb.) Benth. Ex Hook. F., *Tamirindus indica* L., *Acacia nilotica* (L.) Willd. Ex Delile., *Acacia catechu* (L.) Willd., Oliv., *Mangifera indica* L., *Terminalia arjuna* (Roxb.) Wight & Arn., and *Dendrocalamus* Nees available either fields bunds or boundary. The region's soils include entisol, inceptisol, and alfisol, with nitrogen, phosphorus, and potassium levels ranging from 188.6-276.64, 7.62-10.72, and 121-242.5 kg/ha, respectively. Major crops include rice, maize, and millets during the monsoon season, and wheat, maize, moong bean, and vegetables in other seasons. Agroforestry has been promoted for three decades in the Country to raise farmers' incomes [5,29]. Hence, this research designed with the aim to identify tree-crop combinations practiced in agroforestry at Bastar.

2. MATERIALS AND METHODS

The study was carried during the period of 2016-17 in Bastar district (Chhattisgarh), located at 19°10'71" N latitude and 81°95'35" E longitude at an altitude of 850 meter. The district experiences an average annual rainfall and temperature was 1250 mm and 18.9°C - 34.1°C respectively. Twelve villages were randomly selected from each blocks of Bastar district (Table 1 and Fig. 1). Twenty five farmers from each block were randomly selected based on availability of different tree-crop combination in their farming systems. The survey was conducted through regular visits to farmers' fields during which questionnaires were filled out by

interviewing the farmers [30]. The questionnaire covered different aspect of agroforestry such as available tree species on the farm, crops grown, mixed cropping techniques, utilization of tree products, income from tree produces.

3. RESULTS AND DISCUSSION

The result was revealed in agroforestry system practiced by the farmers of different blocks. The maximum number of farmer practiced agrisilvihorticulture system about 67 % while the 23% aagrisilviculture system, 7% silvihorticulture system, 1% agrisilvipastoral, 1% silvihortipastoral, 1% agrisilvihortipastoral system were recorded (Fig. 2). Adaptation of suitable agroforestry system have been depending upon the various factors i.e. topography of the farm, physiochemical properties of soil, agro-climatic

features of the regions, availability of labour and irrigation facilities, and size of the farm etc [20]. The dependency of farmers on agrisilvihorticulture system was highest due to the their diversified produces such as tree provides wood for their house construction and making agriculture implements, crops provided food grains, and horticulture system provides fruits, flowers, vegetables for selling [31]. The Bastar area employs a wide range of agro - forestry approaches. The selection of tree species varies from based on site to site, need of the farmer, and their socioeconomic considerations [24,32]. This gives several examples of where farmers in the area have successfully used traditional agro - forestry techniques and indigenous techniques and agroforestry systems plays crucial role in ensuring the sustainability in resources for livelihood [33].

Table 1. Blocks and villages were selected for surveyed during the study

SI. No.	Blocks	Villages
1	Jagdapur	Pandripani, Parpa, Pamela, Karkapal, Lamni, Sargipal, Neeyanar, Podaguda, Asana, Turenar, Ghatpadmur, Nagarnar
2	Bastar	Marlenga, Chokar, Bharni, Mondapal, Bastar, Bhirlinga, Mohpal Barai, Khatpal, Kudkanar, Ghatlohanga, Kaviaashana, Parchanpal
3	Bakawand	Bakawand, Sautpur, Karpawand, Chiurgaon, Chhotedevda, Kumharawand, Dumarguda, Sonpur, Kaundawand, Narawand, Mangarguda, Kosmi
4	Tokapal	Tekameta, Chotemorthpal, Telimarenga, Kalepal, Bhaluguda, Karanji, Bademorathpal, Padarguda, Koynar, Kalepal, kuranga, Burungpal

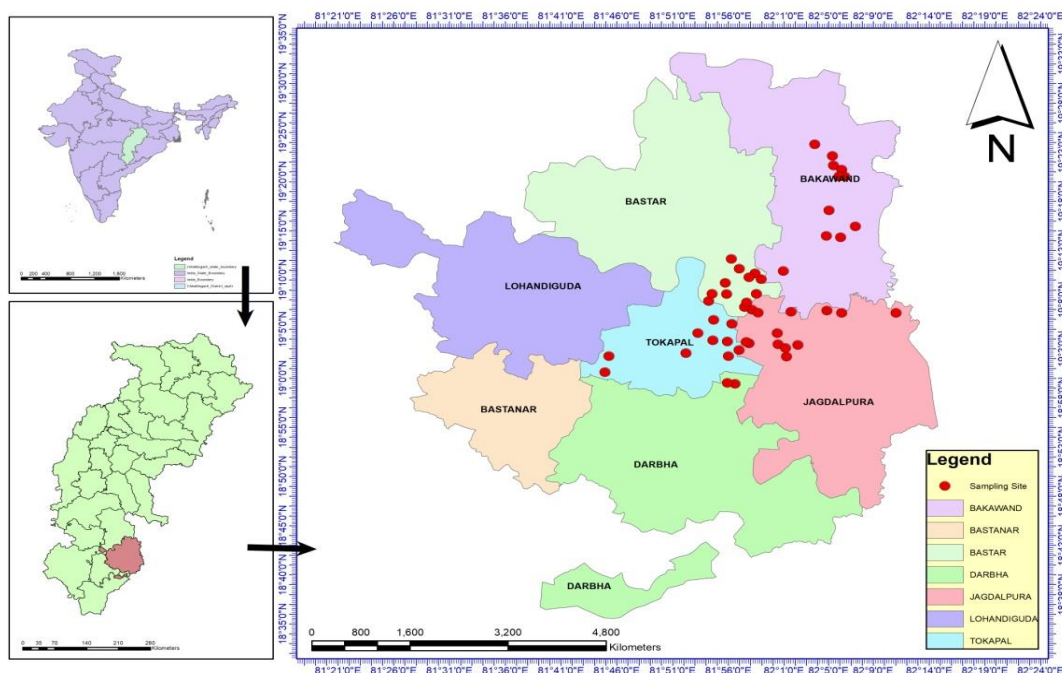


Fig. 1. Map of the study sites

3.1 Tree-Crop Combination Practiced in Agroforestry System

The study was revealed the six type of agroforestry system practiced by the farmers in Bastar such as agrisilvihorticulture, agrisilviculture, silvihorticulture, agrisilvipastoral, silvihortipastoral, and agrisilvihortipastoral. The maximum variation in species of agroforestry system was recorded in agrisilvihorticulture. Whereas 29 tree species, 17 horticultural crops, 20 vegetables crop species and 11 agricultural crops were used in tree-crop combination system. *Mangifera indica* and *Eucalyptus* tree species was reported almost all type of agroforestry system while the other trees such as *Phoenix sylvestris*, *Acacia nilotica*, *Schlecharia oleaosa*, *Caryota urens*, *Cocos nucifera*, *Terminalia tomentosa*, *Psidium guajava*, *Ziziphus marutiana*, *Moringa olifera*, and *Bombax ceiba* practiced in scattered form or on the bunds in an agroforestry system. Frequency of tree species present in an agroforestry system were also recorded (Fig. 3).

This study was reported the combination of agriculture crops, horticulture crops and tree

species practiced on the field of farmers in Bastar region as shown in Table 2 and Figs. 4 & 5. Agroforestry system provide wide range of benefits to the farmers such as food for life, woods for furniture and construction home, fruits for nutrition, etc. Similarly investigation were reported on the hortsilviculture based agroforestry models whereas horticulture species includes *Emblca officinalis*, *Psidium guajava*, *Punica granautum*, *Aegle marmelos*, *Z. mauritiana* combination with trees species includes *T. grandis*, *G. arborea*, *A. lebbeck*, *T. arjuna* and *A. nilotica* on the field [33].

Studied in Bastar region on different aspect of agroforestry system and reposted the agrisilvihorticulture system were highly practiced with the combination of tree species like *Acacia auriculiformis* *Psidium guava*, *Tectona grandis*, *Cocos nucifera*, with the horticultural fruits crops like *Punica granatum*, *Anacardium occidentale*, *Emblca officinalis*, *Manilkara achras*, *Mangifera indica*, *Psidium guava*, *Terminalia Arjuna*, *Tamarindus indica*, *Terminalia belerica*, *Litchi chinensis* [24].

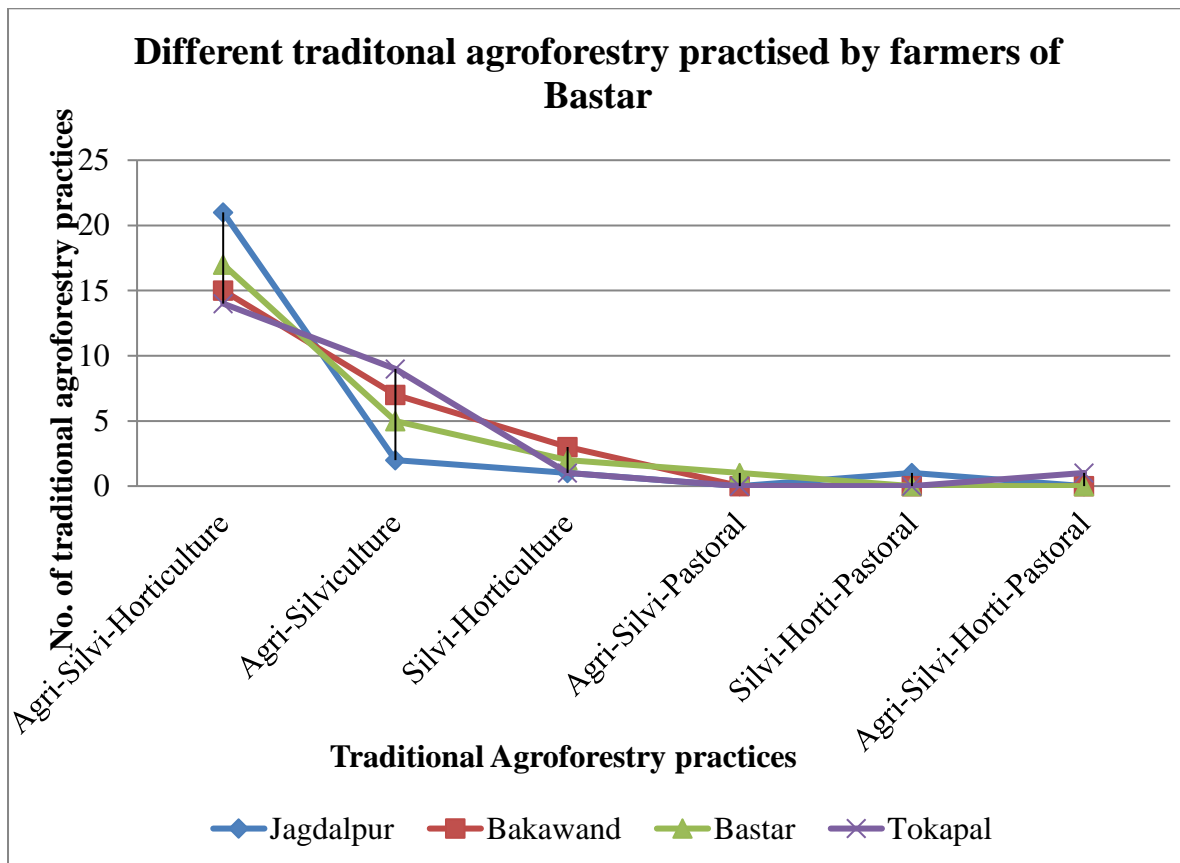


Fig. 2. Different agroforestry systems were used by farmers of Bastar

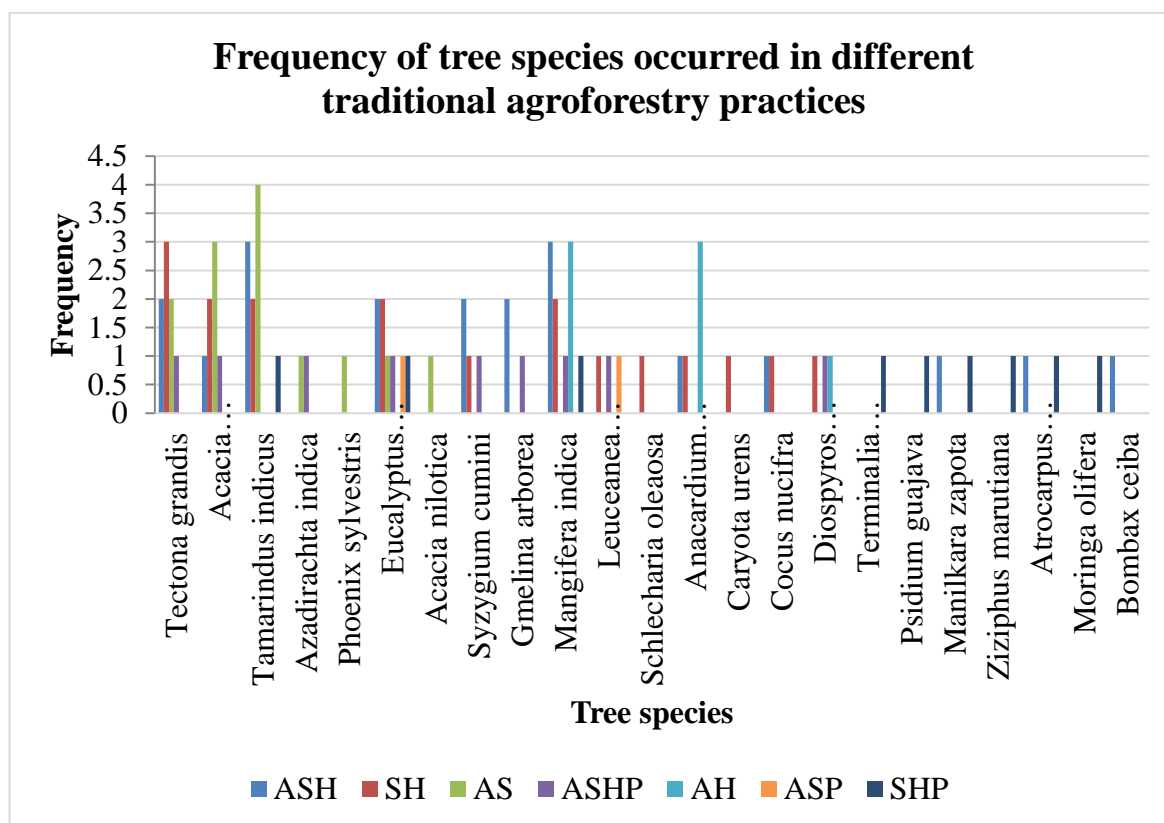


Fig. 3. Frequency of tree species occurred in different agroforestry system (ASH- agrisilvihorticulture, SH- silvihorticulture, AS- agrisilviculture, ASHP- agrisilvihortipastoral, AH- agrihorticulture, ASP- agrisilvipastoral, and SHP- silvihortipastoral).

Table 2. Tree- crop combination practiced by the farmers of Bastar in various Agroforestry systems

Sl. No.	Agroforestry System	Combination of trees, horticultural crops, agricultural crops and fodder crops on the same piece of land in same time
1	Agrisilviculture system	<i>Tectona grandis</i> + <i>Oryza sativa</i> / <i>Zea mays</i>
		<i>Tamarindus indicus</i> + <i>Eucalyptus tereticornis</i> + <i>Manihot esculenta</i>
		<i>Phoenix sylvestris</i> + <i>Oryza sativa</i>
		<i>Acacia nilotica</i> + <i>Oryza sativa</i>
		<i>Eucalyptus tereticornis</i> + <i>Oryza sativa</i>
		<i>Azadirachta indica</i> , + <i>Tamarindus indica</i> + <i>Saccharum officinarum</i>
		<i>Acacia auriculiformis</i> + <i>Zea mays</i> / <i>Oryza sativa</i> / <i>Saccharum officinarum</i>
		<i>Tamarindus indica</i> + <i>Zea mays</i> / <i>Zingiber officinales</i>
2	Silvihorticulture system	<i>Tectona grandis</i> + <i>Mangifera indica</i> / <i>Capsicum annum</i>
		<i>Syzygium cumini</i> + <i>Capsicum annum</i>
		<i>Eucalyptus tereticornis</i> + <i>Momordica charantia</i> + <i>Abelmoscus esculentus</i>
		<i>Acacia auriculiformis</i> + <i>Abelmoscus esculentus</i>
		<i>Anacardium occidentale</i> + <i>Abelmoscus esculentus</i>
		<i>Gmelina arborea</i> + <i>Abelmoscus esculentus</i> / <i>Capsicum annum</i>
		<i>Caryota urens</i> + <i>Cocus nucifera</i> + <i>Vigna anguiculata</i>
		<i>Tectona grandis</i> + <i>Tamarindus indicus</i> + <i>Leucaena luecocephala</i> + <i>Schleichera oleosa</i> + <i>Semecarpus anacardium</i> + <i>Litchi chinensis</i> + <i>Manilkara zapota</i> + <i>Mangifera indica</i> + <i>Syzygium cumini</i> + <i>Psidium</i>

Sl. No.	Agroforestry System	Combination of trees, horticultural crops, agricultural crops and fodder crops on the same piece of land in same time
		<i>guajava</i> + <i>Carissa carandus</i> + <i>Capsicum annum</i> + <i>Abelmoscus esculentus</i>
		<i>Mangifera indica</i> + <i>Abelmoscus esculentus</i> + <i>Polianthes tuberosa</i> <i>Eucalyptus tereticornis</i> + <i>Acacia auriculiformis</i> + <i>Caryota urens</i> + <i>Tamarindus indicus</i> + <i>Diospyros melonoxylon</i> + <i>Mangifera indica</i> + <i>Anacardium occidentale</i>
3	Agrisilvipastoral System	<i>Eucalyptus tereticornis</i> + <i>Leucaena leucocephala</i> + <i>Oryza sativa</i> / <i>Zea mays</i> + <i>Ipomoea batatas</i> + <i>Nepiar grass</i>
4	Silvihortipastoral system	<i>Eucalyptus tereticornis</i> / <i>Tamarindus indicus</i> + <i>Terminalia tomentosa</i> + <i>Mangifera indica</i> + <i>Manilkara zapota</i> + <i>Psidium guajava</i> + <i>Cynadon dactylon</i> / <i>Nepiar grass</i>
5	Agrisilvihortipastoral system	<i>Azadirachta indica</i> + <i>Eucalyptus tereticornis</i> / <i>Diospyros melonoxylon</i> + <i>Leucaena leucocephala</i> (Fodder) + <i>Ziziphus mauritiana</i> + <i>Atrocarpus heterophyllus</i> / <i>Syzygium cumini</i> + <i>Allium cepa</i> + <i>Abelmoscus esculentus</i> / <i>Phaseolus species</i> + <i>Oryza sativa</i> / <i>Zea mays</i> + <i>Saccharum officinarum</i> / <i>Cynadon dactylon</i> (Fodder)
		<i>Tectona grandis</i> / <i>Gmelina arborea</i> + <i>Acacia auriculiformis</i> + <i>Mangifera indica</i> + <i>Moringa oleifera</i> + <i>Cocus nucifera</i> / <i>Vigna anguilata</i> + <i>Oryza sativa</i> / <i>Zea mays</i> + <i>Cynadon dactylon</i> / <i>Pennisetum glaucum</i>
6	Agrisilvihorticulture system	<i>Tamarindus indicus</i> + <i>Capsicum annum</i> + <i>Zea mays</i> + <i>Helianthus annus</i>
		<i>Tamarindus indicus</i> + <i>Eucalyptus tereticornis</i> + <i>Acacia auriculiformis</i> + <i>Mangifera indica</i> + <i>Atrocarpus heterophyllus</i> + <i>Syzygium cuminii</i> + <i>Zea mays</i>
		<i>Tamarindus indicus</i> + <i>Gmelina arborea</i> / <i>Tectona grandis</i> + <i>Cocus nucifera</i> + <i>Atrocarpus heterophyllus</i> + <i>Mangifera indica</i> + <i>Manilkara zapota</i> + <i>Oryza sativa</i> / <i>Zea mays</i>
		<i>Gmelina arborea</i> + <i>Tectona grandis</i> + <i>Eucalyptus tereticornis</i> + <i>Bombax ceiba</i> + <i>Mangifera indica</i> + <i>Anacardium occidentale</i> + <i>Syzygium Cuminii</i> + <i>Oryza sativa</i>

The agroforestry systems have used to intensify in the farming system by maximizing of resources. The agroforestry system was a very promising method for Mediterranean areas with intercropping, such as growing olives with grain crops like barley and mixes of barley and leguminous plants [34]. Landscapes for agriculture have always included windbreaks as a vital component. Among its many functions are crop protections from wind, conserving habitats for biodiversity, safeguarding against soil erosion, and creating microclimates that mitigate the impact of adverse weather conditions [35,36].

3.2 Benefits from Tree in an Agroforestry System

This study found that trees on agricultural farms, whether naturally occurring or planted, have varied uses. It revealed that the economic and ecological importance of various tree species and their market values (Table 3). These trees

offer a range of benefits, including timber, fuel wood, fruits, fodder, medicinal products and beverages. Marketable values include mango fruit (80-100 INR/kg), dried jamun seeds (42 INR/kg), tendu patta (4000 INR/standard bag), neem seeds (27 INR/kg), ber fruit (40-80 INR/kg), and mahua flower (30 INR/kg). Some products, such as teak timber and eucalyptus oil, have unspecified market values. Farmers benefited from these trees and agroforestry, which can be combined with a variety of crops. The study found that most farmers in Bastar district expressed a desire to plant tree species like *Tamarindus indica*, *Mangifera indica*, *Artocarpus heterophyllus*, *Anacardium occidentale*, *Caryota urens*, *Madhuca indica* and *Diospyros melanoxylon* in their fields based on their needs.

According to CAFRI, Jhansi, there are 1,023 million hectares of agroforestry globally, with 13.75 million hectares in India. It indicate hadly

10% of India's agricultural areas are covered with agroforestry [37]. Agroforestry systems produce high-quality fruits, vegetables and lumber [38], interacting with ecosystem functions and contributing to sustainable agriculture [39]. Silvopasture, an agroforestry practices, combines tree benefits (timber production) with livestock production including meat and dairy

[40]. Similarly, agrisilviculture models enhance the quality of both agricultural grains and timber, resulting to higher profits per unit of land for farmers [41]. Due to the diverse range of products, agroforestry also offers nutritional security. The normative return from cultivating vegetables is higher than that of ordinary field crops [42].



***Tectona grandis* with *Abelmoscus esculentus* in Neeyanar**



***Mangifera indica* with *Tagest* species in Pandripani**



***Acacia auriculiformis* with *Zea mays* in Tekameta**



***Tamarindus indicus* with *Capsicum annum* in Aashana**



***Eucalyptus teretocornis* with Bitter gourd in Ghatpadmur**



***Acacia auriculiformis* with *Abelmoscus esculentus* in Karanji**



***Acacia auriculiformis* with *Oryza sativa* in Tekameta**



***Mangifera indica* with *Cymbopogon flexuosus* in Kodipara**

Fig. 4. Agroforestry systems using by farmers of Bastar



***Mangifera indica* with *Solanum melongina* in Pandripani**



***Tectona grandis* with *Capsicum annum* in Bastar**



***Anacardium occidentale* with *Cymbopogon flexuosus* in Kodipara**



***Tamarindus indica* with *Zingiber officinalis* in Kodipara**



***Tectona grandis* with *Mangifera indica* in Mohpal Barai**



***Mangifera indica* with *Zea mays* in Bastar**



***Mangifera indica* with *Curcuma longa* in Sargipal**



***Syzygium cumini* with *Capsicum annum* in Pandripani**

Fig. 5. Agroforestry system using by farmers of Bastar

Table 3. Farmers of Bastar used of tree species for different purposes

Tree species	Common name	Uses	Marketable value (In INR)*
<i>Mangifera indica</i>	Mango	Fuel wood, fruit	80-100/ kg
<i>Leucaena leucocephala</i>	Subabul	Fodder, fuel wood	-
<i>Syzygium cumini</i>	Jamun	Fruit	Dried seeds- 42/ kg
<i>Bombax ceiba</i>	Semul	Timber, fibre	-
<i>Acacia auriculiformis</i>	Australian babul	Timber, fuel wood	-
<i>Diospyros melonoxylon</i>	Tendu	Fruit, timber, fuel wood, tendu patta	4000/standard bag
<i>Azadirachta indica</i>	Neem	Timber, medicinal value, Seeds	Seeds- 27/ kg
<i>Ziziphus mauritiana</i>	Ber	Timber, fruit, fodder	40-80/ kg
<i>Terminalia tomentosa</i>	Saja (Aasan)	Timber, silk rearing, fuel wood	Silk rearing- 400/ 100 pieces
<i>Tectona grandis</i>	Teak	Timber	-
<i>Gmelina arborea</i>	Khamhar	Timber, fodder	-
<i>Eucalyptus tereticornis</i>	Nilgiri	Timber, oil extraction	-
<i>Cocus nucifera</i>	Coconut	Fruit	50/ piece
<i>Moringa oleifera</i>	Drum stick	Fruit	50-80/ kg
<i>Atrocarpus heterophyllus</i>	Jack fruit	Fruit, fuel wood	50-60/ kg

Tree species	Common name	Uses	Marketable value (In INR)*
<i>Tamarindus indicus</i>	Imli	Fruit pulp, fuel wood, seeds, flower	Seeds- 36/ kg Flower- 63/ kg Pulp- 35-40/ kg
<i>Psidium guajava</i>	Guava	Fruit	50-80/ kg
<i>Schleichera oleosa</i>	Kusum	NWFP, Lac production	Lac- 300-400/ kg
<i>Semecarpus anacardium</i>	Bhelva	Fuelwood, fruit	9/ kg
<i>Manilkara zapota</i>	Sapota	Fruit	80-100/ kg
<i>Litchi chinensis</i>	Litchi	Fruit	80-100/ kg
<i>Phoenix sylvestris</i>	Chhind or silver date palm	Fruit, beverage	Beverage- 40.00/ litre
<i>Madhuca india</i>	Mahua	Seeds, Flower, beverage	Seeds -29/ kg Flower-30/ kg Beverage – 60/ litre
<i>Caryota urens</i>	Sulfi	Beverage	80-10/ litre
<i>Shorea robusta</i>	Sal	Seeds	20/ kg

*Source of marketable value – local market and Chhattisgarh minor forest produce limited [43].

4. CONCLUSION

Agroforestry is a dynamic and sustainable land management system that involves deliberately growing of woody perennials along with agricultural crops on farmlands to secure both direct and indirect benefits for farmers. This study reported the identification and documentation of patterns of tree-crop combinations used in the agroforestry system by the farmers of Bastar District. The agrisilviculture agroforestry system was mostly practiced throughout the Bastar district, and *Tectona grandis*, *Shorea robusta*, *Eucalyptus tereticornis*, *Phenix sylvestris*, *Mangifera indica*, *Syzygium cuminii*, *Gmelina arborea*, *Pongamia pinnata*, *Tamarindus indica*, *Bambosa bambos*, *Ancardium occidentale*, *Terminalia arjuna*, *Terminalia balerica*, *Madhuca indica*, *Acacia auriculiformis*, and *Acacia nilotica* tree species were grown by the farmers on their field.

These practices contribute to enhance carbon sequestration, mitigate climate change and improve environmental health by increasing biodiversity and soil fertility.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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