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**THE ROLE OF AGROFORESTRY IN THE
SUSTAINABLE BIOECONOMY
TRANSITION OF THE COLOMBIAN
AMAZON BASIN**

Theses of the PhD dissertation

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1. INTRODUCTION

Due to the forest losses and environmental destruction so far, scientists' models suggest that the Amazon Basin may be extremely close to a tipping point, beyond which the forest ecosystems of the region are inevitably at risk of collapse (Lovejoy & Nobre, 2019).

The rapid decline of the Amazon Basin's ecosystems necessitates that the countries in the area quickly shift to a development model that realizes economic development not through raw material-intensive methods, but through activities that reduce social inequalities and create significant added value (Nobre & A. Nobre, 2019). Beyond scientific literature, more and more plans are being formulated at the policy level in the region to implement a sustainable tropical bio-economy model. This could both prevent imminent natural, economic, and social catastrophes associated with the destruction of tropical rainforests and position sustainable, knowledge- and innovation-intensive economic sectors that generate substantially more noteworthy added value and significant economic benefits for these South American countries than sectors based on the cheap exploitation of nature.

Amazonian acidic soils have low phosphorus and organic matter content and a rapid nutrient turnover, with their fertility sustained by organic matter continuously provided by trees. At the same time, the existence of tropical rainforests is crucial for the long-term stability of the terrestrial water cycle, as well as for maintaining what are known as atmospheric flying rivers, upon which a large part of South America's water supply depends. Therefore, land use forms that restore the original forest ecosystems and integrate into them can only be ecologically sustainable. One such land use form is agroforestry, which has a millennia-long history in indigenous cultures in the region and, when appropriately applied to the specific area, can serve ecological, economic, and social sustainability simultaneously.

Exploring the potential for a sustainable, knowledge-based bioeconomy and the role of agroforestry in transitioning to bioeconomies within the raw material-dependent Amazon Basin can facilitate the identification of sustainable alternatives and economic diversification opportunities, ultimately leading to timely and effective policy proposals.

Among the countries of the Amazon Basin, for the analysis I have chosen Colombia, which has the second-largest economy.

The country is a Great Power of forestry: more than half of its area is covered by forests, and it has the second-largest biodiversity in the world after Brazil. The Western Amazonian territories are suited for bioeconomy development due to their diverse geographical features, climate, and various ecosystems, with ecologically and socially sustainable land use methods playing an important role.

The fundamental objective of my research is as follows:

To examine the role of agroforestry in the sustainable bio-economic transition of the Colombian territories of the Amazon Basin.

To achieve this fundamental objective, I have defined five goals:

- 1. To examine the concept of agroforestry as an agroecological practice, its alignment with the theoretical framework of ecological economics, and its relationships with indigenous knowledge and bioeconomy.*

2. *To present the different interpretations of economic development in the Amazon Basin: the raw material-intensive model versus the knowledge and biodiversity-based model.*
3. *To demonstrate the position of the Amazon Basin in the global economy and the internal and external factors that determine its development.*
4. *To identify and analyse challenges that may hinder Colombia's transition to sustainable bioeconomies and propose solutions to the most challenging issues.*
5. *To analyse the role of agroforestry in the transition to bioeconomies in the Colombian territories of the Amazon Basin in relation to the challenges that hinder the transition.*

To achieve the fourth objective, I sought answers to three questions in my empirical research:

1. *What are the main challenges affecting the transition to sustainable bioeconomies in Colombia?*

2. *How relevant are these challenges according to experts, local entrepreneurs and social leaders?*
3. *How are these challenges related to each other, according to the interviews?*

The research questions related to the fifth objective are as follows:

1. *How does agroforestry support the bioeconomy transition in the Colombian territories of the Amazon Basin?*
2. *What are the most suitable agroforestry objectives and practices to promote an ecologically and socially sustainable bioeconomy transition?*
3. *How do the challenges of the bioeconomy transition affect agroforestry as a sustainable land-use practice in the region?*

2. MATERIALS AND METHODS

The chosen research strategy employs qualitative research utilizing analytical and descriptive methods. By processing the entire literature on the Colombian bioeconomy, I identified seven challenge categories that hinder the country's sustainable transition to bioeconomies, namely: fair knowledge creation and exchange; funding; infrastructure and technology; institutional framework; stakeholder engagement; sustainable production, value creation, and market challenges; and political and economic structures.

Following the definition of the challenge categories, I conducted semi-structured interviews in Spanish with the most recognized Colombian bioeconomy experts, as well as entrepreneurs/local producers of bioproducts and local community leaders actively engaged with the subject. The aim of the interviews was to significantly deepen the existing knowledge available in the literature regarding these categories, with a particular focus on the challenges, their significance, and their interrelations. Analysing these interrelations helps define appropriate policy directions. No new, previously unidentified categories emerged during the interviews.

In the next phase of the empirical research, I conducted semi-structured interviews in Spanish with Colombian experts in agroforestry to understand the role of agroforestry in the transition to bioeconomies in the Colombian territories of the Amazon Basin. The structure and framework of the interviews and analysis were guided by the previously defined seven challenge categories. In this phase of the research, I analysed how agroforestry, as a land use system, relates to the challenge categories used in the study; that is, what benefits its application can provide for the bioeconomy transition, what the best-known agroforestry practices are, and how certain challenges may impose limits on the development and spread of agroforestry.

I complemented the expert interviews with three transect walks to observe the local role of agroforestry. Economic and ecological criteria were applied for selecting the farms: significant agrobiodiversity, the application of indigenous agroecological methods, and production for commercial markets were among the conditions. This allowed me to gain firsthand knowledge of the advantages and difficulties of Amazonian agroforestry, as well as replicable best practices.

The qualitative data were processed and analysed using Excel and ATLAS.ti software.

3. RESULTS

3.1. Summary

Research on the bioeconomy transition has shown that fair knowledge creation and exchange – ranked last by experts regarding their role in the transition to bioeconomies – emerges as a crucial and central category based on the analysis of its co-occurrence with other categories. The development of research and educational infrastructure, as well as biodiversity research and product innovation; enhancing the capacities of the rural population; effective dialogue with traditional knowledge systems; and changing farming practices are closely interconnected elements in establishing the necessary knowledge base. Properly addressing the knowledge issue through policy can have significant impacts on other bioeconomy areas as well. For local entrepreneurs and producers, infrastructural and technological developments are crucial. The two groups of respondents evaluate the connection between the categories of sustainable production, value creation, market challenges, and stakeholder engagement in the same way. The Amazonian bioeconomy could gain momentum primarily through the application of more sustainable farming

methods, better coordination among value chain actors, and the awareness of consumers.

The research results reveal three main development dilemmas. Indigenous knowledge systems clash with market economy priorities in many ways and are in decline, while epistemological injustices due to the dominance of Western knowledge play a significant role in the absence of genuine, equal dialogue. The second contradiction lies between the infrastructural development needs for the transition to bioeconomies and the possibilities for ecological sustainability: according to experiences, well-developed transportation infrastructure could promote deforestation. The third contentious issue revolves around the balance between sustainable agroecosystems and market-oriented production. The rise in demand for certain products in external markets may lead to the spread of monoculture farming in biologically diverse regions. The solution in all three cases is related to knowledge system dialogue and intelligent planning that considers ecological and social aspects.

The research findings indicated that the conditions for the successful operation of biologically diverse, multifunctional agroforestry integrated into value chains and adjusted to

geographic, ecological, and socio-economic circumstances, and of high value-added sustainable bioeconomy, are very similar. Both can only be achieved within an integrated system, the functionality of which results from a complex set of conditions.

The challenges tied to political and economic structures delineate the current boundaries of the bioeconomy transition, and their resolution can only be achieved in the long term. A favourable institutional framework, fair knowledge creation and exchange, sustainable infrastructural and technological investments, coordinated financing, and stakeholder engagement through effective participatory mechanisms can all help establish well-functioning, high added value bioeconomy value chains based on multifunctional and diverse agroforestry.

3.2. New scientific results

1. The theoretical innovation of the dissertation is that it examines the role of agroforestry within the context of the bioeconomy transition in the ecologically critical Colombian territories of the Amazon Basin through a complex framework of social, economic, and ecological aspects using a systemic approach. The

organization of the Colombian bioeconomy literature according to challenge categories paved the way for the methodology, while the challenge framework mapped through empirical results provides a thematic framework for the region's successful, sustainable land-use-based bioeconomy development.

2. Using qualitative research methods, I developed a methodology that can be replicated in any other country in the Amazon Basin interested in moving beyond raw material dependence and in a sustainable bioeconomy transition. This methodology enables the identification of critical areas related to the challenges of model transition and the development of context-specific policy recommendations.
3. During the empirical research – drawing on research findings from the literature and qualitative data collected during the study – I presented the complex challenges that may hinder Colombia's transition to sustainable bioeconomies. By illustrating the relevance of specific bioeconomy challenges and the interrelationships among the challenge categories, the most critical challenges and the interrelations between

them become visible. Their interpretation allows development policy to create opportunities for effective strategic planning and action.

4. Analysing the interrelations of the challenges of the bioeconomy transition has revealed that experts and entrepreneurs working in rural areas identify very similar challenges in this economic model change; however, they emphasize different problems based on their circumstances. For example, issues related to fair knowledge creation and exchange appear with greater emphasis in the expert interviews, while local interviews demonstrate how poor infrastructure, and the lack of technological investments restrict the production and market sale of products.
5. Throughout the empirical research, I identified both the best agroforestry practices that support the transition to bioeconomies and the challenges that sensitively affect agroforestry in the Colombian territories of the Amazon Basin. In this process a systemic perspective was applied that has not been previously recognized in the literature. The research findings indicated that integrated development of agroforestry, which

considers geographical, ecological, and socio-economic characteristics, and the establishment of conditions for a sustainable bioeconomy point in very similar directions for decision-makers, albeit from different approaches.

6. As a result of the empirical research, I created a graphical illustration of the conditions for a "sustainable, forest-based bioeconomy transition," which includes the seven challenge categories used during the research and their interrelations. The diagram also serves as a preliminary model of the governance strategy for the bioeconomy transition in the Colombian territories of the Amazon Basin, presented in an easily comprehensible format.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1. Fair knowledge creation and exchange

- There is very little dialogue in practice between scientific and traditional local knowledge systems. Comprehensive agroforestry and bioeconomy strategic plans, the scientific infrastructure being developed in biologically diverse rural areas, research on biodiversity management and product development, professional training, and participatory processes must be built upon intensive knowledge system dialogue.
- Sustainable management practices and a well-functioning bioeconomy value chain require transdisciplinary, adaptive education that aligns with local conditions and needs.
- There is a significant lack of information about Colombian ecosystems and biodiversity in a continuously changing environment. To address this, it is necessary to enhance biodiversity research in rural areas by establishing the required infrastructure and professional capacities.
- The social benefits of biodiversity are minimal, and there is a considerable gap between laboratory results

and the creation of a tangible product. To remedy this, collaboration between science and decision-making must be strengthened, along with more effective use of information. This requires adequate funding and human capital.

- Strengthening agroforestry research and utilizing its results should be part of an integrated rural development strategy. The incorporation of new species into farming practices is desirable.
- Due to the lack of social awareness about biodiversity and the underdevelopment of value chains, local and national bioproduct markets are underdeveloped. Therefore, it is necessary to promote biodiversity products and create a new type of consumer culture with intensive state support.
- There is limited information available regarding the lessons learned from agroforestry and bioeconomy projects. Proper monitoring and evaluation of such projects are necessary.

4.2. Funding

- Public funding and incentives are not available to promote the bioeconomy. Financial incentives and funding tailored to the country's natural endowments

must be directed towards the bioeconomy as a strategic sector.

- Public funding for agriculture favours monocultures and unsustainable cattle breeding. Biologically diverse production systems require long-term support and genuine incentives, such as payment systems for ecosystem services or credit frameworks to support forest by-products and non-monoculture farming.
- In colonization cultures, forests are not regarded as valuable, and "improving" an area is synonymous with deforestation. There is a need to establish an agroecological agricultural value system and foster environmental awareness from an early age.
- International development cooperation often relies on external approaches rather than local experiences, and the goals and methods of various projects are not coordinated. Long-term, integrated, and participatory approaches are needed for consistently implemented international development strategies.

4.3. Infrastructure and technology

- To sustainably reduce the significant technological and infrastructural disparities between regions, appropriate public services, as well as integrated approaches based

on spatial planning and participation that consider geographical, biological, and socio-economic characteristics, smart infrastructure solutions, and ecological corridors are necessary.

- Infrastructure developments in rural areas must be aligned with indigenous land management and forest conservation.
- The lack of industrialization, processing technologies, and industry support services in biologically diverse regions is hindering the promotion of the bioeconomy. Decentralization of technological and research capabilities is essential so that regions are not merely areas for raw material extraction and information harvesting.
- Small enterprises are disproportionately burdened by high costs due to long distances, expensive transportation, and costly technologies. The solution lies in smart infrastructure development tailored to local conditions, as well as industrialization designed according to economies of scale and customized, cost-effective technological packages. It is necessary to foster cooperative efforts among small producers and to bring processing and innovation closer to the producers.

4.4. Institutional framework

- At this moment, neither the bioeconomy nor agroforestry has a clear policy direction in the country. Prioritizing the bioeconomy as a strategic sector would long-term correlate with the integrated development of the sector, including sustainable management systems operating on agroecological principles.
- The work of the relevant ministries and the national institutional framework associated with them is not coordinated. A unified action plan and coordination mechanisms are necessary to achieve better collaboration and impact.
- There is a lack of an institutional framework to support the new economic model. Government systems should adapt to Colombia's high biological, cultural, technological, and economic heterogeneity. The establishment of a National Office of Bioeconomies and a Forestry Science Institute would be beneficial.
- Punishment-focused, bureaucratic, non-solution-oriented regulations and institutions hinder the emergence of new economic forms. Flexible policies and regulations, differentiated production alternatives, bioeconomy decentralization, strengthening the local institutional framework, establishing unified

governmental services, and public education in bioeconomy could greatly improve the situation.

- Small businesses face excessively bureaucratic and costly authorization and certification processes, while struggling to access financing. Unified and effective decentralized public services are needed in rural areas.

4.5. Stakeholder engagement

- The youth in the Colombian Amazon regions are gradually migrating, and the population is aging. Therefore, training for rural producers should focus on providing viable economic alternatives, public services, digitalization, and innovative training methodologies for young people.
- Transitioning from deforestation and extensive cattle ranching to more knowledge- and labour-intensive, complex, and ecologically and economically sustainable silvopastoral systems is challenging. This requires professional advice from experts with agroecological and pedagogical knowledge, practical demonstration farms, increased community participation, and social acceptance.

- Restoring the deteriorated trust in the institutional framework can be achieved through locally tailored solutions and participatory planning.
- Bioeconomy value chains are rudimentary and disorganized. Producer cooperatives facilitate access to more advanced technologies, collective crop collection and processing, coordination of roles, and direct sales without intermediaries. High value-added, shorter value chains can be created through task sharing and coordinated teamwork among skilled stakeholders.

4.6. Sustainable production, value creation and market challenges

- To mitigate the significant damage caused by alien farming practices in the Amazon Basin, it is worth considering integrated rural development models that involve ecological, economic, and social aspects, and focus on high agrobiodiversity, multifunctional agroforestry systems.
- Good agroforestry applies agroecological principles, using interactions of traditional local knowledge and local species to mimic the biological mechanisms of the forest, while neutralizing pests through biological

means without the introduction of external chemicals. It ensures food security and autonomy for families, as well as diversifies their incomes.

- Transitioning from extensive cattle ranching to regenerative and biologically diverse forest grazing would bring numerous ecological, animal health, and economic benefits for breeders. It would allow for the restoration of degraded areas and sustainable agroforestry providing ecosystem services with non-timber forest products.
- Excessive dependence on external markets could push farmers towards monocultures. The foundation of an ecologically sustainable Amazonian bioeconomy lies in the conscious and gradual construction of a multifunctional, dialogue-based, biologically diverse, and circular agroforestry model that initially ensures producers' food security and self-determination, as well as diversifying income risk.
- Non-timber forest products have significant economic potential; however, currently, the prevailing model is a craft-based bioeconomy as sophisticated processing technologies are not available in rural areas. Significant scientific research and innovation in Amazonian product development are essential.

- There is a need to create a new consumer culture that recognizes and values the products and services of biodiversity.

4.7. Political and economic structures

- In recent decades, Colombia has built a growth-oriented, centralized economic model reliant on fossil fuel extraction, where nature is seen as an obstacle to so-called "development." The current economic structures are difficult to replace, and the alternatives often do not appeal to decision-makers and local communities due to the costs associated with the transition.
- In some Amazonian regions, the most basic security conditions for bioeconomy development are not met due to the territorial and social control exerted by various armed actors.
- The four-year government cycles of democracy prevent the implementation of long-term strategic plans at both the national and local levels.
- A stable presence of state institutions would be a fundamental prerequisite for the development of the bioeconomy. In many of these regions, the most basic

public services are lacking, such as energy, healthcare, and education.

- A historical condition is the strong dependence of colonization cultures on the Andean "mother region," which has led to a limited understanding of local ecosystems and a low level of local adaptation. Because settlers could not farm under the challenging Amazonian conditions, the colonization of the region historically promoted deforestation to make land available for conventional agriculture, including cattle ranching and traditional landholding.
- The most important task currently is the gradual realization of a stable economic transition marked by the bioeconomy and energy transition, supported by a stable presence of state institutions.

5. LIST OF SCIENTIFIC PUBLICATIONS

Book chapter:

Borovics A., & Lenti A. (2020). A chagra, mint működő agrárerdészeti gyakorlat Amazóniában. In Fenntarthatóság és versenyképesség a klímaváltozás árnyékában (pp. 30–48). NAIK.

Papers published in academic journals:

Lenti, A. (2023). A környezetpusztítás és a gazdaság összefüggései az Amazonas-medence országában. *Külügyi Szemle*, 22(1), 20–39.

Lenti, A. (2023). Az emberi jövő kulcsa a múltban: őshonos ökológiai tudás az Amazonas-medence átalakuló indián társadalmában. *Magyar Tudomány*, 184(7), 895–905.

Lenti, A. (2023). Agroforestry: an agroecological practice in the light of Ecological Economics. *Gazdaság és Társadalom*, 16 (34), 93-120.

Research report:

Lenti, A., Kelemen, E., Czett, K., Klusmann, C., & Pataki, Gy. (2023, February). Typology of challenges that hinder the implementation of EU Biodiversity Strategy 2030. Environmental Social Science Research Group. <https://doi.org/10.5281/zenodo.7685651>

Conference papers:

Lenti, A. (2020). Egy fenntartható fejlődési modell keresése az Amazonas-medencében. In VÁLSÁG ÉS KILÁBALÁS: INNOVATÍV MEGOLDÁSOK Nemzetközi Tudományos Konferencia Sopron, 2020. november 5. – Konferenciakötet (pp. 124-139). Soproni Egyetem Kiadó.

Lenti, A. (2022). Szakirodalmi áttekintés az amazóniai indián chagrák – őshonos agrárerdészeti rendszerek – ökológiai, társadalmi és gazdasági jelentőségéről. In PANDÉMIA – FENNTARTHATÓ GAZDÁLKODÁS – KÖRNYEZETTUDATOSSÁG Nemzetközi tudományos konferencia a Magyar Tudomány Ünnepe alkalmából, Sopron, 2021. november 4. – Konferenciakötet (pp. 252-263). Soproni Egyetem Kiadó.