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Towards Transdisciplinary Identification of Suitable Woody Perennials for Resilient Agrosilvopastoral Systems

*Shivam Dinkar[1], Sameer Daniel[2], Joy Phionehas[3], Tanmaya Nayak[3], Subhakanta Samantray[4] and V. Harikrishna Reddy[5]
[1]Ph.D. Scholar, Department of Silviculture and Agroforestry, College of Agriculture, Raipur, IGKV, Chhattisgarh, Raipur, India
[2]Associate Professor, College of Forestry, SHUATS, UP, India
[3]Research Scholar, College of Forestry, SHUATS, UP, India
[4]Regional Research and Technology Transfer Station (RRTTS), Odisha University of Agriculture and Technology (O.U.A.T.), Keonjhar-758002, Odisha, India
[5]Undergraduate Student, ITM, Gwalior, India
*Corresponding Author's email: shivamdinkar1997@gmail.com

Agrosilvopastoral systems integrate trees, crops, and livestock, offering a multifunctional approach to land use that supports biodiversity, enhances soil health, and improves climate resilience. The strategic selection of woody perennial species is critical to the success and sustainability of such systems. This article proposes a transdisciplinary framework to identify suitable woody perennials by integrating ecological, agronomic, socio-economic, and climatic criteria. By leveraging inputs from forestry, agronomy, animal science, ecology, socio-economics, and local knowledge systems, we aim to develop a resilient plant palette for agrosilvopastoral landscapes under changing environmental conditions.

Introduction

Agrosilvopastoral systems, a form of integrated agroforestry, combine woody perennials with crops and livestock in a single management unit. These systems maximize land productivity while enhancing ecological resilience, particularly in marginal and climate-sensitive areas. A central challenge in the design of such systems is the selection of suitable woody perennials. Species must meet diverse requirements—providing fodder, fuel, timber, shade, erosion control, and carbon sequestration—while also being compatible with local biophysical conditions and farming practices.

Why a Transdisciplinary Approach?

Traditional species selection approaches often rely on narrow disciplinary frameworks, typically ecological or agronomic. A transdisciplinary approach goes beyond that by:

- Incorporating local and indigenous knowledge.
- Considering socio-economic drivers and trade-offs.
- Integrating climate models and ecosystem services valuation.
- Engaging stakeholders from design to implementation.

Agrosilvopastoral Systems: Context and Challenges

System Characteristics

- Woody perennials: Trees or shrubs providing biomass, root stability, or ecosystem functions.
- Crops: Annual or perennial food or fodder species.
- Livestock: Grazing or browsing animals benefiting from fodder and microclimate regulation.

Key Challenges

- Species compatibility: Interactions between trees and crops/livestock can be positive (e.g., nutrient cycling) or negative (e.g., shading, allelopathy).
- Climatic variability: Increasing droughts, temperature extremes, and changing rainfall patterns.
- Land-use conflicts: Competition between agricultural intensification and ecological restoration.
- Knowledge silos: Limited collaboration between disciplines or sectors (research, extension, policy, community).

Criteria for Selection of Woody Perennials

A robust selection framework requires balancing functional traits, ecological adaptability, and socio-economic value. Major criteria include:

Domain	Criteria	Examples
Ecological	Drought tolerance, rooting depth, phenology, nitrogen fixation	*Faidherbia albida*, *Leucaena leucocephala*
Agronomic	Compatibility with crops, low allelopathy, pruning ability	*Gliricidia sepium*, *Calliandra calothyrsus*
Livestock	Fodder quality, digestibility, tannin content	*Moringa oleifera*, *Acacia spp.*
Socio-economic	Market value, cultural acceptance, land tenure suitability	*Azadirachta indica*, *Prosopis juliflora*
Climate resilience	Performance under stress, carbon sequestration potential	*Ziziphus mauritiana*, *Balanites aegyptiaca*

Transdisciplinary Framework for Species Identification

Stakeholder Mapping

- Researchers: Soil scientists, foresters, animal scientists, agronomists
- Practitioners: Farmers, extension agents
- Policy makers: Land-use planners, government agencies
- Knowledge holders: Indigenous communities, pastoralists

Methodological Components

Step	Description
Participatory Rural Appraisal (PRA)	Identify local needs, preferences, and constraints.
Ecological Niche Modelling	Use climate-soil data to predict species suitability.
Functional Trait Analysis	Compare key traits influencing system performance.
Fodder Quality Assessment	Measure crude protein, fiber, tannin content, digestibility.
Systems Modelling (e.g. APSIM, WaNuLCAS)	Simulate species interactions with crops/livestock.
Multi-Criteria Decision Analysis (MCDA)	Integrate and weight various selection factors.

Example Workflow

1. Baseline Assessment: Agroecological zoning, existing species inventory.
2. Stakeholder Consultation: Identify desired functions and services.
3. Database Compilation: Species traits, growth data, stress tolerance.
4. Suitability Mapping: Overlay species traits with environmental variables using GIS.
5. Field Validation: Establish demonstration plots with shortlisted species.
6. Feedback Loop: Adjust selections based on monitoring and feedback.

Case Studies

Semi-Arid India

- Key species: *Hardwickia binata*, *Albizia lebbeck*, *Azadirachta indica*
- Function: Soil stabilization, summer fodder, firewood
- Outcome: Improved fodder availability and reduced erosion

East Africa (Rift Valley)

- Key species: *Grevillea robusta*, *Calliandra calothyrsus*, *Ficus sycomorus*
- Function: Shade, fodder, biomass fuel
- Outcome: Increased livestock productivity and tree cover

Benefits of Transdisciplinary Selection

- System resilience: Diverse species buffers against climate shocks.
- Livelihood support: Enhanced income through multi-use trees.
- Biodiversity: Improved soil microbiota, pollinators, and native flora/fauna.
- Policy relevance: Aligns with climate-smart agriculture, land restoration, and sustainable development goals (SDGs 2, 13, 15).

Challenges and Considerations

Challenge	Mitigation
Data scarcity	Use of remote sensing and open-access trait databases
Institutional fragmentation	Promote inter-departmental coordination
Species invasiveness	Screen for ecological risk and control measures
Time to maturity	Balance fast-growing with long-term species
Knowledge gaps	Bridge science-policy-practice via inclusive platforms

Conclusion

Designing resilient agrosilvopastoral systems demands a paradigm shift from discipline-specific selection to transdisciplinary and participatory species identification. Only by integrating ecological, agronomic, socio-economic, and cultural lenses can we ensure the long-term sustainability and adaptability of these complex land-use systems. Future work should focus on digital decision-support tools, local species trials, and inclusive innovation platforms to scale context-specific woody perennial portfolios.

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