ICAR Certified CAFRI Technologies – A Gist

ICAR-Central Agroforestry Research Institute
Jhansi, Uttar Pradesh

Technology: Development of an android based 'Learn Agroforestry' mobile *app* for Capsule Course on Agroforestry

ICAR-Certificate Number: ICAR-NRM-CAFRI-Product--2024-063

ICAR-CAFRI Technology Registration Number: ITMU/2023/020

About Technology

The rapid digitalization of India, with over one billion smartphone users, presents a significant opportunity for expanding agroforestry education and awareness. To leverage this potential, ICAR-Central Agroforestry Research Institute (ICAR-CAFRI), Jhansi, has developed an Android-based mobile application titled 'Learn Agroforestry' as part of its broader capacity-building initiative. This mobile app serves as an accessible learning platform for a capsule course on agroforestry, enabling a wider outreach to students, researchers, and professionals interested in agroforestry research and development methodologies.

The app provides users with structured access to educational resources, including lecture notes and reading materials curated specifically for the capsule course. Designed using open-source technologies such as Ionic v6, Cordova v11, Java v11.0.17, Gradle v6.8.2, Android Studio (Electric Eel | 2022.1.1), and Visual Studio Code, the application is currently available for free download on the Google Play Store and the official ICAR-CAFRI website.

The mobile app features four primary sections: (i) About the Course, which outlines the objectives and structure of the capsule course; (ii) Registration Form, offering a downloadable form for course enrollment; (iii) Lecture Notes, providing registered users access to curated learning materials; and (iv) Contact Us, which lists the names and contact details of the course coordinator and director for user support and inquiries.

In addition to independent use, the course is also available for delivery through other institutions on a nominal cost basis, depending on demand. This digital initiative represents a significant step toward democratizing agroforestry education and aligns with ICAR-CAFRI's mandate to strengthen training and knowledge dissemination in agroforestry science.

Source: Learn Agroforestry - Apps on Google Play
Learn Agroforestry mobile *app*
(https://play.google.com/store/apps/details?id=com.agroforestry.course&hl=en-US&pli=1)

Technology: Novel kit for tree plantation and breeding of agroforestry

ICAR-Certificate Number: ICAR-NRM-CAFRI-Product-2024-067

ICAR-CAFRI Technology Registration Number: ITMU/2023/016, ITMU/2023/017

About Technology

The "Novel Kit for Tree Plantation and Breeding of Agroforestry" is a comprehensive, multipurpose tool kit developed by ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi, to support the operational needs of nursery management and tree plantation activities. This specially assembled kit is designed to cater to a wide range of users—including commercial nursery growers, forestry and agriculture students, urban gardeners, and agroforestry practitioners. Each tool in the kit has been carefully selected for its practical utility, ergonomic design, and user-friendliness. These tools are essential for routine nursery and plantation tasks such as seed sowing, pot filling, seedling transplanting, pruning, and soil handling. The primary focus of the kit is to enhance work efficiency while ensuring comfort and ease of use for both beginners and experienced users in the field.

To facilitate portability and convenience, all tools are packed in a specially designed, compact, durable, and water-resistant bag. This practical carrying solution protects the tools from environmental damage and ensures they can be easily transported to nursery or plantation sites. The compact design makes it particularly suitable for urban gardening, small-scale farm activities, and student training programs. This kit plays a significant role in hands-on education and training. It allows students in disciplines such as Forestry and Agriculture to gain practical experience in nursery operations, thereby strengthening their skills and understanding of agroforestry systems. The organized and accessible layout of the kit also makes it a valuable resource for home gardeners and practitioners managing small-scale plantations.

By assembling this practical tool kit, ICAR-CAFRI has taken a significant step toward modernizing nursery and plantation practices. The initiative aims to bridge the gap between traditional methods and contemporary needs, offering a ready-to-use, field-friendly solution that promotes sustainable agroforestry practices. Whether used in academic settings, commercial nurseries, or urban green spaces, the kit supports a more efficient, organized, and accessible approach to tree planting and nursery management.

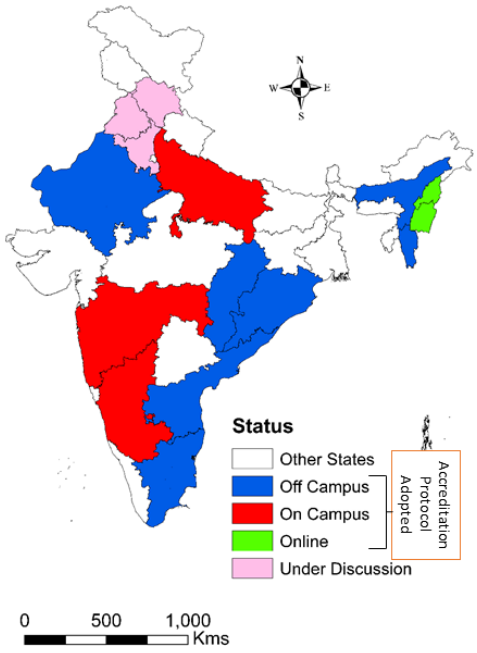
Source: Ramanan, S. S. and Arunachalam, A. (2023) authored the technical bulletin titled Agroforestry Technologies (CAFRI/2023/02), published by ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India, comprising 63 pages.

Technology: Accreditation Protocol for Agroforestry Nurseries

ICAR-Certificate Number: ICAR-NRM-CAFRI-Methodology-2024-061

ICAR-CAFRI Technology Registration Number: ITMU/2025/046

About Technology



Production and access to quality planting material (QPM) are critical for the success of plantations and the widespread adoption of agroforestry systems. Recognizing this, ICAR-CAFRI has developed a comprehensive Accreditation Protocol for Agroforestry Nurseries to standardize and ensure the quality of planting material across India. This initiative builds upon earlier efforts, such as the publication of the "Guidelines for Quality Planting Material of Agroforestry Species," which provided direction for producing QPM in diverse agroforestry species. However, until recently, there has been limited focus on the implementation of these guidelines on scale. A significant shift by emphasizing the operationalization of QPM practices within the framework of the Rastriya Krishi Vikas Yojana (RKVY) and as per the Ministry of Agriculture & Farmers' Welfare notification (F.No.3-1/2021-NRM-SMAF dated 5 April 2023), ICAR-CAFRI was designated as the National Nodal Agency for Agroforestry. In this role, it has developed the Agroforestry Nursery Accreditation Protocol to support the effective implementation of agroforestry initiatives under RKVY and similar schemes. This protocol is grounded in the core principles that define any functional nursery system, regardless of size, ownership, or type of propagation material. It outlines specific criteria that nurseries must fulfill to be accredited. These include the production of healthy, genetically sound, and disease-free seedlings/saplings whose source and pedigree are clearly traceable. The goal is to institutionalize transparency, reliability, and quality assurance in the nursery sector. The Agroforestry Nursery Accreditation Protocol was developed to enhance the implementation of agroforestry initiatives under RKVY and similar schemes. It sets standards for accrediting nurseries based on core principles applicable across nursery types, ensuring the production of healthy, genetically sound, and traceable planting material, thereby promoting transparency, reliability, and quality. The protocol represents a significant technological advancement by ICAR-CAFRI and has already been adopted by over 10 states. Its growing acceptance highlights its practical relevance and potential to improve agroforestry outcomes across the country. Its growing acceptance underscores its relevance and impact on agroforestry outcomes. To support implementation, ICAR-CAFRI has organized Trainer of Trainers (ToT) programs with state nodal agencies across several states, including Odisha, Uttar Pradesh, Maharashtra, Karnataka, Manipur, Nagaland, Chhattisgarh, Assam, Rajasthan, Mizoram, Andhra Pradesh, and Tamil Nadu. The Accreditation Protocol for Agroforestry Nurseries provides a foundation for ensuring consistent production of high-quality planting material, strengthening the agroforestry value chain, and enhancing the sustainability of tree-based systems in India.

Source: https://www.agriwelfare.gov.in/en/whatsnew/24

Technology: Techniques of area estimation of agroforestry in India

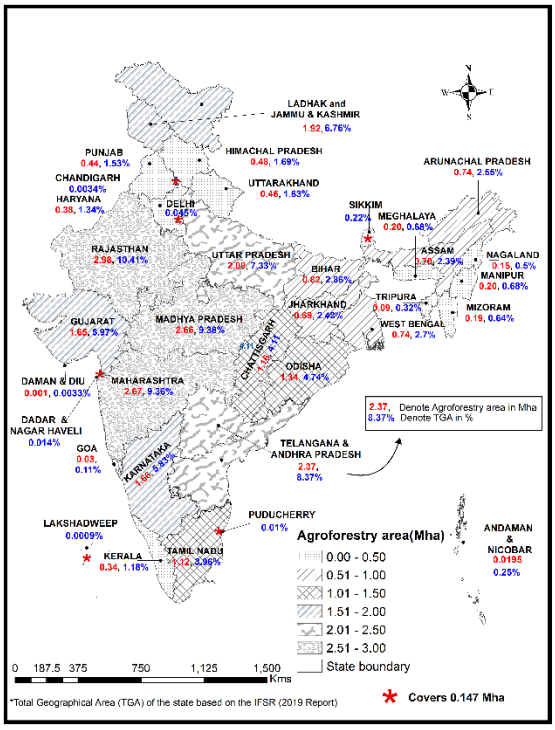
ICAR-Certificate Number: ICAR-NRM-CAFRI-Methodology-2024-065

ICAR-CAFRI Technology Registration Number: ITMU/2023/034

About Technology

India has become the first nation to have systematically mapped the country wide agroforestry area. According to State Forest Report, 2019 of the Forest Survey of India, the extent of trees outside the forest area is 29.38 Mha. Thus, agroforestry area estimates include 9.8 Mha tree cover (rural and urban). Moreover, the agroforestry area reported in this study indicates tree and crop canopy areas. Hence, it is recommended not to equate the agroforestry areas to trees outside forest area. To avoid misconception in the future, there is a need for collaboration between the agriculture and forest ministries for mapping trees outside area for mapping trees outside area as recommended by the Expert Committee. These datasets will help in the planning and management of agroforestry as well as the implementation of National Agroforestry Policy in different states of India on mission mode.

ICAR-CAFRI, a dedicated institution for Agroforestry in the Asia-Pacific region, undertook the mapping of agroforestry areas using geospatial technologies. The preliminary work on 13 out of 15 agro-climatic zones (ACZs) reported an area of 23.25 Mha. In this study, we carried out a complete analysis of all 15 ACZ's of India.



Source:

- Arunachalam, A., Rizvi, R.H., Handa, A.K., and Ramanan S, S. (2024) State-wise area estimation of agroforestry in India. Current Science 127(11): 1267.
- Arunachalam, A., Rizvi, R. H., Handa, A. K. and Ramanan S, S. (2022) Agroforestry in India: area estimates and methods. Current Science, 123(6), 743-744

Technology: Agroforestry Extension Framework

ICAR-Certificate Number: ICAR-NRM-CAFRI-Methodology-2024-069

ICAR-CAFRI Technology Registration Number: ITMU/2023/003

About Technology

The agroforestry extension framework along with a ready reckoner including a training manual & workbook developed by ICAR-CAFRI encompasses a robust approach for adoption of appropriate agro- forestry extension strategies across the country. The extension training module developed covers all the processes involved in agroforestry from end-to-end nursery (pre-planting) to planting & production to post- harvest management

In this context, the National Rain fed Area Authority (NRAA), in collaboration with the Food and Agriculture Organization (FAO-India) of the United Nations, the ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi, and the Indian Institute of Forest Management (IIFM), Bhopal, jointly planned and implemented a Technical Cooperation Project (TCP) titled "Support Implementation of National Agroforestry Policy (NAP) by Enhancing Tree Cover & Production of Wood." This initiative aims to operationalize key aspects of the National Agroforestry Policy by addressing two major thematic areas:

- Design and recommend a facilitative extension module to effectively disseminate agroforestry practices at the grassroots level.
- Delineation and development of tradable parameters for selecting timber and non-timber species, focusing on their economic potential in the states of Uttar Pradesh and Karnataka.

The detailed methodology of the proposed product/technology is structured through a comprehensive framework outlined in this handbook, which covers several key components: it begins with an introduction to the agroforestry concept and overview, providing a foundational understanding of its definitions, principles, and benefits to highlight its significance for sustainable land use and improved livelihoods; it then outlines strategies for scaling up agroforestry across diverse agro-climatic regions by integrating these practices into mainstream agricultural systems, supportive public policies, and market linkages; the methodology also emphasizes the development of robust, farmer-centric agroforestry extension advisory services through capacity building, institutional strengthening, and the application of ICT tools to enhance knowledge dissemination; further, it focuses on improving agroforestry extension programs and processes using participatory approaches, adaptive learning models, stakeholder engagement, and feedback mechanisms to ensure program relevance and effectiveness; and finally, it promotes farmer entrepreneurship by building capacities in nursery management, value addition, market access, and business planning to enable the establishment and growth of agroforestry-based enterprises.

Source: FAO and ICAR-CAFRI (2022) Agroforestry Extension Framework, ICAR-Central Agroforestry Research Institute, Jhansi, India. 24 p.

Technology: Redefined logarithmic for spiral trenching to understand tree root structure & distribution

ICAR-Certificate Number: ICAR-NRM-CAFRI-Methodology-2024-070

ICAR-CAFRI Technology Registration Number: ITMU/2023/0012

About Technology

Studying root architecture and distribution is essential but challenging, particularly in agroforestry and plantation forestry. Traditional root excavation methods provide reliable data but are laborious, time-consuming, and impractical at large scales. Moreover, they often fail to accurately capture fine root activity zones. While radioisotope tracing offers insights, it is costly and difficult to implement in field conditions. To address these issues, Huguet proposed the logarithmic spiral trenching technique, initially applied to olive trees, with results comparable to radioisotope methods. This innovative method was later modified for species like bamboo; however, adaptations for dicot trees require further refinement. We revisited and derived the original mathematical model to suit dicot tree systems. Our objective is to offer a cost-effective, field-friendly alternative to whole root excavation using a refined logarithmic spiral trenching approach. This technique balances practicality and data quality, making it ideal for assessing root distribution and function in trees and woody perennials.

Methodology equation is by the polar equation: $r = ae^{b\theta}$ where r = the distance from the origin; θ = the angle from the x-axis while 'a' and 'b' are arbitrary constants.

$$a = 1.5\ (d)$$

$$b = [\ln (r/d)]/\pi \quad (4)$$

(3) and (4) in (1) $r = 1.5\ (d)\ e^{([\ln (r/d)]/\pi)^{*}\theta}$ (5) where d = diameter of tree in m; r = the average of the crown radius at four cardinal points in m; a = the distance of the starting point of the spiral from the tree in m; b = natural logarithmic of the ratio of crown radius to the diameter of the tree divided by π; z = the distance of any point on the spiral from the tree base in m and θ = 0, 22.5, 45, 67.5, 90, 112.5, 135, 157.5 and 180 The trajectory of the trench has to be laid down on the field using plastic ropes by calculating the distance 'x' on the north side from the tree which will be the origin and further extension is done in the spiral clockwise direction. Root counts are converted -2 into rooting intensity (number of roots m). This method also gives us the extent of lateral root spread. MANCOVA analysis can be performed with sufficient replication. This methodology offers greater scope in agroforestry purposes. However, deployment of this method to understand the effect stand management practices can also be done. The methodology may seem familiar and easy for the forester, but the mathematical technicality is the crux of deploying this methodology. An improper usage of the equation may give rise to the trench that will be a semicircular trench as in the case of previous studies. Employing this technique inside a plantation may be difficult if the spacing is too close. However, moderate spacing of 2.5 x 2.5 m between trees is sufficient for deploying this methodology.

Source: Ramanan S, S. and Kunhamu, T. K. (2021) Redefining the Logarithmic Spiral Trenching to Understand Root Structure and Distribution of Trees. Indian Forester, 147 (2), pp.202–204.

Technology: Package of practice for **"***Har Med Par Ped*"

ICAR-Certificate Number: ICAR-NRM-CAFRI-Methodology-2024-071

ICAR-CAFRI Technology Registration Number: ITMU/2023/024

About Technology

"Har Med Par Ped" is a new technology developed by ICAR-CAFRI, which aligns with *"Har Med Par Ped*" a slogan of the Government of India for enhancing tree cover in the country while also enhancing the income of farmers by advocating agroforestry as an alternative and diversified land-use. This calls for mass awareness about the tree plantation on farm bunds and boundaries so that suitable tree species are chosen for different regions without compromising the prevailing land tenure system. This has a larger canvas of provisioning livelihood and environmental securities together. With these viewpoints, ICAR-Central Agroforestry Research Institute, Jhansi along with its centres of the All India Coordinated Research Project on Agroforestry took the challenge to popularize the concept of farm boundary plantation among the masses including school children and other stakeholders. This technical bulletin not only provides detailed information on suitable tree species for plantation on farm bunds/boundaries. It also highlights the ownership and land tenure issues that are attached to the farm landholdings requiring attention considering the socio-cultural implications. The document is useful for all stakeholders in the farm and forest sector to have a common ground to work together and address the mission '*Har Med Par Ped*' with a larger perspective of meeting the country's ecological sustainability by provisioning thirty-three per cent tree covers.

The document has been prepared fully in academic spirit for educational and ready reckoning purposes so that apt measures are taken to control diseases in agroforestry trees and bamboo. The present bulletin is an attempt to comprehensively compile the information about benefits of boundary/bund plantation, suitable tree species and their management, its appropriateness on-farm, challenges if any and the success stories from different states of the Indian Union.

This technical bulletin covers various aspects of plantation like bund plantation and boundary plantation. It elaborates the status of bund/ boundary plantations, scope of bund/ boundary plantations, soil conservation and amelioration on sloping lands, riverbank stabilization, Aquaforestry canal-side plantation, windbreaks and shelterbelts, bunds for raising nitrogen-fixing plants, trees for bund consolidation, bund/boundary plantation for demarcation, benefits to farmers from bund/boundary planting, short-term benefits, medium-term benefits, long-term benefits. Characteristics of woody perennials suitable for bund/ boundary, plantation, Species suitable for bund/ boundary plantation, Management of bund/ boundary plantation, Basic guidelines for bund plantation in cultivated land Crop yield in presence of bund/ boundary plantations, Socio-cultural and socio-economic aspects of bund/ boundary, plantations.

Source: Arunachalam A., Handa A.K., Ramanan S, S., Bhatt, B.P. Bhaskar, S. and Chaudhari S.K. (2022) *'Har Med Par Ped'*-A Ready Reckoner. ICAR-Central Agroforestry Research Institute, Jhansi, 44p.

Technology: Protocol for agroforestry entrepreneurship training

ICAR-Certificate Number: ICAR-NRM-CAFRI-Protocol-2024-068

ICAR-CAFRI Technology Registration Number: ITMU/2023/007 and ITMU/2023/008

About Technology

Agroforestry, as a sustainable land-use system, addresses key economic and ecological challenges by integrating woody perennials (trees, shrubs, and bamboo) with crops and/or livestock on the same land. This tree-based production system optimizes yields by enhancing resource-use efficiency and ecological balance. It aligns closely with the Sustainable Development Goals (SDG) 2030, particularly the goal of sustainable land use, and contributes to at least 12 out of the 17 SDGs. Recognizing its potential, India became the first country to adopt a National Agroforestry Policy in 2014.

Scaling up agroforestry requires multi-institutional participation and capacity building. Promoting participatory research and identifying region-specific drivers of change are vital to expanding agroforestry practices. Innovation in extension services, especially through social marketing, can drive behavioral change and create demand-led agroforestry adoption. Additionally, digital technologies can be effectively integrated with manpower-based extension approaches for improved service delivery and outreach.

The Government of India has launched coordinated efforts through various ministries and departments to promote agroforestry as a strategy for mitigating climate change, supporting farmers' livelihoods, and rejuvenating ecosystems. This study and accompanying training manual represent a unique and collaborative attempt to promote agroforestry through robust extension systems and appropriate post-harvest practices. It aims to enhance understanding among grassroots functionaries and farmers, ensuring applicability at the field level. The results are expected to garner interest at policy levels and contribute to scaling up agroforestry as a community-led initiative.

The training manual provides a comprehensive and practical resource for both teaching and training purposes. It includes detailed agroforestry designs and models tailored to various states, with a strong focus on value chain development and entrepreneurship. Special emphasis is placed on engaging youth, integrating young farmers into agroforestry-based value chains, and developing high-quality planting materials. It also promotes technological advancement and highlights the critical role of Information and Communication Technology (ICT) in agroforestry extension services.

Additionally, the manual outlines government initiatives supporting agroforestry, alongside information on best practices, biodiversity conservation, and propagation techniques for agroforestry species. This holistic approach positions the manual as a valuable tool to empower stakeholders, enhance agroforestry adoption, and support sustainable rural development across India.

Source:

- FAO and ICAR-CAFRI (2022) Training Manual for Agroforestry Entrepreneurship Building of Rural Youth, Jhansi, India, 60 p.
- FAO and ICAR-CAFRI (2022) Workbook for Agroforestry Entrepreneurship Building of Rural Youth, Jhansi, India, 84p.

Technology: Package of Practice for Strawberry Production in Bundelkhand

ICAR-Certificate Number: ICAR-NRM-CAFRI-Technology-2024-066

ICAR-CAFRI Technology Registration Number: ITMU/2023/025S

About Technology

Strawberry (Fragaria × ananassa), a perennial herbaceous plant belonging to the Rosaceae family, is widely appreciated for its delicious flavor and nutritional value. With its shallow, fibrous root system and occasional tap root development, the plant is well-suited for cultivation under specific agro-climatic conditions. Recognizing its commercial potential in the Bundelkhand region, a region-specific package of practices has been developed to enhance productivity and profitability for strawberry growers. This technology is intended to serve commercial nursery operators, farmers, students, and other stakeholders engaged in strawberry cultivation. It provides a comprehensive set of recommendations specifically the planting duration for Bundelkhand region along with timeline for other practices such as fertigation, cultural operation, etc. Based on key agronomic factors including soil characteristics, climate adaptability, organic and inorganic nutrient management, irrigation scheduling, optimal planting time, mulching techniques, and intercropping options. These production guidelines have been tailored to the unique agro-ecological conditions of Bundelkhand.

Implementation of these recommended practices is expected to significantly improve yield, fruit quality, and economic returns from strawberry cultivation. By adopting these technologies, farmers in the region can effectively manage inputs, conserve resources, and optimize harvest outcomes. The package is a result of careful evaluation of local conditions and offers a practical and scientifically validated approach to commercial strawberry farming in the region.

Source: Yadav, A. and A. Arunachalam (2022) Strawberry Production Technology, Technical Bulletin CAFRI/2022/02, ICAR-Central Agroforestry Research Institute, Jhansi, 49p.

Technology: Methodology for carbon sequestration potential of traditional agroforestry in Rajasthan

ICAR-Certificate Number: ICAR-NRM-CAFRI-Methodologies-2024-064

ICAR-CAFRI Technology Registration Number: ITMU/2025/063

About Technology

A technique and protocol for estimation carbon sequestration and area mapping tested in 57 districts of 17 states in India till March 2020 under NICRA project at ICAR-CAFRI, Jhansi. In arid regions, tree-based systems are vital for livelihoods and environmental stability. As part of our study to assess carbon sequestration potential (CSP) in agroforestry systems across arid regions of Rajasthan, we undertook a detailed field survey in five selected districts—Bikaner, Dausa, Jhunjhunu, Pali, and Sikar. The objective was to document existing agroforestry practices, identify dominant tree species, measure tree density and growth, and evaluate associated soil carbon levels. We employed transect walk methods in representative villages, where trees were enumerated across farmlands, bunds, and culturable wastelands. For each recorded tree, diameter at breast height (dbh) was measured. Soil samples were collected using a soil auger from both agroforestry plots and adjacent pure agricultural fields, following the standard protocol of sampling up to 90 cm soil depth. These samples were analyzed to determine soil carbon stocks, which averaged 9.96 Mg ha^{-1} across the surveyed districts, ranging from 4.28 to 16.5 Mg ha^{-1}.

To estimate the CSP, we applied the CO2FIX V 3.1 model, integrating modules for biomass and soil carbon accounting. Model inputs included species-specific cohort data such as stem current annual increment (CAI), biomass allocation to branches, foliage, roots, turnover rates, and localized climate parameters. The simulation was run for a 30-year period to project annual carbon sequestration rates, biomass accumulation, and soil carbon buildup per hectare. In addition, we used Resourcesat-2/LISS III remote sensing data (23.5 m resolution) to map agroforestry cover in the study districts. Agricultural zones were delineated, and sub-pixel classification techniques were applied to estimate tree cover percentages. Classification accuracy was verified using GPS-based ground truthing, and final outputs were processed into thematic maps using ArcGIS 10.0.

Tree species most observed included *Prosopis cineraria*, *Tecomella undulata*, *Capparis decidua*, *Acacia tortilis*, *Prosopis juliflora*, *Azadirachta indica*, *Dalbergia sissoo*, and *Ziziphus mauritiana*. Our analysis estimated the average CSP across Rajasthan to be 0.26 Mg C ha^{-1} $year^{-1}$ at a mean tree density of 9.71 ha^{-1}. Extrapolating to the state's agroforestry area (1.49 million ha), the total greenhouse gas (GHG) mitigation potential was found to be approximately 1.42 million tonnes CO_2-equivalent per year, using the standard carbon-to-CO_2 conversion factor (44/12).

This research provided a robust, standardized methodology for quantifying carbon sequestration in agroforestry systems, with significant implications for India's climate action strategies. The approach is designed for scalability, allowing for replication across different states and agro-ecological zones. It aligns with international frameworks such as MRV, REDD+, and carbon finance mechanisms, enabling accurate and policy-relevant carbon accounting. By emphasizing the role of indigenous tree-based systems, our methodology supports national efforts toward carbon neutrality and sustainable land management.

Source: Ajit, Dhyani, S.K., Handa, A.K., Newaj, R., Chavan, S.B., Alam, B., Prasad, R., Ram, A., Rizvi, R.H., Jain, A.K. and Uma (2017) Estimating carbon sequestration potential of existing agroforestry systems in India. Agroforestry Systems, 91, pp.1101-1118.

Technology: Ecophysiological traits and microclimate dynamics for assessing efficiency of crops under agroforestry system

ICAR-Certificate Number: ICAR-NRM-CAFRI-Policy-2024-062

ICAR-CAFRI Technology Registration Number: ITMU/2025/064

About Technology

The research conducted at ICAR-Central Agroforestry Research Institute (ICAR-CAFRI), Jhansi, provides new insights into the interactions between tree genotypes and understory crops in agroforestry systems, with a particular focus on microclimate modulation and ecophysiological performance. Despite the recognized potential of agroforestry, crop yield under tree canopies often remains suboptimal, primarily due to resource limitations, especially light. This study aimed to identify and address these limitations by evaluating the effects of different *Dalbergia sissoo* genotypes (PT-2, PT-6, and a local variety) on the microclimate and associated crop responses.

The findings clearly demonstrate that tree genotype plays a significant role in modulating the understory microclimate. Variables such as intercepted photon flux density (iPPFD), leaf area index (LAI), and radiation use efficiency were differentially influenced by genotypes, thereby affecting the light environment and photosynthetic activity of the cowpea crop grown beneath. Among the tested genotypes, PT-6 was found to moderate the microclimate more favorably, resulting in better crop physiological performance and greater adaptation under shaded conditions compared to PT-2 and the local variety.

Moreover, the study identifies several ecophysiological traits—such as net CO_2 assimilation rate (Amax), electron transport rate (ETR), quantum yield of PS-II (ΦPSII), chlorophyll content index (CCI), and vegetation indices like NDVI and PRI—as reliable indicators of crop functional efficiency in agroforestry systems. These traits captured the crop's acclimation responses to microclimate variation and provided valuable insights into the underlying physiological mechanisms. The integration of these indices enabled a comprehensive understanding of how tree-induced microclimate dynamics affect crop performance, and how certain tree genotypes can be strategically selected to optimize system productivity.

Overall, this research fills a critical gap in agroforestry science by providing a genotype-specific evaluation of microclimate modulation and its impact on understory crop physiology. It proposes a framework for identifying component limitations and categorizing beneficial factors within agroforestry systems, especially in semi-arid ecologies. The findings support the need for microclimate-informed genotype selection and offer a pathway toward precision agroforestry practices that consider both tree and crop components for enhanced productivity and sustainability.

Source: Alam, B., Singh, R., Uthappa, A.R., Chaturvedi, M., Singh, A.K., Newaj, R., Handa, A.K. and Chaturvedi, O.P. (2018) Different genotypes of Dalbergia sissoo trees modified microclimate dynamics differently on understory crop cowpea (*Vigna unguiculata*) as assessed through ecophysiological and spectral traits in agroforestry system. Agricultural and Forest Meteorology, 249, pp.138-148.

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