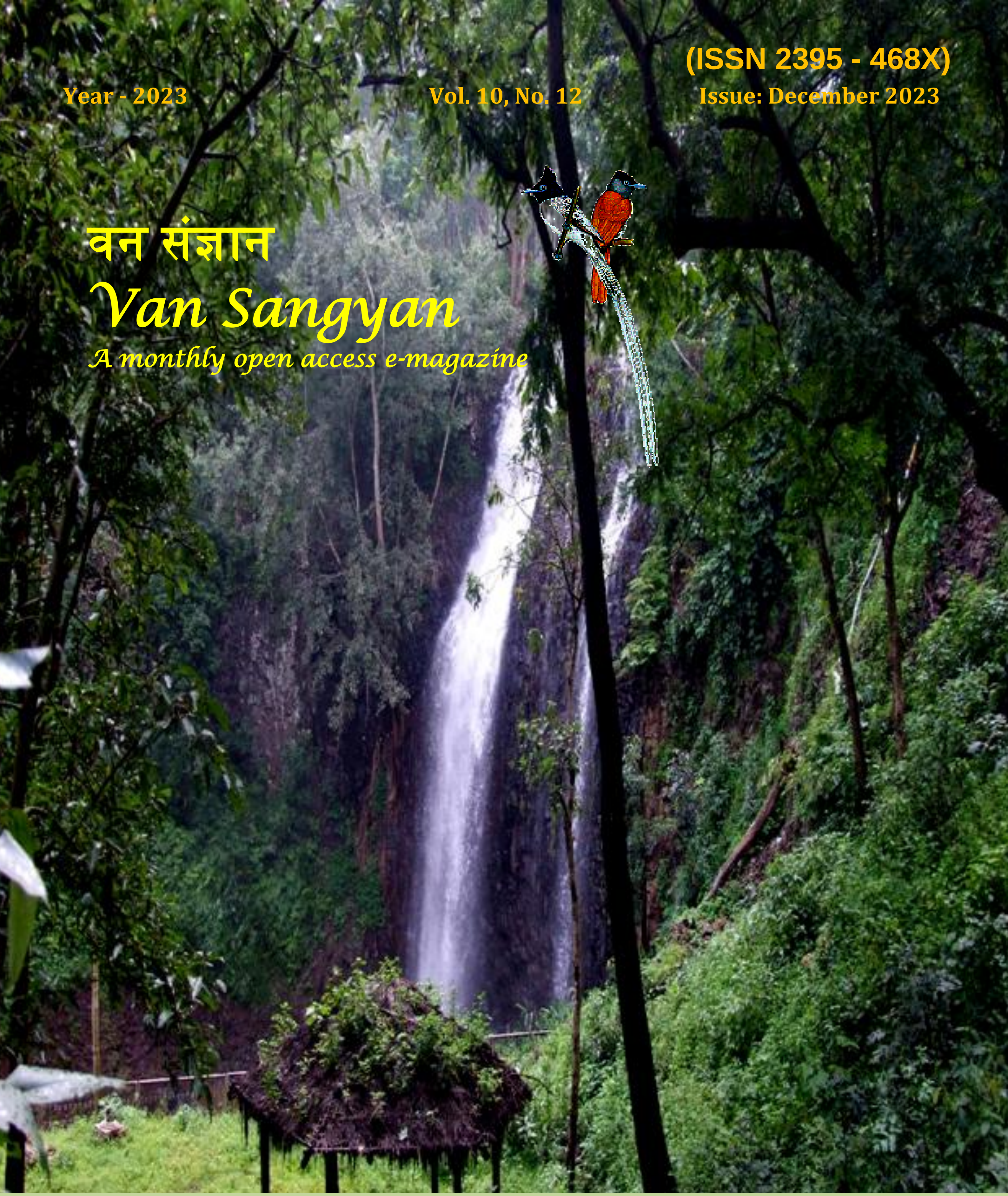
(ISSN 2395 - 468X)

Year - 2023 Vol. 10, No. 12 Issue: December 2023

वन संज्ञान

Van Sangyan

A monthly open access e-magazine



Indexed in:

COSMOS Foundation (Germany)

International Inst. of Org. Res. (Australia)

IIJIF

ICFRE-Tropical Forest Research Institute

(Indian Council of Forestry Research and Education)

Ministry of Environment, Forests and Climate Change (MoEFCC)

PO RFRC, Mandla Road, Jabalpur – 482021, India

Note to Authors:

We welcome the readers of Van Sangyan to write to us about their views and issues in forestry. Those who wish to share their knowledge and experiences can send them:

by e-mail to vansangyan_tfri@icfre.org

or, through post to The Editor, Van Sangyan,
Tropical Forest Research Institute,
PO-RFRC, Mandla Road,
Jabalpur (M.P.) - 482021.

The articles can be in English, Hindi, Marathi, Chhattisgarhi and Oriya, and should contain the writers name, designation and full postal address, including e-mail id and contact number.

TFRI, Jabalpur houses experts from all fields of forestry who would be happy to answer reader's queries on various scientific issues. Your queries may be sent to The Editor, and the expert's reply to the same will be published in the next issue of Van Sangyan.

Cover Photo: Panoramic view of Achanakmar-Amarkantak Biosphere Reserve

From the Editor's desk

Trees architectural models are sophisticated tools that play a crucial role in stand management. These models provide detailed insights into the spatial arrangement and structure of trees within a forest stand, allowing forest managers to understand complex dynamics such as competition, growth patterns, and resource utilization. By simulating the three-dimensional distribution of trees and integrating biological processes, architectural models enable managers to predict stand development under different management scenarios. This predictive capability empowers managers to optimize silvicultural practices, such as thinning and regeneration methods, to achieve desired outcomes such as improved productivity, biodiversity conservation, and resilience to environmental stressors. Moreover, tree architectural models serve as valuable research tools, advancing scientific understanding of forest ecology and facilitating innovation in forest management techniques.

In line with the above this issue of Van Sangyan contains an article on Tree architectural models and its role in stand management. There are also useful articles viz. Shree anna: An initiative to make India a global leader, Carbon storage and sequestration potential of agroforestry systems under different climatic conditions, Urbanization and green vitality: Impact of urban environment on vegetation health, Unlocking ecological histories: Advancements in dendroecology research, रीठा (सैपिंडस मुकरोसी): बंदर प्रभावित क्षेत्रों के लिए एक लाभकारी फसल *, Techniques for studying tree root architecture, Multifunctionality of agroforestry, Mahua: A resilient backbone for tribal livelihoods and The loss and damage fund: Implications for India*

I hope that readers would find maximum information in this issue relevant and valuable to the sustainable management of forests. Van Sangyan welcomes articles, views and queries on various such issues in the field of forest science.

Looking forward to meet you all through forthcoming issues

Dr. Naseer Mohammad

Chief Editor

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Contents **Page**

Tree architectural models and its role in stand management

Dudipala Ravivarma[1], [*]Shakati Swamynath[1], Podishetti Varun[1], Tumma Bargavi[1], Bestha Ashwitha[1]

[1*] Forest College and Research Institute
Mulugu, Hyderabad, India
E-mail: shakati.swamynath@gmail.com

Tree architecture

The architecture of a plant is based on the nature and relative arrangement of each of its parts" (Édelin, 1984; cited by Millet, 2012)Tree architectural studies were first initiated in tropical regions and were, at first, concerned with the analysis of the aerial vegetative structure of tropical trees (Hallé and Oldeman, 1970).Tree architecture can be defined as the three-dimensional arrangement of the organs of a tree. The visible, morphological expression of the genetic blueprint of a tree is referred to, as its architecture.Tree architecture is a consequence of genetics. Genetics encode an adaptation of tree form and function to its surroundings with respect to both biotic and abiotic factors such as competition for space, differential resource distribution (e.g., light), and support and safety against mechanical forces (e.g., gravity or wind) (Chéné et al. 2012; Dassot et al. 2010).Tree shape has been shown to be influenced by environmental factors such as wind (Noguchi 1979; Watt et al., 2005; De Langre 2008), water availability (Archibald and Bond 2003), light availability (Kuuluvainen 1992; Niinemets and Kull 1995), terrain slope(Barij et al., 2007), and competition (Bayer et al., 2013; Juchheim et al., 2017).

Why to Study Tree Architecture?

The structure and dynamics of a forest stand are ultimately related to the architecture of the individual trees (West et al., 2009; Price et al., 2012; Seidel et al., 20190.Therefore, the study of tree structure and form is highly relevant to diverse research fields, such as phylogeny and taxonomy, ecosystem modeling, tree physiology, and crucial for remote sensing of canopy landscapes, tree wind damage studies, carbon stock calculation for climate change mitigation schemes, as well as metabolic scaling theory(Malhi et al., 2018). Tree architecture ranges from slender, pole-like forms to large, sprawling, multilayered canopies (Beech et al., 2017), and there is likely no identically shaped pair of trees amongst all, even within a species (Seidel et al., 2019b).Tree architecture is not entirely random (Valladares and Niinemets 2007), and that it is determined by the dynamic response of tree growth to its abiotic and biotic environment, in the context of its genetic code (Hallé et al., 1978; Scorza et al., 2002; Busov et al., 2008; Burkardt et al., 2020). Tree architecture is an important determinant of the height extension, light capture, and mechanical stability of trees, and it allows species to exploit the vertical height gradient in the forest canopy and horizontal light gradients at the forest floor.Tree architecture directly influences biophysical processes, such as photosynthesis and evapotranspiration (Rosell et al. 2009; Van der Zande et al. 2006), ultimately leading to changes in carbon and water storage.In designing agroforestry combinations, knowledge of the spatial development of the various components is extremely important in order to optimise the crop-tree and/or the tree-tree interactions. The occupation of space by a tree and its evolution with time, as a result of its architecture [Halle et al., 1978], influence physiological functions and interactions, such as light interception and transmission, water and nutrient uptake, and competition. Interactions between components are the main features of interest in agroforestry research, and particularly in agroforestry modelling. The knowledge and understanding of tree architectural development is therefore of utmost importance.Crown metamorphosis occurs in all tree architectures typical of temperate climate (except palms and bamboo). Competition and metamorphosis as its result can be used for planning tree work.Trees behave remarkably plastic in response to environmental conditions. Even so, knowledge of how tree architecture in pure and mixed stands compare is largely underexplored. Such information is relevant from a fundamental ecological and an applied silvicultural perspective, given the increased attention for mixed species silviculture and the close linkages between tree architecture and high-quality timber production

The Concept of Architectural Model

For a tree species the growth pattern which determines the successive architectural phases is called its architectural model (Hallé and Oldeman, 1970). The architectural model is an inherent growth strategy that defines both the manner in which the plant elaborates its form and the resulting architecture.It expresses the nature and the sequence of to the fundamental growth programme on which the entire architecture is established.The identification of the architectural model of any given plant is based on the observation of the features belonging to the four major groups of simple morphological features:

(1) **The growth pattern**, i.e. *determinate vs. indeterminate growth and rhythmic vs. continuous growth*

Determinate growth

Determinate growth corresponds to an irreversible transformation of the apical meristem, which can be due to apical flowering as in *Nerium oleander*, parenchymatization (arrow) of the apical meristem as in *Alstonia* sp. or apical death or abscission (‘X’) as in *Castanea sativa*.

Indeterminate growth

Indeterminate growth corresponds to permanent apical meristem functioning, as illustrated by the main stem of *Picea excelsa*

Rhythmic growth

In rhythmic growth, organogenesis is not continuous, showing pauses between organ creation phases. Elongation is also periodic. Rhythmic growth builds growth units, corresponding to organogenesis cycles.

Continuous growth

Elongation follows organogenesis and both processes are stable and regular as shown by the coconut palm

(2) The branching pattern, *i.e. terminal vs. lateral branching, no branching, monopodial vs. sympodial branching, rhythmic vs. continuous branching, immediate vs. delayed branching*

Monopodial branching is when the buds do not degrade and all the shoots continue to grow.

Sympodial branching is when the terminal buds do degrade (or die out) and the lateral shoot closest to the terminal bud now becomes the terminal shoot and continues the vertical growth.

In plants with lateral branching, a main stem grows from an apical bud or terminal bud (a region of the shoot tip that includes the apical meristem), and lateral (side) branches are produced from lateral buds, each with its own apical meristem. Thus, branching is not caused by division of the shoot apex.

In the case of immediate branching (*Juglans regia*, the first internode is generally long and termed the hypopodium

Delayed branching refers to a system where lateral branching follows a resting phase of the lateral meristem during which it is frequently included in a bud.

When elongated, such delayed branching lateral shoots frequently show a short first internode and proximal scale leaves or bud scale scars when abscissed (*Platanus sp*.)

(3) The morphological differentiation of axes, i.e. *orthotropic vs. plagiotropic vs. axes with mixed morphological and/or geometrical features (with plagiotropic and orthotropic portions)*

Orthotropic axes are generally erect to vertical with a radial symmetry, bear large leaves and long lateral axes (*Fraxinus oxyphylla*. By contrast, horizontal axes tend to exhibit a bilateral symmetry frequently associated with a high reproductive and photosynthetic strategy: they represent plagiotropic axes (*Azara microphylla*,Particular kinds of plagiotropic axes correspond to an immediate hypotonic sympodial branching system of successive indeterminate (plagiotropy by apposition: unidentified Sapotaceae,or determinate (plagiotropy by substitution: *Byrsonima densa*, sympodial units.

Other features include

Acrotony is the preferred development of lateral axes in the distal part of a parent axis or shoot.(The topological lateral arrangement of branches along the parent axis may be associated with an increasing *(Abies sp*.) or decreasing (*Juglans nigra*) gradient in length and/or vigour of the branches.

Mesotony refers to a privileged development of branches in the median part of a shoot or axis.

Basitony is the privileged development of lateral axes in the basal part of a vertical stem or shoot. This may involve the whole plant level as for the shrubby plant *Stenocereus thurberi* or the growth unit level only (*Choysia ternatea*,)

(4) Lateral vs. terminal flowering

Each architectural model is defined by a particular combination of these simple morphological features and named after a well-known botanist.

Architectural Models of Tropical Trees-Illustrated Key

Although the number of these combinations is theoretically very high, there are apparently only 23 architectural models found in nature.Each of these models applies equally to arborescent or herbaceous plants, from tropical or temperate regions, and which can belong to closely related or distant taxa

The following **key is based on Halle, Oldeman and Thomlinson (1978)** “Tropical Trees and Forests” (pp.84–97)

1a. Stem strictly unbranched (Monoaxial trees) ....(2)

1b. Stems branched, sometimes apparently unbranched in Chamberlain's model (polyaxial trees) ………………………………………………………. (3)

2a. Inflorescence terminal...... **Holttum's model**

Monocotyledon: *Corypha umbraculifera* (Talipot palm—Palmae).

Dicotyledon: *Sohnreyia excelsa* (Rutaceae)

2b. Inflorescences lateral...... **Corner's model**

(a) Growth continuous

Monocotyledon: *Cocos nucifera* (Coconut Palm—Palmae), *Elaeis guineensis* (African oil palm—Palmae).

Dicotyledon: *Carica papaya* (Papaya—Caricaceae).

(b) Growth rhythmic:

Gymnosperm: Female *Cycas circinalis* (Cycadaceae).

Dicotyledon: *Trichoscypha ferntginea* *(*Anacardiaceae).

3(a). Vegetative axes all equivalent, homogenous (not partly trunk, partly branch), most often orthotropic and modular ...... 4.

3b. Vegetative axes not equivalent (homogenous, heterogenous or mixed but always clear difference between trunk and branches) ...... 7.

4a. Basitony, i.e., branches at the base of the module, commonly subterranean, growth usually continuous, axes either Hapaxanthic or Pleonanthic...... **Tomlinson's model**

(a) Hapaxanthy, i.e., each module determinate, terminating in an inflorescence:

Monocotyledon: *Musa cv. sapientum* (Banana—Musaceae).

Dicotyledon: *Lobelia gibberoa*(Lobeliaceae)

(b) Pleonanthy, i.e., each module not determinate, with lateral inflorescences

Monocotyledon: *Phoenix dactylifera* (Date palm—Palmae).

4b. Acrotony, i.e., branches not at the base but distal on the axis ...... 5.

5a. Dichotomous branching by equal division of apical meristem...... **Schoute's model**

Monocotyledons:

Vegetative axes orthotropic: *Hyphaene thebaica* (Doum palm—Palmae).

Vegetative axes plagiotropic: *Nypa fruticans* (Nipa palm—Palmae)

5b. Axillary branching, without dichotomy ...... 6.

6a. One branch per module only; sympodium one-dimensional, linear, monocaulous, apparently unbranched, modules hapaxanthic, i.e., inflorescences terminal...... **Chamberlain's model**

Gymnosperm: Male *Cycas circinalis* (Cycadaceae).

Monocotyledon: *Cordyline indivisa* *(*Agavaceae).

Dicotyledon: *Talisia mollis* (Sapindaceae).

6b. Two or more branches per module; sympodium three-dimensional, nonlinear, clearly branched; inflorescences terminal...... **Leeuwenberg's model**

Monocotyledon: *Dracaena draco* (Dragon tree—Agavaceae).

Dicotyledon: *Ricinus communis* (Castor-Bean), *Manihot esculenta* (Cassava), both Euphorbiaceae.

7(a). Vegetative axes heterogeneous, i.e., differentiated into orthotropic and plagiotropic axes or complexes of axes 8

7(b). Vegetative axes homogeneous, i.e., either all orthotropic or all mixed 18

8a. Basitonic (basal) branching producing new (usually subterranean) trunks...... **McClure's model**

Monocotyledon: *Bambusa arundinacea* (bamboo—Gramineae / Bambusoideae).

Dicotyledon: *Polygonum cuspidatum* (Polygonaceae).

8b. Acrotonic (distal) branching in trunk formation (never subterranean) 9

9a.Modular construction, at least of plagiotropic branches; modules generally with functional (sometimes with more or less aborted) terminal inflorescences 10

9b. Construction not modular; inflorescences often lateral but always lacking any influence on main principles of architecture 13

10a. Growth in height sympodial, modular 11

10b. Growth in height monopodial, modular construction restricted to branches 12

11a. Modules initially equal, all apparently branches, but later unequal, one becoming a trunk ...... **Koriba's model**

Dicotyledon: *Hura crepitans* (sand-box tree—Euphorbiaceae).

11b. Modules unequal from the start, trunk module appearing later than branch modules, both quite distinct...... **Prevost's model**

Dicotyledon: *Euphorbia pulcherrima*(Poinsettia—Euphorbiaceae), *Alstonia boonei*(Emien—Apocynaceae)

12a. Monopodial growth in height rhythmic ...... **Fagerlind's model**

Dicotyledon: *Cornus alternifolius* (Dogwood—Cornaceae), *Fagraea crenulata* (Loganiaceae), *Magnolia grandiflora* (Magnoliaceae)

12b. Monopodial growth in height continuous...... **Petit's model.**

Dicotyledon: *Gossypium spp.* (cottons—Malvaceae).

13a. Trunk a sympodium of orthotropic axes (branches either monopodial or sympodial, but never plagiotropic by apposition) ...... **Nozeran's model**

Dicotyledon: *Theobroma cacao* (cocoa—Sterculiaceae)

13b. Trunk an orthotropic monopodium ...... 14.

14a. Trunk with rhythmic growth and branching ...... 15.

14b. Trunk with continuous or diffuse growth and branching ...... 16.

15a. Branches plagiotropic by apposition ...... **Aubreville's model**

Dicotyledon: *Terminalia catappa* (Sea-Almond—Combretaceae).

15b. Branches plagiotropic but never by apposition, monopodial or sympodial by substitution...... **Massart's model**

Gymnosperms: *Araucaria heterophylla* (Norfolk Island pine—Araucariaceae). Dicotyledon: *Ceiba pentandra* (kapok—Bombacaceae), *Myristica fragrans* (Nutmeg—Myristicaceae)

16a. Branches plagiotropic but never by apposition, monopodial or sympodial by substitution ...... 17.

16b. Branches plagiotropic by apposition ...... **Theoretical model I**

Dicotyledon: *Euphorbia sp.* (Euphorbiaceae)

17a. Branches long-lived, not resembling a compound leaf ...... **Roux's model**

Dicotyledon: *Coffea Arabica* (coffee—Rubiaceae), *Bertholletia excelsa*(Brazil nut—Lecythidaceae).

17b. Branches short-lived, phyllomorphic, i.e., resembling a compound leaf ...... **Cook's model**

Dicotyledon: *Castilla elastic* (Ceara rubber tree—Moraceae)

18a. Vegetative axes all orthotropic ...... 19.

18b. Vegetative axes all mixed ...... 22.

19a. Inflorescences terminal, i.e., branches sympodial and, sometimes in the periphery of the crown, apparently modular ...... 20.

19b. Inflorescences lateral, i.e., branches monopodial ...... 21.

20a. Trunk with rhythmic growth in height...... **Scarrone's model**

Monocotyledon: *Pandanus vandamii* (Pandanaceae).

Dicotyledon: *Mangifera indica* (Mango—Anacardiaceae).

20b. Trunk with continuous growth in height...... **Stone's model**

Monocotyledon: *Pandanus pulcher* (Pandanaceae).

Dicotyledon: *Mikania cordata* (Compositae)

21a. Trunk with rhythmic growth in height...... **Rauh's model**

Gymnosperm: *Pinus caribaea* (Honduran pine—Pinaceae).

Dicotyledon: *Hevea brasiliensis* (Para rubber tree—Euphorbiaceae).

21b. Trunk with continuous growth in height ...... **Attims'model.**

Dicotyledon: *Rhizophora racemosa* (Rhizophoraceae)

22a. Axes clearly mixed by primary growth, at first (proximally) orthotropic, later (distally) plagiotropic ...... **Mangenot's model**

Dicotyledon: *Strychnos variabilis* (Loganiaceae).

22b. Axes apparently mixed by secondary changes ...... 22.

23a. Axes all orthotropic, secondarily bending (probably by gravity) ...... **Champagnat's model**

Dicotyledon: *Bougainvillea glabra* (Nyctaginaceae)

23b. Axes all plagiotropic, secondarily becoming erect, most often after leaf-fall...... **Troll's model**

Dicotyledon: Annona muricata (Custard apple—Annonaceae), *Averrhoa carambola* (Carambola—Oxalidaceae), *Delonix regia* (poinciana—Leguminosae / Caesalpinioideae)

(a) Trunk a monopodium (e.g., *Cleistopholis patens*—Annonaceae)

(b) Trunk a sympodium (e.g., *Parinari excelsa*—Rosaceae):

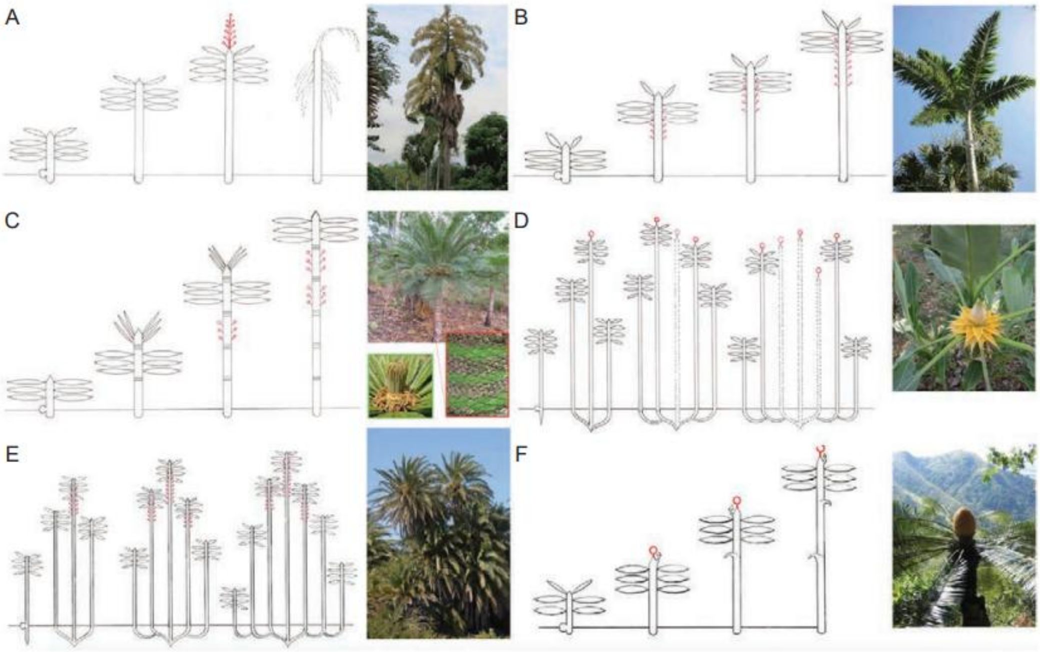

FIG. 2. Architectural models 1. (A) Holttum's model, exemplified by *Corypha umbraculifera*. (B) Corner's model, form with continuous growth, as found in most palm species (here *Veitchia arecina*). (C) Corner's model, form with rhythmic growth, here exemplified by a female *Cycas armstrongii*. (D) Tomlinson's model, form with a terminal inflorescence, here exemplified by *Musella lasiocarpa*. (E) Tomlinson's model, form with a lateral (axillary) inflorescence, here exemplified by *Phoenix theophrastii*. (F) Chamberlain's model, here exemplified by a male *Cycas pectinata*. Photo credit: Wikipedia, except (B), (D) and (E): G. Chomicki. All architectural models were drawn by Yasumin Sophia Lermer.

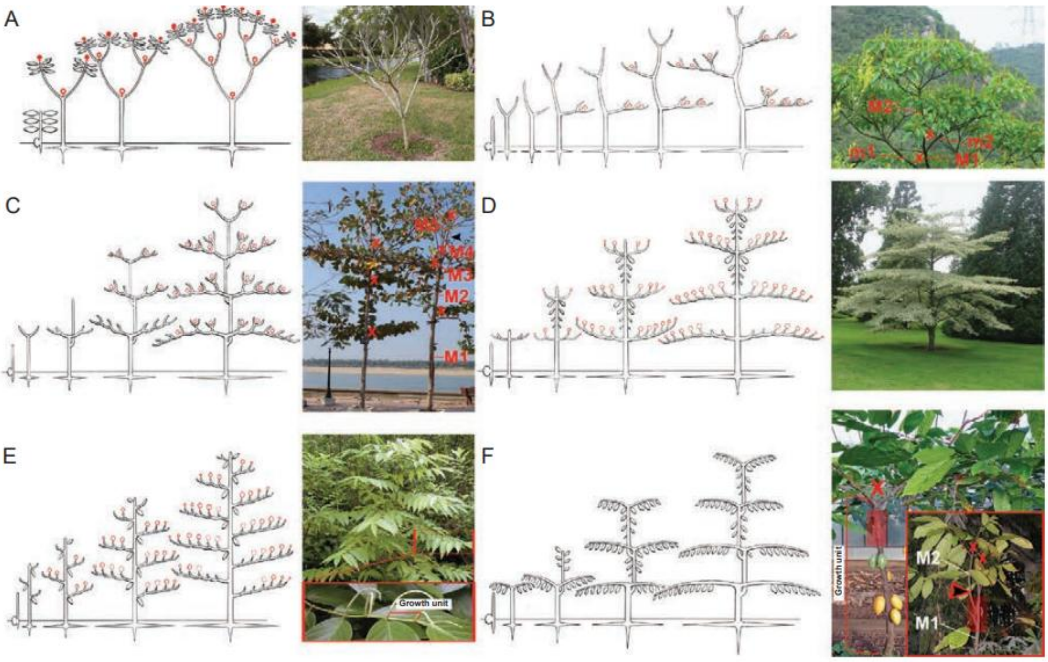

FIG. 3. Architectural models 2. (A) Leeuwenberg's model, exemplified in *Plumeria rubra*. (B) Koriba's model, exemplified in *Sapium discolor*. (C) Prévost model, here exemplified in *Alstonia scholaris*. (D) Fagerlind's model, here exemplified in *Cornus alternifolia*. (E) Petit's model, here exemplified by *Piper aduncum*. (F) Nozeran's model, here exemplified by *Theobroma cacao*. Photo credit: Wikipedia, except (A): G. Chomicki. All architectural models were drawn by Yasumin Sophia Lermer.

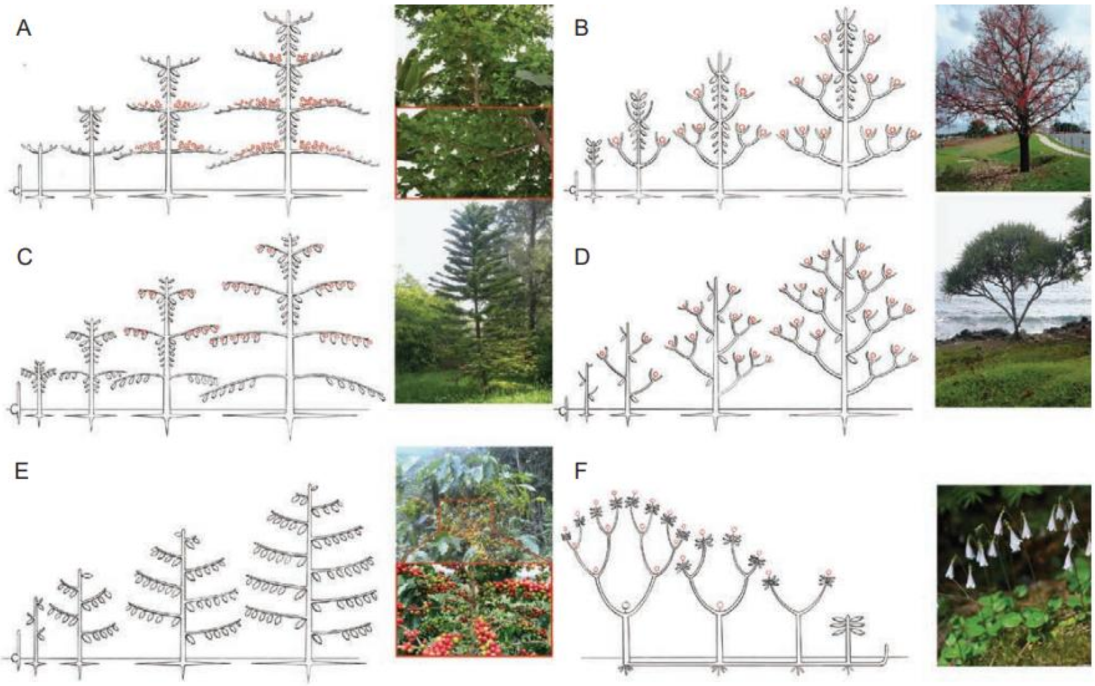

FIG. 4. Architectural models 3. (A) Aubréville's model, here exemplified by *Terminalia catappa*. (B) Scaronne's model, here exemplified by *Brachychiton acerifolius*. (C) Massart's model, here exemplified by *Araucaria heterophylla*. (D) Stone's model, here exemplified by *Pandanus tectorius*. (E) Roux's model, here exemplified by *Coffea arabica*. (F) Bell's model, here exemplified by *Linnaea borealis*. This model is centred on the monopodial plagiotropic shoot system, and the aerial part can take various architectures in different species (Hallé, 2004). Photo credit: Wikipedia, except (A) and (C): G. Chomicki. All architectural models were drawn by Yasumin Sophia Lermer.

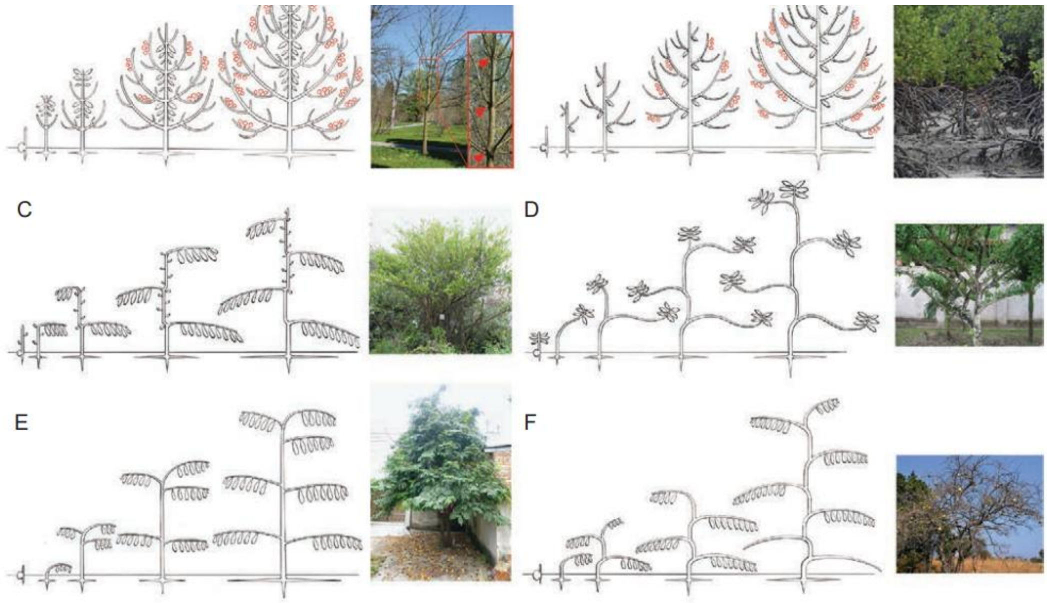

FIG. 5. Architectural models 4. (A) Rauh's model, here exemplified by *Rhus vernicifera*. (B) Attims's model, here exemplified by *Rhizophora mangle*. (C) Mangenot's model, here exemplified by *Eurya japonica.* (D) Champagnat's model, here exemplified by *Crescentia cujete*. (E) Troll's model, monopodial form, here exemplified by *Averrhoa carambola*. (F) Troll's model, sympodial form, here exemplified by *Strychnos spinosa*. Photo credit: Wikipedia, except (A) and (B): G. Chomicki. All architectural models were drawn by Yasumin Sophia Lermer.

Tree Architecture Models	Tree Management Practices (Recommended)
Massart's Model (Abies Type), Attim's Model (Cupressus Type)	Crown thinning and raising is recommended. Crown reduction is difficult. Heading leads to a multiple crown.
Mc Clure's Model (Bamboo Type)	A main axe pruned back cannot extend a second time. If side branches are shortened, axillary buds reiterate dense layers of foliated branches.
Rauh's Model, Section I: Candelabrum Shape (Acer-Pinus Type)	Crown thinning and raising are easy to do. Crown reduction is only possible if the crown is sufficiently branched in its inner parts.
Rauh's Model, Section III: Shrubs (Spinosa Type)	Shrubs of this model can be thinned only by completely removing some older axes.
Koriba's Model (Ailanthus Type)	Crown thinning and raising is easy.
Leeuwenberg's Model (Syringia Type)	Crown thinning and lifting is easy to do. Crown reduction is only possible on small twigs. Buds for rejuvenation should be visible. Pruning back to sleeping buds will damage the natural structure for years.

Recommended Tree management practices for various tree architecture models

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Shree anna: An initiative to make India a global leader

Abhay Tiwari[1], Alka Yadav[2], Dharmendra Kumar Gautam[3] and Prashant Kumar[4]

[1]Department of Agronomy, College of Agriculture, T. D. PG College Jaunpur
[2]Department of Plant Pathology, College of Agriculture, T. D. PG College Jaunpur
[3]Department of Fruit Science, College of Horticulture, Banda University of agriculture andtechnology, Banda
[4]College of Agriculture, Banda University of Agriculture and Technology, Banda
E-mail: gautam1998dharmendra@gmail.com

Introduction

By adopting the policy of global leadership, India is making its own identity globally by telling its culture and tradition. It is celebrating the current year 2023 as the Year of Millets for the purpose of supplying food grains and staying healthy in the world.

Millets are a diverse group of small seeded grassed that are widely grown around the world as cereals crops or grain for fodder and human food.Millets are a group of cereals grains belonging to the Pinaceae family, sometimes referred to as the grass family.

Millets are referred to as Shree anna in all India because their cultural and historical significance. The term Shreeanna, Shree means divine 'grace' and anna means 'food-grain', especially rice so Shree Anna means a food grain with divine grace. Millet is a good source of protein, fiber, key vitamins and minerals.

Type of Millet and their importance

The millets commonly grown in India include jowar, Bjara, ragi, kangn kodo, china, kutki etc. Those details are given below

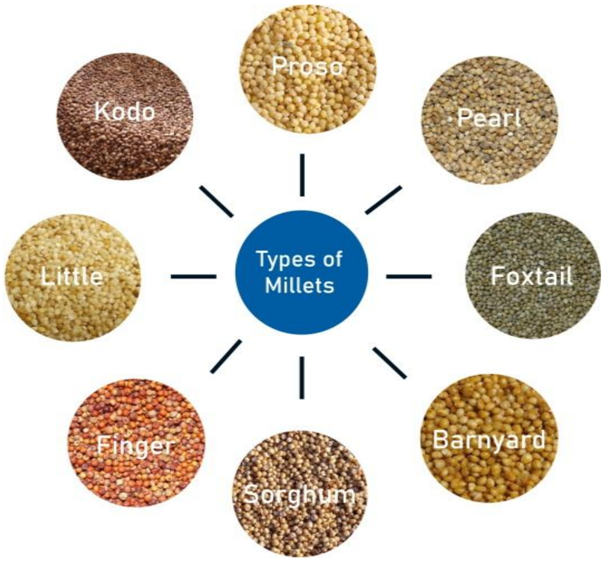
Foxtail millet

Foxtail millet is also adapted to moderate climates. It produces long, cylindrical or lobed, bristly, condensed panicles.

Barnyard millet

Barnyard millet is important in the tropics and subtropics of India.

Kodo millet



Kodo millet is harvested as a wild cereal in Western Africa and India, where it grows abundantly along paths, ditches and low spots.

Sorghum millet

Sorghum bicolor, commonly called sorghum and also known as great millet, broomcorn, guinea com, durra, imphee, jowar, or milo, is a grass species cultivated for its grain.

Pearl millet

Pearl millet is the most widely grown of all millets. It is also known as bulrush millet, babala, bajra, cumbu dukhn, gero, saije, sanio or souna.

Finger millet

Finger millet known as ragi in India is another important staple food in Eastern Africa and in Asia.

Common millet

Proso or Common millet is grown in temperate climates.

Little millet

Little millet is widely grown in India and in Nepal, Pakistan, Sri Lanka, eastern Indonesia and western Myanmar.

Kodo millet

Kodo millet is harvested as a wild cereal in Western Africa and India, where it grows abundantly along paths, ditches and low spots.

Buckwheat millet

Buckwheat Millet is commonly known as Kuttu. Its flour is used in Navratri fasting in almost every house.

History of millet

Millet was grown and consumed as necessary food for thousands of years with evidence of their use dating back to ancient civilization in China, Africa and India. Millet is one of the oldest crops that evidence of consumption by the Indus valley civilization in 3000 BC. In consumption to cultivated many varieties first in India. Millet are cultivation in more than 130 countries and it is traditional food of Asia and Africa more than 500 million peoples.

International Millet year celebration

In 3 March 2021 United Nations general assembly proposal for international year of millet in 2023 this proposal submitted by India and support by 72 countries.

Opening ceremony of International Year of Millet 2023 held in Rome.

Under the leadership of India, the whole world in celebrating the year 2023 as aninternational year of Millets, it was formally launched by Prime Minister Narendra Modi at International conference in New Delhi on 18 March 2023.

Objective

- Speeding awareness about millets food security and nutrition.
- Proving system production and quality.
- Draw focus on enhanced investment in research and development and tension service to achieve the other aims.
- Issue of stamps and coins.

Indian government view on millet

The Prime Minister said, "People in Karnataka understand the importance of the thick food grains (millets). That is the reason that you all call it Shree Dhannya. The country is taking for words Millets by respecting the sentiment of the people of Karnataka." Now the millets will be known as Shree anna across the country. Shree anna means the best among all the food grains.

Indian Prime minister Narendra Modi revealed the rationale behind terming millets as "Shree Anna" as announced by Union Finance Minister Nirmala Sitaraman in her budget speech Feb 2023 "Coars grains are being called "Shree

INTERNATIONAL YEAR OF MILLETS 2023

Anna". Over time, most people have limited themselves to cereals such as wheat and rice and the use of coarse grains has decreased significantly, while India produces many types of coars grains. Thick grains are very beneficial for health.

Agriculture Minister Narendra Singh Tomar said,"that the millets crop is rainfed which can be grown with less expenditure and consumes less water. Poor farmer can produce it in barrer land. The more the use of millets increasing the more nutrient will be available in the food which will be benefit people.

In 10 April 2018 Agriculture Ministry declared 'nutritious cereals' and celebrate National Millets Year of India.

Health benefit of millets

Millets are rich in nutrients and plant compounds. According to ICAR -Indian Institute of Millets Research to millets have 7-12% protein, 2-5% fat, 65-75% carbohydrate, 15-20% fibre. Therefore, they may offer multiple health benefits-

Good for heart

Millets are loaded with impressive profile of antitoxins that are play a crucial role in lowering LDL cholesterol, total cholesterol and helps to maintain the body vessels healthy and clears off the clots there are the control risk of heart disease and stroke.

Bottles cancer cells

Millets such as foxtail and proso varieties are proven by research to be effective inhibiting the growth of cancerous cell in various tissues.

Promotes digestive

The presence of a good amount of dietery fibre in millets working well to improve the digestive system and function.

Helping in reducing weight

It include Shri Anna indirect sothatin a way it was for natural fat burning and give good shape to body also helping in keeping full energy.

Strengther bones

Calcium is found in abundence in coars cereals such as jower, bajara.It is very beneficial for bone health. Also, it relieves the problem of joints pains.

Geographical condition isrequired to millet cultivation

Millets are hardly climate resident crop that can grow in wide range of geographical condition. However, there are few key conditions that are ideal fortheir condition. Some of the geography condition required to cultivation millets

Climate

Millet is typically grown in area with hot and dry climate, although they can also be grown in area with moderate rainfall. Millet requires temperature between 25 to 35°C and can tolerate condition. Millets are often grown as catch crop where other crops have failed due to unfavorable weather.

Soil

Millet prefer will drainage soil with good organic matter content they can grow in wide range of soil types including Sandy, loamy and clay soils and pH between 6 to 7.6.

Sunlight

Millets are required full sunlight for optimal growth and development.

Water ability

Millets are relatively drought tolerant and can grow in area with low rainfall the annual rainfall required 200 to 600 mm rainfall. However, they do require some moisture during growing season especially during the critical stage of growth.

Important of millet the environment and climate change

Millet is a climate-resilient food crop that can adapt to various ecological conditions, reduce irrigation requirements, and improve growth and productivity. It is less susceptible to environmental stress and can withstand climate change better than most other crops. Millet's fibrous roots improve soil quality, control water flow, and promote conservation in erosion-prone areas. As a C4 grain, millet converts more carbon dioxide into oxygen, helping to mitigate climate change. With a carbon footprint of 3,218 kilograms per hectare, millet contributes significantly to reducing carbon dioxide emissions and curbing climate change.

Measures being taken to promote Millet: A multi-pronged strategy

APEDA

The APEDA is also working in collaboration with the Department of Agriculture and Farmers Welfare to increase cultivation area, production and productivity of millets, including bajra, jowar and ragi.

Millets as Nutri-cereals

In view of the nutritional value of the millets, the government has notified millets as nutri-cereals in April, 2018. The millets are a rich source of protein, fibre; minerals, iron, and calcium have a low glycemic index.

International Year of Millets

In March, 2021, the United Nations General Assembly (UNGA) has declared 2023 as International Year of Millets.

Intensive Millets Promotion (INSIMP): Launched in 2012 as a part of the Rashtriya Krishi Vikas Yojana (RKVY), to advance equipment and technology related to millet harvest and increasing productivity of inefficient areas

Rainfed Area Development Programme

Developing and identifying new areas receiving adequate rainfall for millet farming as a part of the Rashtriya Krishi Vikas Yojana (RKVY).

MSP of nutri-cereals

Next, the government hiked the MSP of nutri-cereals, which came as a big price incentive for farmers. As we compare the data on MSPs for food crops from 2014-15 against 2020, we see that the MSP for ragi has jumped a whopping 113 per cent, followed by bajra and jowar at 72 per cent and 71 per cent respectively. MSPs have been calculated so that the farmer is ensured at least a 50 per cent return on their cost of production.

National Food Security Mission

Millets are being promoted under the National Food Security Mission (NFSM) to help provide good nutrition to those who are unable to afford it. To provide a steady market for the produce, the government included millets in the public distribution system.

Efforts by Ministry of Agriculture & Farmers' Welfare

Next the Ministry of Agriculture & Farmers' Welfare is running a Rs 600-crore scheme to increase the area, production and yield of nutri-cereals.

With a goal to match the cultivation of nutri-cereals with local topography and natural resources, the government is encouraging farmers to align their local cropping patterns to India's diverse 127 agro-climatic zones.

Building Value Chains

Provision of seed kits and inputs to farmers, building value chains through Farmer Producer Organisations and supporting the marketability of nutri-cereals are some of the key interventions that have been put in place.

"Millet in Minutes" products:

Recently APEDA launched a variety of "Millet in Minutes" products under the category of Ready-to-Eat (RTE) such as Upma, Pongal, Khichadi, Noodles, Biryani, etc, this is a breakthrough in the food sector as it's the first RTE millet product in the market to cater fast-paced world at their convenience in a healthy way. All the millet products launched by APEDA are gluten-free, 100% natural and patented. All the RTE products are vacuum processed without any additives, fillers and preservatives. Nutrition value is retained as original with a shelf-life of 12 months in ambient temperature.

Nutri-Gardens and Behaviour Change Campaign

The Ministry of Women and Child Development has been working at the intersection of agriculture and nutrition by setting up nutri-gardens, promoting research on the inter-linkages between crop diversity and dietary diversity and running a behaviour change campaign to generate consumer demand for nutri-cereals.

Let's Millet Campaign in Bengaluru

In 2018, the #LetsMilletCampaign in Bengaluru saw the avant-garde use of millets in dishes such as risotto and pizza by restaurateurs.

Cultural associations and festivals

Cultural associations and festivals, such as the North-East Network in Nagaland organized in 2020 and Mandukiya in Vishakhapatnam celebrated annually in June/July, has helped promote the growth of millets.

Integrated Cereals Development Programmes in Coarse Cereals

The government also initiated the 'Integrated Cereals Development Programmes in Coarse Cereals' under Macro Management of Agriculture.

Conversion of Fallow Lands

Efforts by Indian Institute of Millet Research

The Indian Institute of Millet Research, the International Crops Research Institute for the Semi-Arid Tropics and the government of Karnataka are going to collaborate along with more partners to promote millets in India.

The Future of Millets in India

The future of millets in India looks promising, with growing interest in this crop both domestically and globally. The Indian millets Industry will continue to expand as a result of a number of causes, including:

Health and Wellness Trend

With a growing focus on health and wellness, there is an increasing demand for nutritious and sustainable food options, making millets a popular choice

Government Support

The government of India is providing support for the millets sector through various initiatives, such as promoting their use in government-run food programs and providing subsidies and incentives for farmers

Growing Export Market

The global demand for millets is growing, and India has the potential to become a major exporter of these crops.

Diversification of Agriculture

The cultivation of millets can help diversify the agricultural sector and reduce the dependence on a few staple crops, reducing the risk of crop failures and market Volatility.

Conclusion

In world, after the corona pandemic, people are competing to increase the unity system so that they can protect their health. India wants to make Vishwa Guru by using disaster as an opportunity, so after yoga it is now telling the importance of 'Shree Anna' to the whole world. India is promoting its culture in G-20 meeting with '**Vasudhaiva Kutumbakam'** theme. India wants to tell the whole world in various factors that through Shree Anna will improve health, people's food supply and farmers' income will increase.

Carbon storage and sequestration potential of agroforestry systems under different climatic conditions

Kiran, K S Pant and Prem Prakash

Department of Silviculture and Agroforestry, College of Forestry, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, India 173230
E-mail: panwarkiran1998@gmail.com

Abstract

Carbon Sequestration is the process of removing carbon from the atmosphere and depositing it in a reservoir. Carbon pools in such terrestrial systems include the aboveground plant biomass and below ground biomass. Continuous growth of plant also increases the carbon storage and different plants species have different capacity of carbon sequestration. The total amount sequestered in each part differs greatly depending on a number of factors, including the region, the type of system, site quality, and previous land-use. With increasing population, urbanization, industrialization etc., there is an increasing demand for the alternate land use system that can cope with the developmental activities in a sustainable manner making agroforestry, a traditional practice in Himachal Pradesh to emerge at the forefront as is it has proven to be advantageous over monocropping and is also helpful in improving the livelihood security of rural farmland. In the lap of Himalayas, Himachal Pradesh, a biodiversity rich state, is also on the track of developmental activities resulting in the loss of diversity. Agrihortisilviculture and Agrihorticulture systems with diverse components were playing important role in enhancing the biodiversity conservation, soil enrichment, and improving the economic status of the farmers of HP.

Introduction

In India, agroforestry practices are traditional and practiced in a variety of ways and are based on the population's socio-economic, cultural, demographic factors, as well as farmers' experiences and other related factors. Various agroforestry systems have been developed in diverse agro-climatic regions of the country, all of which have proven to be highly productive and environment-friendly. In agroforestry systems there are both ecological and economical interactions between the different components (Tiwari *et al.*, 2018). Trees add organic matter to the soil in various manners, whether in the form of roots or litter fall or as root exudates in the rhizosphere. Western Himalayan Zone consisting of Jammu and Kashmir, Himachal Pradesh and Uttarakhand hill covers an area of 33.85 m/ha which constitutes about 10% of the total geographical area and the soils contribute about 14% of SOC stock of the country. According to 2011 census, the human population of (H.P) was 68,56,509, out of which 6,88,704 persons live in urban and 61,66,805 in rural areas, respectively. The overall rate of human population increase was 12.81% from 2001 to 2011.

Different agro-climatic conditions of Himachal Pardesh:

Himachal Pradesh, the mountainous state is well known for its natural wealth. It is situated between 30˚22’40″ to 33˚12’40″ N latitude and 75˚45’55″ to 79˚04’20″ E longitude in the western Himalayas. The 12 districts *viz*., Bilaspur, Chamba, Hamirpur, Kangra, Kinnaur, Kullu, Lahaul and Spiti, Mandi, Sirmaur, Shimla, Solan, and Una of the state covers 10.5 per cent of the Indian Himalayan Region (IHR) and 1.69 per cent of country’s geographic area. The state experienced high variation in elevation and climatic conditions. The elevation of the state ranges from 350 to 6975 metres above mean sea level (amsl).

These topographic, climatic and demographic factors are responsible for changing status of vegetation systems. The total area under agroforestry is largest in Asia which is about 31.2 million ha (FAO, 2020). The agroforestry area estimate includes 9.8 M ha (Rizvi *et al.*, 2022).

Trees were introduced or deliberately planted on the disturbed as well as productive croplands. Their biomass production and carbon storage potential depends on nature and composition of species, their growth pattern and management practices applied for increasing productivity of system. Productivity studies often ends up with generating data about how much carbon is stored in the living biomass - roots, trunks, and leaves of plants - after tallying up carbon gains through photosynthesis and carbon losses through respiration. The five systems from four agroecological zones were identified and explored for their species composition, biomass production and carbon storage potential

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Table 1: Area under different agro-ecological zones in Himachal Pradesh (HP), India (Bhagat *et al.*, 2006)

Sr. No.	Zone	Elevation range(m)	Area (km^2)	Per cent (%)	Districts within zone
1.	Sub –Montane and Low hills sub-tropical zone (Zone-I)	<1000	10260	18.44	Kangra, Una, Hamirpur, Solan, Chamba, Mandi, Sirmaur, Bilaspur
2.	Mid-hills sub-humid zone (Zone-II)	1000-1500	4664	8.38	Chamba, Kangra,, Mandi, Shimla, Solan, Sirmaur, Kullu, Kinnaur, Hamirpur, Bilaspur
3.	High hills wet temperate zone (Zone-III)	1500-2500	9217	16.56	Shimla, Mandi, Chamba, Kangra, Kullu, Solan, Sirmaur, Kinnaur, Lahul and Spiti
4.	High hills dry temperate	>2500	31509	56.62	Kangra, Lahul and Spiti,

	zone (Zone-IV)				Kinnaur, Chamba, Mandi, Sirmaur, Shimla,

Table 2: Different agroforestry systems-species composition

Agro-climatic zones	Agroforestry systems	Major agricultural crops	Major forest trees	Major fruit trees	Major grasses
Zone-I	Agrisilviculture, Agrihorticulture, Agrisilvihorticulture, Agrihortisilviculture, Hortisilviculture, Silvipasture, Pastoralsilviculture, Agrisilvipasture, Pastoralsilvihorticulture	Maize, Rice, Blackgram, Okra, Onion, Garlic, Wheat, Pea, Potato, Barley, Tomato	Beul, Khirak, Shisham, Khair, Toon, Melia, Eucalyptus, Leucena, Kachnar	Mango, Citrus, Plum, Litchi, Aonla	*Chrysopogon montanus, Heteropogon contortus, Apluda mutica, Imperata cylindrical*
Zone-II	Agrisilviculture, Agrisilvihorticulture, Agrihortisilviculture, Agrisilvipasture, Agrisilvihortipastoral, Agrihorticulture, Hortisilviculture, Silvipastoral, Pastoralsilviculture	Maize, Mustard, Barley, Wheat, Gram, Turmeric, Cauliflower, Pea, Zinger, Cabbage	Beul, Khirak, Salix, Leucena, Kaphal, Semul, Chirpine, Kachnar, Ficus spp, Ban oak	Peach, Pear, Plum, Apricot, Daru, Apple	*Dicanthium annulatum, Themeda annathera, Heteropogon contortus, Paspalum notatum*
Zone-III	Agrisilviculture, Agrihorticulture, Hortisilviculture, Agrisilvihorticulture, Agrihortisilviculture, Pastoralsilviculture, Hortipastoral, Silvipastoral	Maize, Mustard, Barley, Wheat, Amaranthus, Gram, Turmeric, Cauliflower, Pea, Zinger, Cabbage	Beul, Khirak, Toon, Bluepine, Quercus spp, Rhododendron, Spruce, Semul, Alder, Horse chestnut, Deodar	Apple, Peach, Apricot, Almond, Daru, Persimon	*Cymbopogon martinii, Themeda anathera, Cynodon dactylon, Apluda mutica, Andropogon nardus, Dactylis gloemerata*

Zone-IV	Agrisilviculture, Agrihorticulture, Agrisilvihorticulture, Agrihortisilviculture, Pastoralhorticulture, Silvipasture, Agrisilvipasture, Pastoralsilviculture	Maize, Potato, Millets, Peas, Oat, Amaranthus, Barley	Poplar, Salix spp, Robinia spp, Deodar, Blue pine, Chilgoza pine	Apple, Apricot, Grapes, Akhrot, Almond	*Arundinella nepalensis*, *Agrostis spp.*, *Poa annua*, *Trifolium repens*, *Dactylis golemerata*, *Agrostis canina*

Table 3: Biomass production under different agroforestry systems

Agroforestry systems	Zone (Z)	Above ground biomass(t/ha)	Below ground biomass(t/ha)	Total biomass(t/ha)
Agri-Silviculture	Z-I	53.29	13.47	66.76
	Z-II	44.51	13.38	57.89
	Z-III	56.87	16.72	73.59
	Z-IV	89.59	24.58	105.9
Agri-Horticulture	Z-I	60.58	13.51	74.10
	Z-II	44.21	12.95	57.16
	Z-III	52.12	15.29	67.41
	Z-IV	69.70	21.90	91.60
Agri-Silvi-Horticulture	Z-I	-	-	-
	Z-II	57.45	16.92	74.37
	Z-III	67.97	20.20	88.17
	Z-IV	-	-	-
Agri-Horti-Silviculture	Z-I	70.91	21.21	92.12
	Z-II	58.74	17.60	76.34
	Z-III	71.91	21.38	93.29
	Z-IV	-	-	-
Silvi-Pasture	Z-I	45.04	11.30	56.35
	Z-II	67.14	17.33	84.46
	Z-III	77.63	21.17	98.80
	Z-IV	118.8	24.44	143.29

Table 4: Carbon stock potential under different agroforestry systems

Agro-climatic zones	Agroforestry Systems	Carbon stock potential (t/ha)				
		Aboveground carbon stock (t/ha)	Belowground carbon stock (t/ha)	Total vegetation carbon stock (t/ha)	Soil organic carbon stock (t/ha)	Total carbon stock (t/ha)
Zone-I	Agrisilviculture	5.86-26.65	2.16-6.73	8.44-33.38	9.37-32.26	35.11-42.75
	Agrihorticulture	6.33-30.29	2.30-6.76	8.64-37.05	17.05-31.51	36.58-58.39
	Agrisilvihorticulture	8.73-13.01	2.44-2.80	11.17-15.81	19.80-35.63	49.97-52.31
	Agrihortisilviculture	9.41-35.45	2.19-10.60	12.10-46.06	12.40-27.29	32.12-58.46
	Silvipastoral	11.97-22.52	3.36-5.65	15.34-28.17	17.96	46.13
	Pastoralsilviculture	1.01-2.10	0.17-0.54	1.19-4.94	20.18-32.62	29.72-38.32
Zone-II	Agrisilviculture	22.26-24.32	6.69-7.25	28.95-31.57	49.43-50.01	78.38-81.58
	Agrihorticulture	22.11-23.43	6.47-6.87	28.58-45.89	40.49-51.88	78.58-86.38
	Agrisilvihorticulture	28.72-31.57	8.46-9.43	37.18-40.99	50.5-51.18	87.68-92.17
	Agrihortisilviculture	29.37-30.48	8.80-9.01	38.17-39.49	49.74-52.57	87.91-92.06
	Silvipastoral	33.57-35.32	8.66-9.31	42.23-51.06	36.25-49.76	87.31-94.38
Zone-III	Agrisilviculture	28.44	8.36	36.80	51.19	87.99
	Agrihorticulture	26.06	7.65	33.71-51.65	41.19-55.64	88.29-96.67
	Agrisilvihorticulture	33.98	10.10	44.08	56.70	100.78
	Agrihortisilviculture	35.96	10.69	46.65	54.06	100.71
	Silvipastoral	38.81	10.59	49.40-71.61	37.41-53.12	100.28-109.93
Zone-IV	Agrisilviculture	40.29	12.29	52.95	-	52.95
	Agrihorticulture	33.43	10.95	46.04	21.03	67.07
	Silvipastoral	59.4	12.23	71.61	17.91	89.54

Conclusion

The topographic condition and biotic factors like human and livestock pressure along with some edaphic factors are responsible for species distribution, biomass production and carbon storage in different land use systems. Biomass and carbon stock in vegetation was maximum in Hortiagrisilviculture agroforestry system and minimum in Hortiagriculture agroforestry systems. In case of different tree based systems, Silvipasture recorded higher biomass production and carbon storage as they had high number of woody species as compared to all other systems. Forest and silvi-pasture particularly at higher elevation is store house of C-stocks in both plants as well as soil. From CO_2 mitigation point of view, agri-horti-culture land use systems were found better than agriculture, horticulture, silvi-pasture, and forest land use systems at all altitudinal gradients. It is concluded that agroforestry systems, particularly agrihorticulture and agrihortisilviculture land use systems are playing an important role in the biodiversity conservation, soil enrichment, carbon storage and improving the economic status of the farmers of Himachal Pradesh.

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Urbanization and green vitality: Impact of urban environment on vegetation health

Garima Bhatt, Sanchit Semwal, Sarthak Gadre, Bhaskar Saini, Pooja Yadav, Pratiksha Singh and Asmita Joshi

ICFRE-Forest Research Institute (Deemed to be) University
Dehradun – 248006
E-mail: garimabhatt777@gmail.com

Abstract

Urbanization has rapidly transformed the global landscape, leading to the expansion of urban areas and the proliferation of concrete jungles. This rapid growth of urban environments has profound effects on the health and vitality of vegetation. This review article examines the impact of urbanization on vegetation health, focusing on the challenges posed to green spaces, trees, and urban flora. It also explores the crucial role of green vitality in promoting a sustainable and resilient urban environment. By analyzing various studies, methodologies, and case studies, this review highlights the importance of preserving and enhancing vegetation in urban settings to create healthier, more livable cities for the future.

Keywords –Urbanization, Vegetation health, Urban green spaces,UHI (Urban heat island)

Introduction

Towns and cities are the most densely populated areas on Earth and will continue to be the artificial landscapes most widely used by the greater part of the Earth's population in the future. In 2030 more than 60% of humans will live in cities. Changes in urban conditions have often caused deterioration in environmental quality and may result in damage to the health of city-dwellers (Kuttler, 2008).

The urban environment encapsulates a diverse spectrum of features, encompassing not only the physical infrastructure of buildings and roads but also the social, economic, and environmental factors that shape urban life (Alberti, 2019). It is characterized by high population density, intensive land use, and a concentration of activities that often lead to distinct environmental conditions, such as altered microclimates and modified hydrological cycles (Seto*et al*., 2013). These characteristics collectively contribute to the unique challenges and opportunities that the urban environment presents in the realm of vegetation health.

Identifying the effects of urban environments on vegetation along with the mechanisms driving it can help improve our understanding of vegetation growth responses to global environmental change (Zhang *et al*., 2022). Climate changes and human activities have resulted in widespread changes in vegetation growth at both the regional and global scales in the past few decades (Jiang *et al*., 2017; Liu *et al*., 2018). There is a growing recognition of the importance of green spaces and vegetation in creating sustainable and resilient urban environments (Mehdi *et al*.,2017).Green spaces mitigate the effects of air pollution by acting as natural air filters and can also help reduce the urban heat island effect through shading and evaporative cooling (Bhandari and Zhang,2022).

This comprehensive reviewaims to provide an in-depth analysis ofthe impact of urbanization on vegetationhealth, exploring the challenges faced by greenspaces in urban environmentsandthe various strategies employed to enhance green vitality.

Urbanization and green space loss

Urban expansion often involves the clearance of forests, wetlands, and other ecosystems to make way for infrastructure development (Pickett,2015).As green spaces give way to concrete and asphalt, the direct impact on vegetation health becomes evident (Mohajerani*et al*., 2017).

One of the most significant consequences of urbanization is deforestation, which directly contributes to the loss of vegetation cover (Hassan *et al*., 2016). Habitatfragmentation, a consequence of urban expansion, isolates plant populations, reducing genetic diversity and making species more susceptible to disease and extinction (Templeton, 1990).

Urbanization contributes to the creation of urban heat islands (UHIs), where densely built environments absorb and retain heat, causing localized temperature increase (Mohajerani, 2017).Elevated temperatures associated with UHIs can lead to heat stress, affecting photosynthesis, nutrient uptake, and overall plant growth (Aguiar, 2012).The loss of green spaces and the associated challenges of deforestation, land-use changes, and the urban heat island effect collectively undermine the health of vegetation in urban environments.

Air pollution and vegetation health

Urbanization brings with it increased industrial activities, transportation, and energy consumption, leading to elevated levels of air pollution in urban areas (Zhu *et al*., 2019)**.**The pollutants emitted from these sources, including nitrogen oxides (NOx), sulfur dioxide (SO_2), ozone (O_3), and particulate matter (PM), have far-reaching impacts on both human health and the environment (Sharma *et al*., 2013). Air pollution poses a substantial threat to the health and vitality of urban vegetation (Barwise and Kumar, 2020).

Plants are in direct contact with the atmosphere, making them vulnerable to the harmful effects of air pollutants(Manisalidis, 2020). Ozone molecules react with leaf tissues, inducing oxidative stress that damages chloroplasts, the cellular organelles responsible for photosynthesis (Hasanuzzaman*et al*., 2012). Airborne pollutants can physically harm plant leaves, resulting in visible signs of injury such as necrosis, stippling, and discoloration (Vollenweider and Günthardt-Goerg, 2005). Particulate matter, including fine and coarse particles, can obstruct stomata, the microscopic pores on leaves that facilitate gas exchange(Ayala-Cortés*et al*., 2023).This obstruction hampers photosynthesis and transpiration, limiting the plant's ability to regulate water and temperature.

The interaction between air pollution and climate change further exacerbates the challenges faced by urban vegetation (Singh *et al*., 2020). Elevated levels of carbon dioxide, often associated with urban areas, can initially stimulate plant growth through a process known as the CO_2 fertilization effect (Ziska and Bunce, 2006). This growth response can be counteracted by other pollutants, such as ozone, which diminishes the positive effects of elevated CO_2.

Urban air pollution presents a formidable threat to the health and vitality of vegetation in urban environments.By mitigating the impacts of air pollution on vegetation, cities can cultivate healthier, more vibrant, and resilient urban ecosystems (Singh et al., 2020).

Urban heat island and vegetation stress

The urban heat island (UHI) effect, a phenomenon where urban areas experience higher temperatures than their rural surroundings, is a direct consequence of urbanization (Heaviside *et al*., 2017).The rise in temperature associated with UHIs can create an environment of stress for urban vegetation.Plants are highly sensitive to temperature fluctuations, and excessively high temperatures can disrupt their physiological processes (Źróbek-Sokolnik, 2012). Elevated temperatures trigger heat stress in plants, leading to a cascade of negative impacts on growth, metabolism, and overall health (Hasanuzzaman *et al*., 2013).

Heat stress damages chloroplasts, reduces enzyme activity, and disrupts the delicate balance of metabolic reactions, leading to reduced energy production (Sharma *et al*., 2020). Therefore high temperatures during UHIs can impair photosynthesis, the process by which plants convert sunlight into energy and produce oxygen. Elevated temperatures accelerate transpiration rates, leading to greater water loss through leaf pores (stomata) (Bertolino, 2019). This combination of reduced photosynthesis and increased water loss can push plants towards water stress, further compromising their health.

Urban planning and green infrastructure play a pivotal role in mitigating the impact of UHIs on vegetation health (Shao and Kim, 2022). The integration of strategic vegetation, green spaces, and sustainable design principles can counteract the warming effects of UHIs, creating a more favorable environment for urban plants (Lehmann, 2021). Green infrastructure, including urban parks, green roofs, and tree-lined streets, can effectively mitigate the impacts of UHIs on vegetation.

Urban green infrastructure and sustainable planning

As urbanization continues to reshape cityscapes, the need to counteract the negative impacts on vegetation health becomes paramount.There are some diverse green infrastructure practices—such as green roofs, vertical gardens, and urban parks—that play a pivotal role in enhancing urban green vitality.

Green roofs

Green roofs involve the installation of vegetation atop buildings, transforming otherwise unused spaces into thriving ecosystems (Town, 2012). By insulating buildings, absorbing rainwater, and reducing the urban heat island effect, green roofs contribute to energy savings and enhanced vegetation health (Berardi et al., 2014).

Vertical Gardens

Vertical gardens, also known as living walls, bring vegetation to vertical surfaces, offering a striking visual spectacle while maximizing limited space (Babnik, 2020). These structures provide numerous benefits, such as improved air quality, reduced noise pollution, and temperature moderation (Başdoğan and Arzu, 2016).

Urban Parks

Urban parks serve as vital green lungs within urban landscapes, providing space for recreation, relaxation, and habitat conservation.Urban parks also serve as essential gathering spaces, strengthening social cohesion and community interaction (Peters et al., 2010).

Green Corridors

Green corridors are linear networks of interconnected green spaces, facilitating the movement of plants, animals, and ecological processes within urban areas(Bilgili and Gökyer, 2012).

The successful integration of green infrastructure into urban planning requires collaborative efforts among city officials, architects, landscape designers, and community members.By embracing practices like green roofs, vertical gardens, urban parks, and green corridors, cities can enhance their ecological resilience, promote biodiversity, and create healthier, more enjoyable living environments.

Future prospects, recommendations, and conclusion

As urbanization accelerates, prioritizing vegetation health in cities becomes paramount. Challenges like land scarcity, climate change, biodiversity loss, and equitable green access necessitate urgent attention. Policymakers must enact green regulations mandating green infrastructure integration while offering incentives to stakeholders. Urban planners and designers can create resilient ecosystems by emphasizing biodiversity, climate resilience, and innovation. Communities play a pivotal role by advocating for green spaces and participating in greening initiatives.

In conclusion, urban green spaces stand as integral components in nurturing vegetation health amidst rapid urbanization. These spaces offer more than aesthetics, providing essential services like air purification, temperature regulation, and biodiversity support. Sustainable urban planning and green infrastructure integration present a roadmap to foster a healthier, resilient urban environment that benefits both humans and nature. As cities evolve, embracing this vision can pave the way for greener, more vibrant urban futures that strike a harmonious balance between urban development and the well-being of the ecosystem.

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Unlocking ecological histories: Advancements in dendroecology research

Reghu Anandu[1] and Mohammed Haffis[2]

ICFRE-Institute of Wood Science and Technology
Bengaluru
Forest Ecology and Climate Change Division
ICFRE-Forest Research Institute
Dehradun

Dendroecology

Dendroecology is a field of study that examines historical ecological processes using dendrochronology. Tree ring analysis, or dendrochronology, uses historical events and environmental changes to calculate dates. Dendroecology may be utilized to address a variety of ecological issues, including the history of fires, insect outbreaks, forest dynamics, climate change, and the identification of pollutant sources. A potent technique for analysing changes in historical and contemporary forest habitats is dendroecology. Dendroecology researches have been carried out in several tropical and temperate locations utilising a variety of tree species and techniques.

Application of dendroecological analysis

Dendroecology can shed light on historical and present biological processes that form forest ecosystems. There are certain applications of dendroecological analysis that can help us understand more about the past and current ecological processes that impact forest ecosystems. Dendroecology is frequently used to recreate historical climatic conditions. Temperature, precipitation, and other climatic factors are recorded in tree rings. Scientists may generate historical climate records, which are crucial for comprehending long-term climate trends and variability, by analysing tree ring patterns from various time periods.

Here are a few examples: A research that reconstructed the history of contamination source identification in soil, groundwater, and tree tissues (Morrison *et al*., 2009) using tree rings and stable isotopes. A research project that used tree rings to retrace the history of fire and climate in the Sierra Nevada and southwest of the US during the last 1000 years (Rozendaal *et al*., 2011) another investigation that examined individual trees' long-term development patterns in a tropical rainforest and how they related to environmental variables using tree rings (Amoroso *et al*., 2017). Using tree rings, it is assessed that how mangrove plants responded to changes in salinity caused by seasonality in precipitation and temperature. A research that used tree rings to evaluate a forest development model and predict a pine plantation's wood yield. These are only a few of the many uses of dendroecology in the tropics and elsewhere.Tree rings can reveal information about past fire regimes in a specific location.

Fire History and Ecology

The frequency, severity, and seasonality of historical fires may be ascertained using fire scars, also known as fire scars, on tree rings. This knowledge is useful for managing ecosystems that are vulnerable to fire and comprehending how fire shapes landscapes. Dendroecology is useful in determining how disturbances like logging, insect outbreaks, and disease occurrences affect forest ecosystems. Forest management and disturbance history: Researchers can ascertain the date and size of disturbances as well as how trees react to these occurrences by analysing tree rings. The growth rate and productivity of a tree are revealed by its rings, and this information is related to the carbon and nutrient cycling that occurs within ecosystems. Scientists can better understand how alterations in the environment and in land management practises affect these crucial ecological processes by examining tree rings.Glacial and Permafrost Studies: In areas with both permafrost and glaciers, tree rings can reveal details on the stability of permafrost as well as the retreat and advance of glaciers. Researchers can reconstruct previous glacier movements and infer paleoclimatic conditions by examining tree growth patterns and dating old wood preserved in glacial deposits. Dendroecology helps with archaeological and historical research by determining the age of timber buildings, artefacts, and cultural locations. The age and provenance of historical artefacts can be verified by comparing tree ring patterns from these sources to known chronologies.Dendroecological information can support conservation efforts and direct restoration procedures. Scientists and land managers may make knowledgeable choices to save and restore natural ecosystems by comprehending the historical context of ecosystems. These studies can also shows the interactions between tree species, competition for resources, and changes in species composition through time.

Biodiversity and Species Interactions

Scientists may learn more about the dynamics of forest ecosystems and how they respond to environmental changes by analysing tree ring data.

Advancing Dendroecological studies in India

Dendroecology study holds great promise in unravelling the climatic history of regions across the globe. In India, while dendroecological research is still in its infancy, significant strides have been made by various national institutes. The Indian Institute of Tropical Meteorology (IITM) in Pune, Birbal Sahni Institute of Palaeobotany (BSIP) in Lucknow, and the Indian Institute of Science in Bangalore have spearheaded research initiatives, primarily focusing on coniferous trees in the Himalayan region and teak and toon trees in the tropical climate. With a particular interest in rainfall variability, dry season ground fires, and reconstructing climate patterns, researchers are now turning their attention to explore new tree species that might yield valuable insights.

Target Species: *Tectona grandis* and beyond:

Tectona grandis, commonly known as teak, has emerged as a target species for tree-ring research due to its reliable annual ring formation. This tropical hardwood species not only presents a feasible avenue for studying climate signals but also offers valuable insights into its growth response to environmental conditions. Additionally, researchers are exploring other tree species, such as *Lagerstroemia microcarpa*, *Cedrela toona*, and *Terminalia bellirica*, to expand the scope of dendroecological studies in India. These species, found in deciduous forests and known to produce annual rings, hold the potential to provide further understanding of climate as well as ecological dynamics. Efforts are underway to explore several other tree species in India that might produce annual rings, which have yet to be discovered by the scientific community. By studying these unknown species, researchers aim to expand the knowledge base of dendrochronology in the Indian context and unlock new insights into climate patterns and environmental changes. This exploration opens up avenues for multidisciplinary collaboration and the possibility of refining existing methodologies while developing novel approaches to extract climate information from tree rings. (Suresh, H.S., 2012)

Challenges in dendroecological analysis

Dendroecological analysis in the tropics is more challenging than in temperate regions due to certain obstacles.

- Among these difficulties are: Due to weak or variable seasonality, complicated phenology, and cambial activity, many tropical tree species lack or have irregular yearly growth rings (Quintilhan *et al*., 2021). Due to the lack of shared development signals, synchronisation, and replication, it is difficult to cross-date tree-ring series from various trees or sites. (Groenendijk *et al*., 2014). There aren't enough long-lived tree species to give lengthy chronologies for climatic reconstructions or disturbance histories (Quintilhan *et al*., 2021)
- The scarcity of reference material to calibrate and validate tree-ring data, such as climate records, forest inventories, or historical documents. The logistical and methodological restrictions of gathering, processing, and analysing tree rings in distant and varied tropical forests(Quintilhan *et al*., 2021).

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रीठा (सैपिंडस मुकरोसी): बंदर प्रभावित क्षेत्रों के लिए एक लाभकारी फसल

संजीव कुमार[1], नीरज संख्यान[1]*, नितिन शर्मा[1], शिवानी चौहान[2]

[1]मूल विज्ञान विभाग, कॉलेज ऑफ़ फॉरेस्ट्री
डॉ वाई.ऐस.परमार.यूनिवर्सिटी ऑफ़ हॉर्टिकल्चर एंड फॉरेस्ट्री, नौनी, सोलन (हि.प्र.)
[2]मृदा विज्ञान विभाग
कॉलेज ऑफ़ हॉर्टिकल्चर एंड फॉरेस्ट्री नेरी, हमीरपुर (हि.प्र.)
* ई-मेल: neerajsankhyan80@gmail.com

भूमिका

मानव-पशु संघर्ष समाज और सरकार दोनों के लिए एक बड़ी चुनौती है जिसका समाधान प्राथमिकता के आधार पर जरूरी है। बंदर अब मानव बस्तियों के करीब पहुंचकर कृषि व बागबानी के लिए खतरा बन चुके हैं । बंदरों के हमले से हिमाचल प्रदेश, जम्मू-कश्मीर, उत्तराखंड, उत्तर प्रदेश, महाराष्ट्र आदि राज्यों में करोड़ों रुपये की फसल का नुकसान होता है। अकेले हिमाचल प्रदेश में ही बंदरों और अन्य जानवरों के कारण हर साल लगभग 500 करोड़ रुपये की फसल का नुकसान दर्ज किया जाता है। वर्तमान में भारत के हिमाचल प्रदेश की 3226 पंचायतों में से 2301 पंचायतें बंदरों और आवारा पशुओं की समस्या से ग्रसित हैं । इसके अलावा तेजी से बदलती जलवायु के कारण पश्चिमी हिमालय के कई हिस्सों में कृषि व बागवानी अधिक लाभदायक प्रस्ताव नहीं रहा है जिसकी वजह से किसान चिंताजनक दर पर कृषि को छोड़ रहे हैं। कृषि में विविधीकरण के लिए नई फसलों व किस्मों को आर्थिक रूप से व्यवहार्य बनाने और जंगली जानवरों से कम से कम प्रभावित होने के साथ-साथ तेजी से बदलती जलवायु की स्थितियों के अनुकूल बनाने की आवश्यकता है।

परिचय

रीठा एक स्वदेशी प्रजाति है जो मौसम की खराबी और जंगली व आवारा जानवरों से प्रभावित क्षेत्रों में सफल खेती की सम्भावना जगाती है। यह एक सहिष्णु प्रजाति है जिसके फल लंबे समय तक ख़राब नहीं होते । सपिंडस मुकोरोसी: रीठा, सोपनट, डोडान, डोडनी, अरिठा और वॉशनट जैसे कई नामों से जाना जाता है। यह बड़े पैमाने पर ऊंचे सिंधु-गंगा के मैदानों, शिवालिक और उप हिमालयी इलाकों में 200 मीटर से 1500 मीटर की ऊंचाई तक पाया जाता है। रीठा एक काफी बड़ा पर्णपाती पेड़ है जिसका सीधा तना 12 मीटर तक ऊँचा होता है । कभी-कभी इसकी ऊँचाई 20 मीटर और घेरा 1.8 मीटर तक भी होता है। छाल गहरे से हल्के पीले रंग की व चिकनी होती है , जिसमें कई रेखाएं और बारीक दरारें होती हैं। इसकी ब्लेज़ 0.8-1.3 से मी, कठोर, बगैर रेशेदार, हल्के नारंगी भूरे रंग की , भंगुर और दानेदार होती है। इसकी पत्तियां 30-50 से.मी. लंबी, पेटीओल बहुत संकीर्ण सीमा से घिरा हुआ, ग्लैबरस, विपरीत या वैकल्पिक, 2.5-5 से.मी., लांसोलेट होती है। पुष्पक्रम एक टर्मिनल पैनिकल होता है, जो लंबाई

में 30 से.मी. या उससे अधिक होता है। फूल लगभग 5 मि.मी. चौड़े, छोटे, टर्मिनल, हरे सफेद व असंख्य होते हैं। फल ग्लोबोज,1-बीज वाले ड्रूप, कभी-कभी दो ड्रूपल एक साथ, लगभग 1.8-2.5 से.मी. के पार होते हैं। बीज 0.8-1.3 से.मी. व्यास के, गोलाकार, चिकने, काले और सूखे फल में ढीले ढंग से रखे हुए होते हैं। अजैविक से लेकर जैविक उत्पादों के प्रति लोगों की बदलती जीवन शैली के कारण इसकी मांग न केवल भारत में बल्कि विदेशों में भी काफी बढ़ गई है। इसके पेरीकार्प में मौजूद सैपोनिन (जो की एक जैविक डिटर्जेंट है) होने के कारण विकसित देशों में इसकी भारी मांग है और भारत से हर साल इसके नट्स का करोड़ों रुपयों का निर्यात मुख्य रूप से अमेरिका, इंग्लैंड , जर्मनी, ऑस्ट्रेलिया, नेपाल और बांग्लादेश आदि देशों में किया जाता है। ये भारत से होने वाले पूरे साबुन निर्यात में 73.91 प्रतिशत से अधिक की हिस्सेदारी रखते हैं। वर्ष 2020-21 में भारत ने 0.69 मिलियन अमेरिकी डॉलर (05 करोड़ रुपये) मूल्य का निर्यात किया है। गत वर्षों के सालाना निर्यात की कुल मात्रा लगभग 372780 मीट्रिक टन थी। भारत से साबुन आयात के लिए अमेरिका सबसे बड़ा बाजार है।

रीठा के इस्तेमाल

सैपोनिन अथवा रीठा दवा उद्योगों, डिटर्जेंट और पारिस्थितिक उपचार में प्रयोग लाया जाता है। जैसा कि नवीकरणीय स्रोतों से प्राप्त किया गया है, ये गैर-विषाक्त हैं या कम विषाक्तता दिखाते हैं, सूक्ष्मजीवों, मनुष्यों, वनस्पतियों और जीवों को प्रसन्न करते हैं और आसानी से बायोडिग्रेडेबल होते हैं। यह सिंथेटिक सर्फैक्टेंट्स के लिए एक पारिस्थितिक विकल्प है। रीठा (सोपनट) उच्च गुणों के साथ, गुणवत्ता वाले बाल धोने के हर्बल शैंपू के विभिन्न ब्रांडों का मुख्य घटक है। इसका उपयोग नाजुक कपड़ों, विशेष रूप से ऊनी और रेशम को धोने के लिए किया जाता है। व्यावहारिक रूप से रीठा के सभी हिस्सों का उपयोग संभवतः लाभप्रद रूप से किया जा सकता है जैसे सैपोनिन के लिए पेरिकार्प, तेल के लिए कर्नेल आदि। इसके अलावा दंत क्षय, पिंपल्स, गठिया, मिर्गी, क्लोरोसिस, माइग्रेन, कब्ज एक्जिमा और सोरायसिस जैसे कई रोगों के इलाज के लिए इसके औषधीय गुण काफी महत्व रखते हैं। साहित्य में रीठा (सैपिंडस म्यूकोरोसी) फलों पर फाइटोकेमिकल परीक्षणों से सैपोनिन (6% -17%) , शर्करा (10%) और विभिन्न जैविक कार्यों के साथ श्लेष्म की उपस्थिति का पता चला हैं। परिवर्तनशील पर्यावरणीय परिस्थितियों के तहत विभिन्न उपभेद मौजूद हैं, इसलिए इस संयंत्र में काफी मात्रा में आनुवंशिक विविधता की उम्मीद करना स्वाभाविक है, जो अब तक अज्ञात है।

निष्कर्ष

रीठा (सैपिंडस मुकोरोसी) एक उष्णकटिबंधीय पेड़ है जिसके कई आर्थिक अनुप्रयोग अंतरराष्ट्रीय स्तर पर इसके प्रति गहन रूचि जगा रहे हैं। इसकी खेती उन अधिकांश क्षेत्रों में व्यापक रूप से की जानी चाहिए जहाँ बंदरों की समस्या व जलवायु परिस्थितियां इसके अनुकूल हैं । इस प्रकार मानव जाति के कल्याण के लिए इसके विभिन्न योग्य भागों की अधिकतम उपज प्राप्त की जा सकती है। अंतिम उद्देश्य किसानों को साबुन की प्रारंभिक


रीठे के वृक्ष


रीठे के फल

गुणवत्ता वाली रोपण सामग्री प्रदान कराना, मौसम की खराबी और जंगली जानवरों से प्रभावित क्षेत्रों में किसानों को खेती में वापस लाना है। चूंकि यह प्रजाति बाजार में 6,000-10,000 रुपये / वर्ग मीटर से कहीं अधिक मूल्य प्राप्त कराती है इसलिए 'किसान आय को दुगना बनाने के' भारत सरकार के मिशन को साकार बनाने की दृष्टि से रीठा की उच्च उपज देने वाले जीनोटाइप एक महत्त्वपूर्ण भूमिका निभाएंगे।

Techniques for studying tree root architecture

*Shakati Swamynath[1], Milkuri Chiranjeeva Reddy[1], Mhaiskar Priya Rajendra[1], Podishetti Varun[1], Dudipala Ravivarma[1] and Bheemreddyvalla Venkateshwar Reddy[1]

[1]Department of Silviculture and Agroforestry
Forest College and Research Institute Mulugu, Siddipet, Telangana
E-mail: shakati.swamynath@gmail.com

Introduction

Plant scientists have long been fascinated by the topic of plant roots. Plants use their roots for a variety of purposes, including anchoring and nutrient and water absorption. In order to enable greater absorption and assimilation of water and nutrients under various environmental conditions, roots have a high degree of plasticity in their development and directional growth (Awasthi & Laxmi 2021) and it can be difficult to comprehend how roots emerge in agroforestry systems.Soil profiles typically, the distribution of roots in the soil profile is employed to reveal a plant species nutrient absorption method (Isaac & Borden 2019). Therefore, when selecting species for compatible agroforestry, root system architecture is a crucial factor and yet studying architecture of roots is challenging (Zhou *et al.*, 2022). There is no one method of root measuring that works in all circumstances. The availability of facilities and equipment is likely to be the main determinant of the method of choice the root system effect type of interest as well as the crop and/or soil under investigation (Mackie-Dawson & Atkinson 1991).

Methods for studying root architecture

Destructive sampling or root excavation are common practises although it can produce findings that are more reliable, doing it on a big scale is highly time-consuming. In order to understand the root system better, root excavation is used. Destructive sampling's primary imperfections, though, it takes a lot of time and effort. Further, it does not establish the precise region in which fine roots and their activity are contained, which is crucial in the context of agroforestry.

Core Sampling

Using a core sampler, undisturbed soil cores are obtained using this method from predefined sites. The roots found in these soil cores are used to measure length and weight after being gently cleansed. Due to the minimal frictional resistance between the soil and the core walls, this method of root analysis is less expensive and simple to utilise. It doesn't take much technical expertise to use this strategy (Pradhan *et al.*, 2012).

Trench Profiling

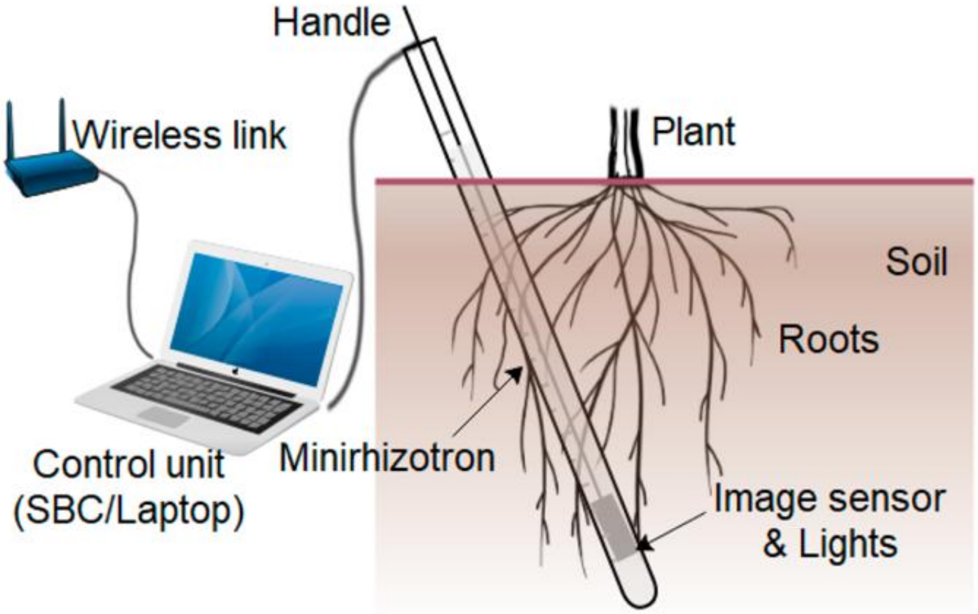
A method for observing the vertical and horizontal root distribution of crops is the trench profile method (Böhm 1979) and it entails digging a trench parallel to the row or next to a single plant, then mapping or photographing the exposed roots (Pradhan *et al.*, 2012). Huguet introduced the novel technique of "logarithmic spiral trenching" to get over the problem of destructive sampling (Sundaram & Kunhamu 2021).

Excavated logarithmic spiral trench and root distribution estimation mention tree species. (Image Credits: Sundaram & Kunhamu 2021)

Non-Destructive Methods

Minirhizotrons

In rhizotron facilities, glass windows are frequently added to watch root development.Bates (1937) first introduced the MR(Minirhizotrons) idea, Rhizotrons are installations that examine soil roots through transparent "walls" (Böhm 1979).A minimally disruptive imaging technique for tracking and analysing the growth of plant root systems is the use of minirhizotron camera systems (Majdi 1996).It entails placing a camera-mounted clear plastic tube into the soil and regularly taking root imagery over time (Xu *et al.*,2022).From minirhizotron RGB root images, a number of root phenotypes, including lengths, diameters, patterns, turnover, and distributions at various depths, can be identified (Weihuang *et al.*, 2020).



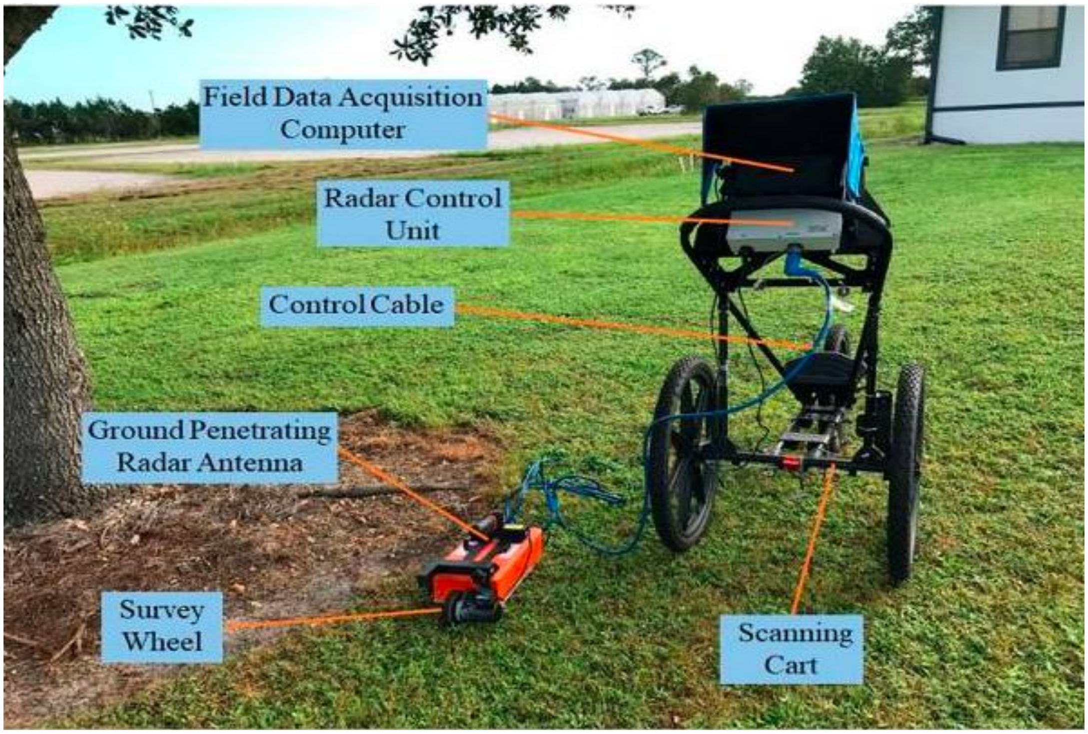
Field operation of a common minirhizotron with a wireless interface as advancement (Image Credits: Rahman *et al.*, 2020)

(Image Credits: https://minirhizotron.com/)

Ground Penetrating Radar (GPR)

Coarse roots (>2 mm diameter) are essential to the functioning of plants and terrestrial ecosystems, hence it is critical to identify and measure their size, architecture, and biomass. Traditional excavation techniques are labor-intensive, damaging, and only partially quantifiable and repeatable over time. Ground penetrating radar (GPR), a non-destructive geophysical instrument, has been used for coarse root detection since 1999. GPR is a method of identifying buried structures in the subsurface. (Guo *et al.*, 2013)

A geoimaging technique called ground-penetrating radar (GPR) allows for the quick collection of subsurface data with little disruption to root systems (Stokes*et al.*, 2002).To find coarse roots in situ, ground penetrating radar (GPR) has been employed as a non-intrusive geoimaging method (Hruska 1999). GPR uses Electromagnetic waves when there is a sufficient difference in dielectric permittivity, such as at the root-soil interface or, more particularly, when the water content of the root is higher than the surrounding soil, radar signals can reflect (Hirano 2009).



A ground-penetrating radar (GPR) mounted to a scanning cart (Zhang *et al.*, 2019)

Magnetic Resonance Imaging (MRI)

Precision and non-destructive 3D imaging methods, such magnetic resonance imaging (MRI) are a modern trend in root phenotyping (Takahashi &Pradal 2021) and frequently utilised non-destructive 3D root phenotyping technique is magnetic resonance imaging (MRI). Strong magnetic and radio-frequency fields may be used to alter the numerous magnetic moments of atomic nuclei found in living tissues to create 3D datasets.(Van Dusschoten*et al.*, 2016)

DNA metabarcoding

The utilization of root DNA metabarcoding has witnessed a growing trend in evaluating root diversity across diverse vegetation categories (Träger*et al.*, 2019). In this method, DNA from an unspecified multitude of species is extracted through a mixed or collective sample, subsequently sequenced, and then linked to known plant species' DNA. This eliminates the necessity of isolating and sequencing individual plant species.

Conclusion

In summary, the utilization of advanced technologies for understanding belowground root dynamics holds the key to effectively analysing plant productivity and growth within agroforestry systems. These cutting-edge techniques also offer valuable insights into the behaviour of fine roots, a significant factor in agroforestry's success. It's worth noting that each method comes with its own set of advantages and limitations, with their applicability dependent on available resources and the desired level of accuracy. Nevertheless, these advancements in agroforestry methodologies have the potential to greatly enhance our understanding of the root systems.

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Multifunctionality of agroforestry

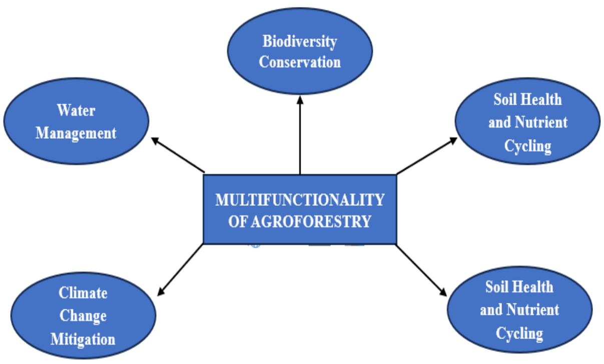
Bheemreddyvalla Venkateshwar Reddy, Milkuri Chiranjeeva Reddy, Mhaiskar Priya Rajendra, Yerrawada Naveen and Shakati Swamynath

Forest College and Research Institute
Mulugu, Siddipet District, Telangana-502279
E-mail: bvreddy12121@gmail.com

Introduction

Land-use strategies that promote livelihood security while decreasing susceptibility to climate and environmental change are required. Traditional resource management adaptations, such as agroforestry systems which is defined as a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. Which has the ability to enhance lives by producing food, fodder, and firewood while mitigating the effects of climate change (Singh and Pandey 2011).Agroforestry has received a lot of attention recently as a sustainable farming approach. This novel land-use system combines the advantages of agriculture with forestry, providing a variety of environmental, social, and economic benefits. One of the most important characteristics of agroforestry is its multifunctionality, which refers to its ability to deliver different ecological and economical services at the same time. There are several claims made about the goods and services delivered by agroforestry operations(Jose 2009). Incorporating trees, agricultural crops, and/or animals into an agroforestry system has the potential to improve soil fertility, minimize erosion, improve water quality, boost biodiversity, improve aesthetics, and sequester carbon. In this article, we will explore the various ways of multifunctionality of agroforestry such as Biodiversity conservation, Soil Health and Nutrient Cycling, Climate Change Mitigation, Water Management and Socio-Economic benefits promotes sustainability and enhances agricultural productivity.

Multifunctionality of agroforestry

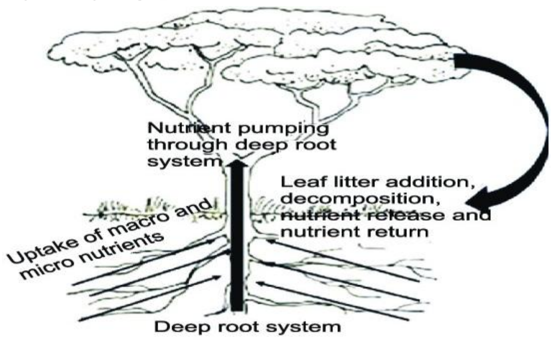


Biodiversity conservation

Agroforestry contributes significantly to biodiversity conservation by incorporating trees and other plants into farms.Agroforestry plots' trees and bushes provide nesting locations, food supplies, and protection for a variety of animals, including birds, insects, and mammals. In turn they can improve pollination services on agricultural crop and increase productivity. These habitats can act as links between fragmented natural ecosystems, allowing species to travel and disperse more freely, increasing genetic diversity and lowering the risk of extinction (Bentrup *et al.* 2019).

Soil health and nutrient cycling

Agroforestry is critical for enhancing soil health and nutrient cycling in agricultural areas. Through leaf litter, fallen branches, and root exudates of trees and other perennial plants in agroforestry systems contribute to the deposits of organic matter in the soil, which enhances soil structure, water-holding capacity, and nutrient retention. Agroforestry systems can improve nutrient cycling by varying plant species and rooting depths. Certain tree species in agroforestry, such as legumes (e.g., nitrogen-fixing trees and shrubs), can take atmospheric nitrogen and transform it into forms that other plants can use. This natural nitrogen fixation process provides critical nutrients to the soil. Windbreaks and buffer strips are provided by trees and shrubs in agroforestry systems, which aid in soil erosion prevention. Agroforestry systems create diverse microenvironments that support a wide range of soil organisms. When compared to conventional agriculture, agroforestry systems frequently have a more complex root structure, which aids in soil porosity and water penetration. This minimizes surface runoff, increases groundwater recharge, and reduces nutrient losses caused by water. Agroforestry systems have diversified plant canopy intercepts rainfall and lessen the impact of heavy showers on the soil surface. This decreases nutrient leaching and aids in the retention of nutrients in the root zone, where crops can access them.



Role of Tree component in Agroforestry on Soil Health and Nutrient Pumping

Sarvade *et al.* 2019

Climate change mitigation

Agroforestry is important in climate change mitigation because it sequesters carbon dioxide, improves ecosystem resilience, reduces greenhouse gas emissions, and promotes sustainable land management practices. Agroforestry systems use trees and perennial plants to absorb carbon dioxide from the environment and store it in their biomass and soil. This process contributes to the decrease of greenhouse gases in the atmosphere; therefore minimizing the consequences of climate change.Agroforestry is land-use alternatives that can assist minimize deforestation and forest degradation. Agroforestry systems can assist to maintain existing carbon-rich ecosystems by integrating trees into agricultural landscapes, relieving demand on natural forests for wood and land conversion. By diversifying plant species, lowering soil erosion, and improving water management, agroforestry improves landscape resilience. These techniques assist to mitigate the effects of extreme weather events like droughts and floods, which are predicted to become more often and severe as a result of climate change. Carbon-sequestering agroforestry systems may be able to participate in carbon trading markets or receive payments for ecosystem services, giving financial incentives for landowners to pursue climate-friendly practices. (Montagnini and Nair. 2004)

Water management

Agroforestry holds significance in water management because it improves water quality, reduces soil erosion, improves groundwater recharge, mitigates floods and droughts, and promotes overall sustainable land and water use practices. In agroforestry systems, the presence of trees, bushes and other vegetation helps stabilize the soil, minimizing the impact of rainfall on the soil surface. Their root systems link soil particles together, reducing water body erosion and sedimentation. Agroforestry can help to replenish groundwater by increasing water penetration into the soil. The presence of trees and their extensive root systems helps water to more efficiently infiltrate the soil, refilling subsurface aquifers. Agroforestry can improve landscape resistance under drought conditions. In Agroforestry systems, trees and other perennial plants use water more effectively and offer shade, lowering soil evaporation and helping to retain soil moisture during dry seasons. Agroforestry systems diversify farmer’s revenue streams, which can lead to improved livelihoods and less strain on water resources from unsustainable land usage. (Tomar *et al.* 2021)

Socio-Economic benefits

Agroforestry practice offers a wide range of socio-economic benefits that contribute to the well-being of local communities and economies. Key roles of agroforestry in socio-economic development are diversification of income sources, improved food security, enhanced livelihoods, rural employment opportunities etc., Multiple income streams are frequently available from agroforestry systems, including agricultural yields, lumber, fruits, nuts, and other non-timber forest products. This diversity improves financial resilience in rural areas and lessens reliance on a single source of revenue. It is possible to cultivate a variety of crops and goods, improving the availability of nutrients-rich foods and lowering the likelihood that crops would fail due to pests or climatic changes, thus integration of trees with crop enhances the food security. When compared to conventional agriculture Agroforestry practices often require more labors and there is also chance of establishing a small-scale industry based on Agroforestry components which creates a lot of employment opportunities to the rural people. (Dhyani, 2014 and Jamnadass *et al.* 2013)

Conclusion

Agroforestry demonstrates sustainable land management by balancing human and environmental activities. Its ability to generate socioeconomic benefits while also increasing resilience makes it an appealing alternative. Agroforestry exhibits integrated methods for global concerns ranging from revenue diversification to biodiversity protection. In the midst of uncertainty, it's a roadmap for communities to survive, ecosystems to thrive, and nature to harmonize. Adopting agroforestry is more than simply a decision; it is a step toward a more equitable, sustainable future for future generations.

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Mahua: A resilient backbone for tribal livelihoods

Balaji Vikram[1], Priya Awasthi[1], Purnima Singh Sikarwar[2] and Dharmendra Kumar Gautam[3]

[1]Department of Post Harvest Technology
Banda Agriculture and Technology University, Banda- 211001 (U.P.) India
[2]Department of Horticulture
AKS University, Satna (M.P.)
[3]Department of Fruit Science
Banda Agriculture and Technology University
Banda- 211001 (U.P.) India

Mahua (*Madhuca longifolia*) a valuable non-timber forest product, holds a multitude of uses, but its presence is predominantly limited to remote tribal areas of India. Mahua stands as a dependable source of livelihood for tribal communities. Its significance extends beyond being a non-timber forest product, as it plays a crucial role in sustaining the economic well-being of these communities. For generations, tribes have relied on Mahua for various purposes, including its diverse uses in food, medicine and craftsmanship.

India is a really amazing place with lots of different people, cultures, languages and seasons. This diversity is one of a kind and can't be found anywhere else in the world. Even if we just try to understand the basics of this diversity in things like art, culture, people and languages, it would take a whole lifetime. What makes this diversity even more special is how the plants and animals in the country also have a big impact on this varied landscape.

About 10.4% of India's whole population, which is a big number - 110 million people, are from tribal groups. The government now understands how important it is to take care of these people. There's a big part of India called Central India, with places like Madhya Pradesh, some of Maharashtra and Chhattisgarh. Lots of different tribes live there. They mostly live in the big forest areas of India and are like a really important part of the environment, depending on the forests to live. The tribes' survival totally relies on what the forest gives them and they're like best friends with the forest, helping each other.

In Central India, there's a tree called the Mahua tree, also known as the "Honey tree" in other places. This tree is super important. For these tribes to live well, they need these trees around. Every day, starting early in the morning and sometimes without shoes, the tribes, including men, women, kids and old folks, go all over the forest hills of the Satpura ranges. They work hard to collect Mahua leaves and fruits, which are yellowish or amber in color. They put them in big baskets made from woven materials and carry them carefully on their heads.

The collection and processing of Mahua provide employment opportunities and income for tribal populations, particularly during the flowering season. The collection of mahua flowers, which typically occurs during the months of February and March each year, has faced challenges due to lack of awareness among villagers regarding the diverse range of uses beyond local alcohol production. This limited understanding has also impacted the income of village residents, as they previously relied on collecting and selling mahua flowers to traders during the lean agricultural season to meet their modest household needs. The flowers are harvestedand their extract is used to produce a range of products such as edible oils, syrupsand alcoholic beverages. The sale and trade of these Mahua-based products contribute directly to the economic sustenance of tribal households. Moreover, Mahua cultivation and management often involve community-led initiatives, strengthening social cohesion and fostering collective responsibility. The knowledge and skills associated with Mahua processing are passed down through generations, ensuring the preservation of cultural traditions and enhancing the sense of identity within tribal communities.

The majestic Mahua tree has graced for centuries, serving as an irreplaceable lifeline for the tribal economy. Its contributions to the well-being of the indigenous communities are so vast that it is challenging to fully acknowledge its invaluable role. While often associated with its use in homemade liquor, Mahua has also found its place in a wide array of recipes, both simple and intricate.

The Mahua tree is an abundant source of diverse products, encompassing vegetable butter, medicinal extracts, syrups, purees and liquor. Remarkably, in a series of pioneering endeavors, the Agricultural and Processed Foods Export Development Authority successfully shipped a consignment of dehydrated Mahua flowers from Chhattisgarh to Paris, France in 2021, introducing India's renowned "Kacchisharab" (country liquor) to global audiences for the very first time.

Notably, this year witnessed significant milestones in the recognition and acceptance of Mahua-related products. Madhya Pradesh declared Mahua as heritage liquor, while neigh boring Maharashtra took a groundbreaking step by amending the "Bombay Mahua Flower Rules 1950," thereby legalizing the collection, sale and transport of Mahua flowers. Furthermore, the Tribal Cooperative Marketing Development Federation, in collaboration with IIT-Delhi, recently ventured into producing "Mahua Nutra," a health beverage crafted by blending fermented Mahua flowers with pomegranate and guava juices in Jharkhand. Additionally, they unveiled "Mahua cookies," which blend millet flour, in Uttar Pradesh, Madhya Pradesh, Bihar Jharkhand, Odisha and Maharashtra.

These significant developments signify a remarkable and positive shift in government priorities, attitudes and policies towards an indigenous tribal product that was once perceived as a "dangerous blight" requiring eradication. The government's stance on Mahua has undergone a complete transformation, shifting from an outright ban to a celebration of India's country liquor, exemplifying a newfound appreciation for this unique cultural heritage.

The intricacies of Mahua commerce are noteworthy and provide valuable insights for replicating similar models with other forest fruits found in India. In the states of Uttar Pradesh, Madhya Pradesh, Bihar

Jharkhand, Odisha and Maharashtra, the entire Mahua produce is procured from tribal gatherers through the "Van Dhankendras" system. This procurement operates under a scheme with a uniquely specific name, the "Scheme for Marketing of Minor Forest Produce through Minimum Support Price and Value Chain Development." Interestingly, this scheme was not prevalent a decade ago. The purchased Mahua is subsequently sold through auctions or to the government.

The Ministry of Tribal Affairs oversees and determines the scheme and the specific Minimum Support Price (MSP), while the state forest department regulates the collection of Mahua flowers from the forest and issues necessary permissions. Additionally, the excise departments of Uttar Pradesh, Madhya Pradesh and Bihar are involved in monitoring and regulating Mahua when it is fermented for its market value. Recognizing the potential of Mahua, several enterprising districts across India have started harnessing its benefits. States like Maharashtra, Jharkhand, Odisha and others have already begun promoting Mahua as both liquor and a value-added food product.

Even though Mahua is seen as a special product in some government programs like "One District One Product" and the "PM Formalization of Micro Food Processing Enterprises" scheme, some governments don't really want to promote making alcohol from it. This has caused problems in places like Chhattisgarh where they wanted to develop things locally. But in other states like Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand, Odisha and Maharashtra, things are different. The people who live in the forests there are happy because they are getting good things from picking Mahua flowers for the first time. Now, the government is working with them and helping them sell what they collect for a good price, like they do with other crops.

Every morning, men, women and even kids carry baskets full of Mahua flowers and fruits on their heads and go to markets along the roads to sell them. They walk without shoes and it's quite a journey.

In the last two years, during the COVID-19 pandemic, the way people live and do business has changed. This has given new hope to the local people. Even in these tough times, the government went directly to the homes of tribal communities and gave them a lot of money. Because of this, the connection between the tribal people and the forests, where they used to get their money from, got stronger again. Before, a lot of tribal people had left these forests to go to cities in different states. This was because cities were growing quickly and seemed more attractive.

However, under the new dynamics of the Modi government, the situation has taken a positive turn, acting as a blessing in disguise for the hapless tribal population. There have been numerous instances where tribal men and women have earned substantial sums, reaching up to 3.5 lakhs of rupees per monthequivalent to about four years' worth of wages as labourers by selling Mahua produce. These earnings far exceed what they would have earned while working jobs unrelated to their traditional way of life in the cities. Mahua-producing states have established multiple procurement centres to directly purchase Mahua produce from the tribal communities. Many states have also collaborated with prominent traders to procure Mahua flowers at or above the Minimum Support Price (MSP) of Rs 35 per kilogram directly from the source. Additionally, various villages have received nets through the bank-funded "Green India Mission" and other initiatives, leading to better collection of high-quality Mahua produce. These improved collection methods have resulted in higher prices ranging from Rs 40 to 45 per kilogram.

Mahua, as a product, holds a rich historical significance, dating back to the British era. According to historian Vinita Damodaran's essay titled "Famine in Bengal - A Comparison of the 1770 famine in Bengal & the 1897 famine in Chota Nagpur," Mahua fruits were not only consumed as food but the fleshy corolla also served as a staple diet for the poor for several months of the year. During periods of droughts, famines and epidemics under colonial rule, Mahua played a crucial role in saving thousands from starvation. It was a lifeline for the people of this land. Sir Charles Watt, a Scottish botanist, quotes a former magistrate of Manghyar (now Munger) who stated that Mahua fruit, specifically in the year 1873-74, prevented virtual decimation of the population.

Towards the end of the 19th century, colonial capitalism led to the depletion of food sources that forest communities depended on. The situation worsened when the colonialists classified Mahua as a dangerous intoxicant through the enactment of the "Mhowra Act of 1892." This move aimed to suppress the local liquor industry and monopolize the Indian markets for their imperial liquor brands. Turning to the culinary delights associated with Mahua, it is worth mentioning that this forest produce, when combined with yogurt, can be transformed into deep-fried purees known as "Kuldum." Additionally, it can be used to sweeten "Puran Polis," a traditional Indian dessert.

Conclusion

Tribal people and the forests are like best friends who can't be separated. Mahua is really important for tribal communities because it helps them a lot economically and culturally. Even before they are born, there's a link between them and the mahua tree. Mahua is connected to every part of their culture, from when they are born to when they pass away and even during their marriages and funerals. The mahua tree is really useful because it gives them many things like syrups, purees, alcohol and medicines. Expectant mothers are provided with chutney made from mahua flowers due to its nutritive value, rich in vitamins, proteins, minerals and fats. Mahua alcohol is important in many ceremonies and is a big part of weddings. It's part of their everyday life, used for food, medicine and drinks. For them, mahua is not just a tree. It's like a whole way of living that includes their traditions, how they get their food and their culture.

The loss and damage fund: Implications for India

M. Rajkumar and Avinash Jain

Forest Ecology and Climate Change Division
ICFRE-Tropical Forest Research Institute
PO. RFRC, Mandla Road, Jabalpur

In the recently held The 28th Conference of Parties (COP28) Climate Conference a crucial milestone was reached among the members to operationalise the Loss and Damage Fund. This is widely seen as a step to respond to the needs of vulnerable countries facing the unavoidable impacts of climate change.

The Loss and Damage fund is a financial mechanism designed to address the irreversible consequences of climate change that cannot be avoided or mitigated through adaptation efforts. This fund was launched during COP 28, which was a longstanding demand from developing and under-developed countries that have contributed the least to global warming.

Immediately after the fund's adoption, several countries – led by the United Arab Emirates (UAE) – pledged upwards of a total of $400 million to the fund. The UAE and Germany pledged $100 million each to the fund, followed by $50.5 million from the U.K. and $10 million from Japan. The U.S. – the world's largest historical emitter – pledged only $17.5 million to the fund. The European Union made a substantial €225 million commitment. The World Bank will temporarily host the fund for four years. It will be managed by a board that will have equal representation from developed and developing countries. It will be open to all developing countries that are party to the UNFCCC.More pledges to the loss and damage fund are expected during the World Climate Action Summit.

The Loss and Damage Fund is expected to provide financial assistance to vulnerable countries that are already experiencing the impacts of climate change, such as rising sea levels, floods, droughts, heat waves (extreme weather events), desertification and so on.

Climate change has been causing extreme weather events such as floods, droughts, and heat waves, and they are becoming more frequent, intense, and prolonged. But the consequences of climate change aren't equal for everyone. For example, In2022, Pakistan experienced devastating floods that submerged roughly one-third of the country, affecting over 33 million people and causing economic losses exceeding $30 billion. In Vanuatu, a Pacific Island nation, has already been forced to relocate six entire towns due to irreversible and accelerating sea level rise. Therefore, developing nations of the Global South have been persistently calling for adequate funding, in the form of a Loss and Damage Fund. They claim that developed nations must bear the responsibility for assisting them in adapting to climate change, given their historical contribution to the carbon emissions that have fuelled global warming. The US, for example, is responsible for almost 25 percent of all historical emissions from 1750 till 2021. In contrast, India's share is only 3.4 percent. Wealthier nations, however, have been reluctant in providing sufficient financial support. At the COP27 summit in Egypt in 2022, they finally agreed to establish a Loss and Damage Fund.

The World Meteorological Organization (WMO), the UN's weather agency, has predicted that 2023 is likely to be the hottest year on record, signalling a troubling trend of worsening floods, forest fires, glacial melt, and heat waves in the years to come. This makes the decision to operationalise the Loss and Damage Fund at COP28 a pivotal moment for the Global South. It means that for the first time, developing countries will be able to secure a dedicated source of funding to address the loss and damage caused by climate change.

This is far short of the estimated $400 billion that developing countries need every year to address loss and damage. As a result, there is still much work to be done to ensure that the fund is adequately resourced and that it meets the needs of vulnerable countries. Yet, the adoption of the loss and damage fund is a hopeful sign that the international community is finally taking the issue of climate justice seriously.

Implications for India

India ranks seventh amongst the 10 countries most affected by climate change in the Global Climate Risk Index 2021 and has faced several devastating climate disasters in the last few years. As a developing country which is vulnerable to climate change, the loss and damage mechanism for India is critical. India has a dual opportunity to further cement itself as the leader of the global south, while also holding the developed countries accountable for their financing commitments.

India has also already undertaken several leadership initiatives in the field of loss and damage, such as the launching of the Coalition of Disaster Resilient Infrastructure (CDRI), a multi-stakeholder global, governmental, and multilateral partnership to address the challenges of building resilience into infrastructure systems and development associated with it. Under India's leadership, CDRI is currently engaged in a Fiscal Risk Assessment Study that would support the development of a comprehensive disaster-risk financing strategy in more than 35 countries and multilateral entities.Therefore, through its strong leadership, India is uniquely positioned to act as the voice of the global south in the dialogues around loss and damage.

The loss and damage mechanism provide another opportunity for India and other developing countries to put pressure on the developed countries to meet their financial obligations and provide timely finance for loss and damage.

India through its strong institutional and technological capacity, can provide technical and scientific expertise as its contribution to the loss and damage mechanism and through CDRI, lead a network of south-led research institutions around loss and damage. Such a network would enrich climate science, as it would shed more light on vulnerable regions and build research capacities.

Van Sangyan (ISSN 2395 - 468X) Vol. 10, No. 12, Issue: December 2023

Published by:

Impact Factor

SJIF: 2022-6.071

ICFRE-Tropical Forest Research Institute
(Indian Council of Forestry Research & Education)
(An autonomous council under Ministry of Environmnet, Forests and Climate Change)
P.O. RFRC, Mandla Road
Jabalpur – 482021, M.P. India
Phone: 91-761-2840484
Fax: 91-761-2840484
E-mail: vansangyan_tfri@icfre.gov.in, vansangyan@gmail.com
Visit us at: http://tfri.icfre.org or http://tfri.icfre.gov.in