THE 5th INTERNATIONAL CONFERENCE ON AGROFORESTRY (ICAF)

"Agroforestry for Sustainable Development (AG4DEV)"

PROCEEDINGS
NOVEMBER 2024

Maejo University

November 27 – 29, 2024

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Preface

Background

The Southeast Asian Network for Agroforestry Education (SEANAFE), through its national networks in the Philippines, Thailand, Indonesia, Vietnam, Lao PDR, and Malaysia, has been organizing a biennial International Conference on Agroforestry to serve as a platform for sharing recent developments in various aspects of agroforestry.

Agroforestry is a land use management system that combines the production of short-term crops and woody perennials in the same unit of land, to address the socioeconomic productivity of the farmers while ensuring ecological stability within the farms and across the landscape. Because of its economic and ecological contributions, agroforestry is always considered the main production technology for climate change mitigation and adaptation, food security, and forest landscape restoration, among others. Several researchers and literature claim that agroforestry promotes sustainable livelihoods and resilience among smallholder farmers.

Agroforestry, being a nature-positive production system contributes to the achievement of several Sustainable Development Goals such as SDG 1 (No Poverty); SDG 2 (Zero Hunger); SDG 11 (Sustainable Cities and Communities); SDG 12 (Responsible Consumption and Production); SDG 13 (Climate Action); SDG 15 (Life on Land); and SDG 17 (Partnership for the Goals).

Thus, the 5th International Conference on Agroforestry convened researchers, academe, development workers, extensionists, policymakers, students, and practitioners to highlight the role of agroforestry in the attainment of SDGs.

Objectives

The 5th ICAF was organized to serve as a platform for the exchange of scientific information about agroforestry education, research, and development. Specifically, it aimed to :

1) Highlight initiatives in mainstreaming agroforestry education in the academic programs of various universities and institutions
2) Share results of agroforestry research and development with emphasis on agroforestry’s ecosystem services, and its role in climate change mitigation and adaptation, sustainable production and consumption, and food security;
3) Provide a venue for articulating issues and challenges in agroforestry research, development, and extension; and,
4) Strengthen individual and institutional collaborations for enhancing agroforestry promotion towards the achievement of SDGs.

Sub-themes

1) Recent developments in agroforestry education
2) Role of agroforestry in climate change adaptation and mitigation
3) Potentials of agroforestry in ensuring food security
4) Ecosystems services of agroforestry
5) Potential crop components of agroforestry systems
6) Agroforestry systems and practices

Expected Participants

The 5th ICAF gathered different stakeholders such as the researchers, faculty/academia, students, practitioners, policymakers, development and extension workers.

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Conference Committee

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Associate Professor Dr. Weerapon Thongma	Maejo University
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Assistant Professor Dr. Rachanee Pothitan	Kasetsart University
Dr. Prajate Umnat	Maejo University Phrae Campus
Dr. Affendy Hassan	Universiti Malaysia Sabah
Dr. Leila Landicho	University of the Philippines Los Baños

Organizer:

Maejo University International College
Maejo University Phrae Campus

Co-hosts:

Philippine Agroforestry Education and Research Network
ThaiNAFE (Thai Network for Agroforestry Education)
SEANAFE (Southeast Asian Network for Agroforestry Education)

5th INTERNATIONAL CONFERENCE ON AGROFORESTRY

NOVEMBER 27-29, 2024

International Education and Training Center

Maejo University, Chiangmai, Thailand

SCHEDULE

DAY 1. NOVEMBER 27

Time	Activities	Location
07:00-08:00	**REGISTRATION**	Conference hall, 1st floor
08:00-09:00	**OPENING CEREMONIES**	
09:00-09:30	1st Keynote Speaker Assoc. Prof. Dr. Weerapon Thongma *Topic: Maejo University IWA through Net Zero*	
09:30-10:00	2nd Keynote Speaker Prof. Dr. Wilfredo M. Carandang *Topic: Landscape Agroforestry Towards Climate Resilient and Sustainable Communities in Southeast Asia*	
10:00-10:30	3rd Keynote Speaker Prof. Dr. Blanda R. Sumayao *Topic: From Farm to Forest and Forest to Farm: Extension as a Tool for Agroforestry and Sustainable Rural Development*	
10:30-10:45	Open Forum/Discussion	
10:45-11:00	BREAK	Dining room, 1st floor
11:00-12:00	**PARALLEL SESSION I** **Theme A** Potentials of Agroforestry for Ensuring Food Security **Theme B** Recent Developments in Agroforestry Education **Theme C** Ecological Services of Agroforestry **Theme D** Potential Crop Components of Agroforestry Systems	Conference room 202, 2nd floor Conference room 205, 2nd floor Conference hall, 1st floor Conference room 203, 2nd floor
12:00-13:30	LUNCH BREAK	Dining room, 1st floor
13:30-14:10	**PARALLEL SESSION I** **Theme A** Potentials of Agroforestry for Ensuring Food Security **Theme B** Role of Agroforestry in Climate Change Mitigation and Adaptation **Theme C** Ecological Services of Agroforestry	Conference room 202, 2nd floor Conference room 205, 2nd floor Conference hall, 1st floor

Time	Activities	Location
	Theme D Potential Crop Components of Agroforestry Systems	Conference room 203, 2nd floor
14:50-15:05	BREAK	Dining room, 1st floor
15:05-16:05	**PARALLEL SESSION II** **Theme A** Potentials of Agroforestry for Ensuring Food Security **Theme B** Role of Agroforestry in Climate Change Mitigation and Adaptation **Theme C** Ecological Services of Agroforestry **Theme D** Potential Crop Components of Agroforestry Systems	Conference room 202, 2nd floor Conference room 205, 2nd floor Conference hall, 1st floor Conference room 203, 2nd floor
16:05-18:00	**POSTER PRESENTATION AND AGRICULTURAL EXHIBITION**	In front of conference hall, 1st floor
18:00	WELCOME DINNER	Dining room, 1st floor

DAY 2. NOVEMBER 28

08:30-09:00	4th Keynote Speaker: Prof. Dr. Ir. Kurniatun Hairiah *Topic: Agroforestry in Action: Carbon Stocks, Soil health and Flash Floods on the Slopes of Mount Arjuno, East Java, Indonesia*	Conference hall, 1st floor
09:00-09:30	5th Keynote Speaker: Dr. Krik Meemungkit *Topic: Three Forests, Four Benefits: The Foundation of Agroforestry for Economy and Nature*	
09:30-09:45	Open Forum/Discussion	
09:45-10:00	BREAK	Dining room, 1st floor
10:00-12:20	**PARALLEL SESSION III** **Theme C** Ecological Services of Agroforestry **Theme D** Potential Crop Components of Agroforestry Systems **Theme E** Agroforestry System and Practices	Conference hall, 1st floor Conference room 203, 2nd floor Conference room 205, 2nd floor
	PARALLEL SESSION ONLINE *Session Chair: Assist. Prof. Khuanjarat Choengpanya* *Co-Chair: Dr. Jirapong Sornsakdanuphap*	Conference room 203, 2nd floor
12:20-13:30	LUNCH BREAK	Dining room, 1st floor
13:30-15:30	**SEANAFE MEETING**	Conference hall, 1st floor
15:30-15:45	BREAK	Dining room, 1st floor
15:45-16:30	**AWARDING AND CLOSING CEREMONY**	Conference hall, 1st floor
16:30-18:00	**CAMPUS TOUR**	Maejo University
18:00-21:00	FAREWELL DINNER	Dining room, 1st floor

DAY 3, NOVEMBER 29

08:30-16:00 Field Trip and Cultural Tour (Optional) Muang Kham Zero Waste Muang Kham Village, Mae Rim, Chiang Mai, Thailand

PARALLEL SESSION DETIAL

DAY 1. NOVEMBER 27: PARALLEL SESSION I

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Session Chair: Prof.Dr.Christine Wulandari, Indonesia *Co-Chair: Dr. Nipon Chuamuangphan*	*Session Chair: Dr. Leila Landicho, Philippines* *Co-Chair: Assist. Prof. Dr. Tawan Chatsungnoen*	*Session Chair: Dr. Affendy Hassan, Malaysia* *Co-Chair: Mr. Worawut Ngampiboonwet*	*Session Chair: Dr. Krittiya Tongkoom* *Maejo University* *Co-Chair: Dr.Rodjanacorn Chuengpanya*
A1: Challenges and Strategies for Preserving Raised-Bed Farming: A Traditional Agroforestry System Nonthaburi Province, Thailand **Niwut Laicharoenchokchai, Rachanee Pothitan**	B1: Half Century of Social Forestry in Asia, A Review and Lessons from Sumatra Province **Yonariza, Yenny Octavia, Yozarwardi Usama Putra, Rakhmat Hidayat, Syafredo, Dwiki Ridhwan**	C1: Carbon Storage Potential of Forest Buffer Zones and Banana Plantations in Southern Philippines **Adrian M. Tulod, Eric N. Bruno, Angela Grace T. Bruno, Lowell G. Aribal, Guillermo A. Mendoza**	D1: Effect of Biostimulants and Pgrs on the Reproductive Characters of Cacao Under Monocrop and Intercrop Planting Systems **Vences C. Valleser and Calixto M. Protacio**
A2: Correlation of Community Characteristics to Vegetation Type Preference in Agroforestry Systems in Protected Forests and Community Forests **Christine Wulandari, Dewi Sri Wahyuni, Putra Pangestu, Hari Kaskoyo, Indra Gumay Febryano, Susni Herwanti, Dian Iswandaru, Rahmat Safei, Yuliana Rahma Fitriana, Novriyanti, Arief Darmawan, Machya K Tsani, A. Nizam Syahiib**	B2: Promoting Organic Agriculture through Edutourism: Experience of the UPLB Organic Agriculture Research, Development and Extension Center **Christine Joy B. Manalo, Leila D. Landicho, Ian Mari Reano**	C2: Soil Runoff and Erosion Control Potential of Agroforestry **Maria Theresa Nemesis P. Ocampo, Ma. Armie Janica R. Pleto, Reden D. Macalagay, Wilfredo O. Banasihan**	D2: Soil Health and Growth Performance of Red Spanish Pineapple (*Ananas Comosus* L.) to Varying Soil Fertility Management on a Contour Farming System in Aklan, Philippines **Eva R. Orlina, Ezra N. Zonio, Mark Angel D. Relingo, Evelyn P. Vedasto, Carmenchita M. Tumaca, Melba L. Raga-as and Ruby M. Besana**
A3: Community-Based Bamboo Production for Sustainable Livelihood and Environmental Protection **Josiemay Salamanca** **<u>(Online)</u>**		C3: Game-Based Analysis of Tree Diversity and Land-Use Choices in Agroforestry Systems **Rika Ratna Sari, Lisa Tanika, Erika N. Speelman, Arief Lukman Hakim, Rizki M. Ishaq, Danny D Saputra, Danaë M.A. Rozendaal, Meine Van Noordwijk**	

Theme A Potentials of Agroforestry for Ensuring Food Security	**Theme B** Role of Agroforestry in Climate Change Mitigation and Adaptation	**Theme C** Ecological Services of Agroforestry	**Theme D** Potential Crop Components of Agroforestry Systems
Session Chair: Prof.Dr.Christine Wulandari, Indonesia *Co-Chair: Dr. Nipon Chuamuangphan*	*Session Chair: Dr. Leila Landicho, Philippines* *Co-Chair: Assist.Prof. Dr. Tawan Chatsungnoen*	*Session Chair: Dr. Affendy Hassan, Malaysia* *Co-Chair: Mr. Worawut Ngampiboonwet*	*Session Chair: Dr. Krittiya Tongkoom* *Maejo University* *Co-Chair: Dr.Rodjanacorn Chuengpanya*
A4: Do the Farming Futures Desired by Upland Farmers Match the Aims of External Stakeholders in Southeast Asia? **Caroline D. Pinon, Anthony Ringrose-Voase and Wendy Merritt**	B3: Enhancing Multifunctionality in Cacao Agroforestry: The Role of Climate-Specific Tree Selection and Root Development **Danny Dwi Saputra, Ni'matul Khasanah, Rika Ratna Sari, Meine Van Noordwijk**	C4: Diversity and Abundance of Arthropod in an Agroforestry Demonstration Farm in Baybay City, Leyte, Philippines **Retchel R. Cuizon, Hernando L. Mondal**	
A5: Perceived Impacts of Agroforestry Adoption on Livelihood, Income, Farmland Condition, and Equity (Life) Among Members of the Liliw Upland Farmers Marketing Cooperative (LUFAMCO) in Liliw, Laguna **Cyrene Jira J. Carbonell and Lorena L. Sabino**			

DAY 1. NOVEMBER 27: PARALLEL SESSION II

Theme A Potentials of Agroforestry for Ensuring Food Security	**Theme B** Role of Agroforestry in Climate Change Mitigation and Adaptation	**Theme C** Ecological Services of Agroforestry	**Theme D** Potential Crop Components of Agroforestry Systems
Session Chair: Dr.Nipon Chuamuangphan, Maejo University *Co-Chair: Mr. Worawut Ngampiboonwet*	*Session Chair: Assoc.Prof.Dr.Torlap Kamyo, Maejo University* *Co-Chair: Dr. Jirapong Sornsakdanuphap*	*Session Chair: Prof. Dr. Wilfredo M. Carandang* *Co-Chair: Dr.Prajate Umnat*	*Session Chair: Dr. Krittiya Tongkoom* *Maejo University* *Co-Chair: Dr.Rodjanacorn Chuengpanya*
A6: How Resilient Are the Community-Based Forest Management (CBFM) Areas in the Philippines?: Case of Selected Areas in Calabarzon **Leila D. Landicho, Maria Theresa Nemesis P. Ocampo, Rowena Esperanza D. Cabahug, Roberto G. Visco, Ma. Armie Janica P. Ramirez, Mary Anne G. Abadillos, Russel Son C. Canilan, Arnold Karl Castillo, Venice Jiezzelle C. Nesperos, Christine Joy B. Manalo**	B4: Agroforestry Farmers Intentions, Perceived Impact of Climate Change and Adaptation Strategies in Southern Java, Indonesia **Lina Dwi Lestari and Kazuhiro Harada**	C5: Influence Differences of Agroforestry Typology in State Forests and Community Forests on Stored Carbon Content **Christine Wulandari, Putra Pangestu, Hari Kaskoyo, Indra Gumay Febryano, Susni Herwanti, Yuliana Rahma Fitriana, Novriyanti, Arief Darmawan, Rahmat Safei, Dian Iswandaru, Bainah Sari Dewi, A. Nizam Syahiib**	D3: Disease Spectral Identification and Analysis on the Bark of Gmelina *(Gmelina Arborea Roxb)* **Annie Ayag, Kyra Luminarias Padonat, Chaly Benson Mangubat, Jade Jusoy, Joey Arles Vergara, Cornelio Sacquiap Casilac Jr.**
A7: People's Participation in Community Forest Management, Northern Thailand **Kritsada Phongkaranyaphat Lamthai Asanok Pittayatorn Inkaew and Wannaubon Singyoocharoen**	B5: Dynamics of Energy Forest Plantation Development in Jambi Province **Bambang Dipokusumo, Andi Chairil Ichsan, Hairil Anwar, Anggi Putra Prayoga, Tenri Waru**	C6: Optimizing Agroforestry-Based Social Forestry Management to Support Water Security and Other Ecosystem Services in Padang City, West Sumatra **Soniartha Simarmata, Dwiki Ridhwan, Syafredo, Yonariza, Mahdi**	
A8: Assessment of Economic Value and Design of Agricultural Crop and Perennial Plant Cultivation in the Agroforestry System at Ban Boonchaem, Namlao Subdistrict, Rong Kwang District, Phrae Province **Teradaporn Thongphan,**	B6: Carbon Sequestration Potential and Leaf Litter Decomposition of Different Forest Stands at Caraga State University, Butuan City, Philippines **B S Bactol, M Reyes, K Quimno, R N Cossid, C S Casilac[1]and V L Corbita**	C7: Agroforestry as a Win-Win Solution: Promoting Biodiversity, Carbon Storage, and Sustainable Livelihoods in Mankayan Watershed of Benguet, Philippines	

Theme A Potentials of Agroforestry for Ensuring Food Security	Theme B Role of Agroforestry in Climate Change Mitigation and Adaptation	Theme C Ecological Services of Agroforestry	Theme D Potential Crop Components of Agroforestry Systems
Wanniphaphon Munfu, Worawut Ngampiboonwet, Yutthana Thoenglom, Premchai Sootthakun, Prajate Umnat, Kasama Thaeye		**Nelson M. Pampolina, Bernard Peter O. Daipan and Erwin L. Tabaco**	
A9**:** Environmental, Social, and Economic awareness of Farmers to Tibig (*Ficus nota*) in selected barangays of San Jose, Occidental Mindoro **Arvin Jonathan L. Flores and Josiemay V. Salamanca** **(Online)**	B7: Comparison of Overall Carbon Storage between Teak Monoculture and Mixed Plantation of Teak and Eucalyptus in Maesai Village Phrae Province, Thailand **Areerat Yaochueang, Jiraporn Pakketanang, Worawut Ngampiboonwet, Yutthana Thoenglom, Premchai Sootthakun, Prajate Umnat, Patpen Penjumras**	C8: Biodiversity and Carbon Storage Capacity of Different Agroforestry Systems in Sariaya, Quezon, Philippines **Adona Joana S. Urmeneta, Roberto G. Visco, Marco A. Galang, Juancho B. Balatibat** **(Online)**	
	B8: Resilience-Building of Corn Upland Farming Communities in the Province of Isabela, Philippines through Agroforestry **Maria Theresa Nemesis P. Ocampo, Jose Nestor M. Garcia, Emerson V. Barcellano, Leila D. Landicho, Rowena Esperanza D. Cabahug Adona Joana Urmeneta**		

DAY 2. NOVEMBER 28: PARALLEL SESSION III

Theme C Ecological Services of Agroforestry	Theme D Potential Crop Components of Agroforestry Systems	Theme E Agroforestry System and Practices
Session Chair: Prof. Dr. Yonariza, Indonesia *Co-Chair: Assoc.Prof.Dr. Lamthai Asanok*	*Session Chair: Assoc.Prof. Dr.Torlap Kamyo, Maejo University* *Co-Chair: Mr. Yutthana Thoenglom*	*Session Chair: For. Rowena Esperanza Cabahug, Philippines* *Co-Chair: Dr. Krittiya Tongkoom*
C9: Agroforestry for Soil Health and its effect on litter decomposition rates. Case study from the Education Forest (UB-Forest), Malang Regency, East Java, Indonesia **Hanifa SA, Jihanadhira B, Wati IAS, Saputra DD, Ishaq RM, Sari RR and Hairiah K**	D4: Cultural Management Practices Employed in 'Baligonhon' Yam During Dry Season Cropping **Jean L. Valleser**	E1: A Shift in Farming Systems and Practices Among Upland Farmers in Buhi, Camarines Sur, Philippines **Abby Grace E. Bermejo and Felisa L. Malabayabas**
C10: Plankton Composition and Abundance in Aquasilviculture System in Infanta, Quezon, Philippines **Venice Jiezzelle C. Nesperos, Roberto G. Visco, Pastor L. Malabrigo, Jr., Roselyn F. Paelmo, and John Vincent R. Pleto**	D5: Intercropping effects of cocoa seed clones with *Neolamarckia cadamba* on root traits under controlled conditions **Nurella Eziwana Juwahir, Aida Nabihah M Khatta, Mohamadu Boyie Jalloh, Boney Muda and Affendy Hassan**	E2: Factors of Adoption of Smallhold Agroforestry-Based Farmers in Silang, Cavite, Philippines **Arnold Karl A. Castillo, Russel Son C. Canilan and Roselyn F. Paelmo**
C11: Building Resilient Communities Along Aklan River (BRCAR), Philippines **Nenia N. Bohulano, Melba L. Raga-As, Carmenchita M. Tumaca, Anna Mae C. Relingo, Arthur E. Jismundo**	D6: Stand Structure, Morphology, and Bio Physico-Chemical Characteristics of Soils in Maganhop (*Albizia lebbekiodes D.C.*) and Abaca (*Musa textiles L.*) Production Systems **Melba Raga-as, Carmenchita M. Tumaca, Paterno I. Rebuelta Jackson A. Vilorente Cornelia N Ningas and Julia Z. Beltran**	E3: Vulnerabilities, Challenges, and Opportunities of Socioecological Production Landscapes (SEPLs): Case of Sta. Cruz Sub-Watershed in the Philippines **Russel Son C. Canilan, Leila D. Landicho, Arnold Karl A. Castillo, Maria Theresa Nemesis P. Ocampo, Rowena Esperanza D. Cabahug, Mary Anne G. Abadillos, Ma. Armie Janica Ramirez, Romnick S. Baliton**
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Theme C Ecological Services of Agroforestry	Theme D Potential Crop Components of Agroforestry Systems	Theme E Agroforestry System and Practices
C13: The Role of Stakeholders in Promoting Agroforestry under Social Forestry Program in West Sumatra, Indonesia **Mahdi, Yonariza, Yozarwardi Usama Putra, Dwiki Ridhwan, Heriza Leni, Rakhmat Hidayat**	D8: Enhanced National Greening Program Implementation On Selected Indigenous People Organization in San Jose and **Rizal Occidental Mindoro** **Rizzi Angelica Dagos and Josiemay Salamanca** **(Online)**	E5: Pest Management in Agroforestry: Evaluating Practices in Mankayan, Benguet, Philippines **Sheryl A. Yap, Kimberly Ann S. Domingo, Nelson M. Pampolina, Philip Alviola, Erwin L. Tabaco**
C14: Stewards of the Forest: Arthropods as Bioindicators of an Agroforestry in Mankayan, Benguet, Philippines **Sheryl A. Yap, Kimberly Ann S. Domingo, Nelson M. Pampolina, Philip Alviola, Erwin L. Tabaco**		E6: Kaingin Farming Practices of Alangan Farmers in the Indigenous Community of Sta. Cruz, Occidental Mindoro **Garry L. Calitang and Ronaldo G. Orpiano** **(Online)**
		E7: Indigenous Agroforestry Practices of Gubatnon Farmers in Purnaga, Magsaysay, Occidental Mindaro **Garry L. Calitang and Rizzi Angelica T. Dagos** **(Online)**

POSTER PRESENTATION AND AGRICULTURAL EXHIBITION

P1. Effect of drying condition on quality of Robusta coffee blossom tea

Kamonporn Panngom[1], Thanyarat Chuesaard[2], Anuwat Jaradrattanapaiboon[2], and Patpen Penjumras[3]*

[1]Program of Basic Science, Maejo University-Phrae Campus, Phrae, Thailand

[2] Program of Crop Production Technology, Maejo University-Phrae Campus, Phrae, Thailand

[3]Program of Agro-industrial Biotechnology, Maejo University-Phrae Campus, Phrae, Thailand

P2. The effect of Xanthan gum and swamp algae incorporation on properties of banana flour substituted noodles

Sasinun Arjan[1], Wirod Painan[1], Anuthida Phaiphan[2] and Patpen Penjumras[1*]

[1] Program of Agro-Industrial Biotechnology, Maejo University-Phrae Campus, Phrae, Thailand

[2] Program of Food Technology, Ubon Ratchathani Rajabhat University, Ubon Ratchathani Province, Thailand

P3. Evaluation of Total Phenolic Content, Antioxidant Activity and Chlorophyll Content of *Murraya siamensis* leaf extract

Thanyarat Chuesaard[1], Matchima Suphavimonphan[2], Laaorthip Naloka[1], Sirisopha Inkha Wannawong[1], Pattraporn Pukklay[3], Patpen Penjumras[4*]

[1]Program of Crop Production Technology, Maejo University-Phrae Campus, Thailand 54140

[2]Program of Community Innovation Management, Maejo University-Phrae Campus, Thailand 54140

[3]Program of Forestry, Maejo University-Phrae Campus, Thailand 54140

[4]Program of Agro-industrial Biotechnology, Maejo University-Phrae Campus, Phrae, Thailand 54140

P4. Development of Sauce from Rejected Gros Michel Bananas (*Musa sapientum*) Cultivated for Exporting

Chatnalin Kaewsom [1], Panida Kuntad [2], Patpen Penjumras [3]*

[1] Program of Entrepreneurial Management, Maejo University at Chumporn, Thailand 86170

[2] Program of Crop Production Technology, Maejo University at Chumporn, Thailand 86170

[3] Program of Agro-industrial Biotechnology, Maejo University-Phrae Campus, Phrae, Thailand 54140

P5. Study of Weed Diversity and Their Population Density in Different Fields

Soonthorn Singkaew[1], Waraporn Khiwlee[1], Worawut Ngampiboonwet[1], Yutthana Thoenglom[1], Premchai Sootthakun[1], Prajate Umnat[1], Apiradee Siangsuepchart[2]*

[1]Program of Agroforestry, Maejo University-Phrae Campus, Thailand 54140

[2]Program of Agro-industrial Biotechnology, Maejo University-Phrae Campus, Thailand 54140

P6. The Effect of Shading on Growth of Young Arabica Coffee Plant

Thanyarak Lapchok[1], Thamonwan Chunthongkham[1], Worawut Ngampiboonwet[1], Yutthana Thoenglom[1], Premchai Sootthakun[1], Prajate Umnat[1*]

[1]Program of Agroforestry, Maejo University-Phrae Campus, Thailand 54140

P7. The Effect of Slope Aspect on Growth of Plants in Nan Province Highland

Punyisa Thongiad[1], Nannapin Suebpong [1], Worawut Ngampiboonwet[1], Premchai Sootthakun[1], Prajate Umnat[1], Yutthana Thoenglom[1*]

[1]Program of Agroforestry, Maejo University-Phrae Campus, Thailand 54140

Abstract of Keynote Speakers

Maejo University IWA through Net Zero

Weerapon Thongma[1]

[1]Associate Professor Dr., The President of Maejo University, Thailand

Abstract

Maejo University, located in Thailand, is known for its commitment to advancing agricultural knowledge and practices. The university likely plays a significant role in integrating sustainable practices within its agricultural programs and in shaping sustainable agricultural transformation through higher education, fostering intelligent well-being agriculture by combining research, innovation, community engagement, and a forward-thinking curriculum. Intelligent Well-being Agriculture encompasses a holistic framework that integrates economic sufficiency and culture, convergence technology, and eco-agricultural development. By focusing on these three interconnected elements, agriculture can achieve sustainability that not only enhances productivity but also improves the quality of life for farmers and promotes environmental stewardship. This comprehensive approach is essential for addressing the complexities of modern agriculture, ensuring that it meets current needs without compromising future resources or the well-being of communities. As the agricultural landscape continues to evolve, embracing this paradigm will be crucial for fostering systemic change and achieving long-lasting sustainability. Intelligent Well-being Agriculture through Net Zero envisions a sustainable agricultural landscape where economic viability, environmental stewardship, and social equity coexist. By adopting practices that align with the Net Zero ethos, agriculture can contribute to global climate goals while enhancing the well-being of communities and ensuring food security for future generations. This comprehensive approach is essential for transforming agricultural systems into resilient, sustainable frameworks that can endure the challenges of a rapidly changing world.

Assoc. Prof. Dr. Weerapon Thongma
President of Maejo University

Landscape Agroforestry Towards Climate Resilient and Sustainable Communities in Southeast Asia

Wilfredo M. Carandang[1]

[1]Executive Director, Southeast Asian Network on Agroforestry Education (SEANAFE) Los Banos, Philippines

Abstract

Agroforestry has now evolved into a full pledged science as a result of the many researches undertaken and resulting technologies generated by these studies. Characteristically, these researches have now expanded to studies involving the landscape from the more traditional individual farm-based experiments where results are essentially dependent on arbitrary physical and biological traits of the specific farms where the study occurred. Considering that the environmental impacts of the said agroforestry practices are best interpreted from the landscape perspective, the benefits of agroforestry are best appreciated when looked at from a larger scale.

In the Philippines, landscape agroforestry can best be appreciated within the context of watershed ecosystem management (WEM) or ridge-to-reef (R2R) approach. The R2R/WEM approach has long been enunciated by the Philippine government but it is only now that its long term effects are being recognized and its implementation particularly in land use planning is being promoted. In 2017, the Guidelines on Watershed Integrated Area Land Use Planning (WILUP) was developed as a result of a project funded by the government. The implementation of these guidelines is now being tested in three municipalities in the Philippines which are currently reviewing and revising their comprehensive land use plans (CLUP). The R2R/WEM recognizes the role of agroforestry as practiced in the landscape (watershed) as well as its interconnection with other ecosystems, land-uses, and the degradation resulting from unsustainable forestry, agriculture and urbanization processes. In due time, the implementation of WILUP would result to policy recommendations to more effectively put in place the different mechanisms that go with integrated land use planning within the watershed.

In the context of R2R/WEM, management activities are mostly directed towards streamflow regulations, soil conservation, enhancement of soil infiltration capacity, soil erosion minimization, optimum production of ecosystem goods and services, poverty reduction and environmental stabilization/climate change mitigation. These are essentially the purposes for which landscape agroforestry are geared towards to. When implementing any landscape agroforestry programs, the steps involved in R2R/WEM can very well guide the planning, implementation and monitoring activities.

Prof. Dr. Wilfredo M. Carandang
University of the Philippines Los Banos,
SEANAFE Executive Director

From Farm to Forest and Forest to Farm: Extension as a Tool for Agroforestry and Sustainable Rural Development

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[1]Retired Professor in Extension Education, UP Los Baños, Philippines

Abstract

President Dr. Weerapon Thongma and to all of you here in this conference, good morning.

It is a great pleasure to be with you here today, experts and practitioners of agroforestry, because we share the belief that through agroforestry we can help change our communities, especially the rural communities, for the better. It is in conferences like this that we call attention not only to what we can and should do in our institutions or in our personal capacities, but more especially, a genuine attention to the plight of the poor and the vulnerable members of our society, especially those in the rural areas who, sadly, we always use as our rationale for gatherings like this.

You'll notice the bias in the title of my paper. My field is extension education and so I'd like to highlight the critical and potential role of extension if we are to see the improvement of livelihood and well-being of rural people worldwide through agroforestry. Through extension we hope to enable farmers in agroforestry to maximize their contribution to sustainable rural development. The economic, social, and environmental benefits of agroforestry could only be realized if this natural resource management system which has always been an integral component of many global development frameworks, policies, and programs especially in the areas of climate change mitigation and adaptation, combatting desertification, conservation of biological diversity and security has reached a "critical mass" in its adoption which means a sufficient number of individuals have adopted it and its continued adoption becomes self-sustaining. It is at this point that we could say that this natural resource management system has gained the desired level of social acceptability among its intended clientele and all other stakeholders which is the overall aim and the very challenge to our extension programs and activities. The key word here is adoption and I'd like to underscore sustained adoption. The extension organization needs to look more deeply and more seriously into this process. It will not be an easy road to take because although agroforestry is seen as a promising alternative to address the unsustainable use of forests, the fact is that, just like any new idea or innovation introduced to intended clientele, there are certain constraints to its adoption. Among the many constraints identified, I'd like to focus on what FAO (1997) has identified especially (a) competition for land because of increasing population pressure which could mean giving way to the more urgent need of land to support immediate need for food production and income, (b) the timescale of forestry which means use of lands for trees where benefits could only be available only several years into the future would conflict with the rural poor's priorities focused on meeting their present basic needs for food and income, (c) the spatial distribution of benefits, which means benefits from trees would be enjoyed not by the farmer himself and his family and community but by businesses outside the community, and (d) institutional and technical requirements such as sophisticated, elaborate, and costly requirements which are beyond the farmer's capability.

But what is agroforestry that we want is adopted and so we spend our time, talents, and resources taking about it? You are the experts on this subject matter and I'm pretty sure you have the answers to these questions. I'm not an expert on the subject matter but I'd like to bring to the fore what interested me so much in my readings. It is the 17 Sustainable Development Goals (SDGs) adopted by all United Nations

member states in 2015 when they defined the 2030 Agenda for Sustainable Development . The member states made agroforestry a low hanging fruit for achieving six (6) or about 35% of the 17 SDGs, which means the member states accept the significant contribution of agroforestry to rural development. The six SDGs and their goals are:

SDG 1 – no poverty
SDG 2 – zero hunger
SDG 5 – gender equality
SDG 12 – responsible consumption and production
SDG 13 – climate change
SDG 15 – protect, restore, and promote sustainable use of terrestrial ecosystem, and sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Attainment of these six goals puts a heavy challenge to agroforestry extension through the adoption of agroforestry not only by its direct practitioners but also by all persons who have authority in public affairs, the policy makers, such as government ministers, planning commissions, and senior officials involved in all aspect of rural development.

If we, like the United Nations member states accept these potentials of agroforestry where rural development is concerned, what, in your small group discussions could you identify as:

1. things you have to do?
2. things you want to do?
3. reasons for why you have and want to do them.

As you go to your group sessions, put yourselves into the shoes of the agroforestry extensionists as you work on the above questions.

Thank you very much President Dr. Weerapon Thongma for the invitation to keynote this conference, Dr. Winitra Leelapattana for the technical assistance, Dr. Filma C. Calalo of the University of Guam for the materials on agroforestry and extension, and Ms. Susan D. Eugenio for encoding my hard-to-read handwritten notes.

And to all of you, thank you very much and success on your work.

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CAPSULE CURRICULUM VITAE

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Nationality: Filipino
Date of Birth: May 10, 1940
Place of Birth: Pili, Camarines Sur

Education:
Ed. D. Extension Education
1983, Louisiana State University, Baton Rouge, USA
Minor: Socioeconomics

M.S. Agricultural Education
1968, University of the Philippines, College of Agriculture
Minor: Extension Education

B.S. Agricultural Education, magna cum laude
1964, Camarines Sur State Agricultural College

Fields of Interest:
Extension, Adult Education, Monitoring and Evaluation, Educational Evaluation, Social Research Methodology, Human Resource Development

Administrative Positions Held:

Associate Dean
College of Agriculture, U.P. Los Baños
May 3, 1995 to July 1998

Associate Program Coordinator
Agro-Industrial Development Program
College of Agriculture, U.P. Los Baños
May 3, 1995 to July 1998

Chairperson
Department of Agricultural Education and Rural Studies
College of Agriculture, U.P. Los Baños
January 2, 1987 to July 31, 1990

Director
International Training in Rural Extension Project
U.P. Los Baños
March 1, 1992 to 1996

Membership in Professional Organization:
Gamma Sigma Delta Honor Society in Agriculture,
Louisiana State University Chapter, USA

Gamma Sigma Delta Honor society in Agriculture,
U.P. Los Bahos Chapter, Philippines

Philippine Association of Agricultural Educators, Inc.

National Research Council of the Philippines (NRCP)

Consultancies:

Vietnam-IRRI-UNDP Technology Transfer Program April 1-30, 1993

Evaluation of the UPLB Science Teaching Using Distance Instruction (STUDI) Program 1985-1987

DECSIEDPITAF Agricultural Technology Education Project, 1990-1994

Awards and Honors Received

The 2005 International Publication Award for the publication of Institutional Arrangements in the Modernization of Cutflower Postproduction Systems in Selected Communities in Benguet, Philippines, the Philippine Agricultural Scientist, 85 (2): 49-64, March 2005.

The 2002 International Publication Award for the publication of Resource Management in the Mixed Crop-Animal Farming Systems in a Hillyland Community in Batangas, Philippines, the Philippine Agriculture Scientist, 85 (2): 194-203, June 2002.

SEARCA Professorial Chair, July 1, 2001-June 30, 2002.

Philippine National Bank Professorial Chair, July 1.1996-June 30, 1998.

Ayala Professorial Chair, July 1, 1979-June 30, 1980.

USAID Grant, Louisiana State University, January 1981-December 1983.

UP/Cornell Teaching Fellowship, 1966-1968.

University Scholar, University of the Philippines, 1967-1968.

Magna cum laude, Camarines Sur National Agricultural College, 1964.

The Gurong Patnubay Award (Higher Education Level) given by the Philippine Association of Agricultural Educators, Inc. on 27 October 1995 on the occasion of the 8th Biennial PASSAGE Convention at the University of North Eastern Philippines, Inga City.

UPLB Outstanding Teacher Award for the Social Sciences and Humanities given on March 6, 1995 during the 86th Foundation Day at the UPLB, College, Laguna

Certificate of Recognition for Selfless Dedication and Commitment to the Promotion Of Agricultural Education given on March 16, 1990 at CSSAC, Pili, Camarines during its 8th Charter Day Anniversary.

Plaque of Recognition for 36 years of committed service to the University, Outstanding teaching performance; selfless dedication to the promotion of agricultural education and extension education; and commitment to the facilitation of learning given on October 7, 2005 at the Agricultural Systems Cluster, UPLB.

Professional Activities After Retirement:

Taught AERS 282 (Social Research Design) for two semesters, June 2005-April 2020

Social Scientist in the research project Biowaste Reuse in South-East Asian Cities (Manila, Vietnam, and Thailand), 2005-2006

Consultant in the revision of the SET (Student Evaluation of Teachers) instrument used by the UPLB and the PET (Peer Evaluation of Teachers) through the Office of the Vice-Chancellor for Instruction, UPLB

Chairperson of the Awards Committee for Best Extensionist and Best Extension Project in the Third and Fourth National Convention of the Philippine Extension Network (PEN), Inc.

Trainor in the Seminar on College Teaching conducted by the Office of the Vice-Chancellor for Instruction, UPLB, every start of the school year.

Resource Person in the formulation of the Ethical Standards and Code of Behavior of the UPLBCDC.

Reviewer for Agricultural Extension in the Professional Board Examination for Agriculture.

Consultant in the drafting of the Extension Manual for the University of Rizal System, Morong, Tanay, Philippines.

Evaluation in the In-House Review of RDE Programs, University of Rizal System, Morong, Tanay.

Member, Training Team for the 90 Days Overseas Training Programs for NAPE Faculty Members.

Member of Project Team on 'Enhancing and Strengthening of Curricular Programs For Graduate Education in Agriculture in Southeast Asia Colleges and Universities' Funded by SEARCA.

Lecturer on Social Research Methods at the College of Tourism, Maejo University, Chiang Mai, Thailand.

Trainer Social Science Research, sponsored by ICLARM and the Asian Fisheries Social Culture Research Network, held in Hanoi,Vietnam, October 4-8,1994.

Trainer Social Science Research Method for Fisheries and Natural Resource Management sponsored by IDRC and Aus Aid, September 11-25,1995, Cambodia.

Agroforestry in Action: Carbon Stocks, Soil health and Flash Floods on the Slopes of Mount Arjuno, East Java, Indonesia

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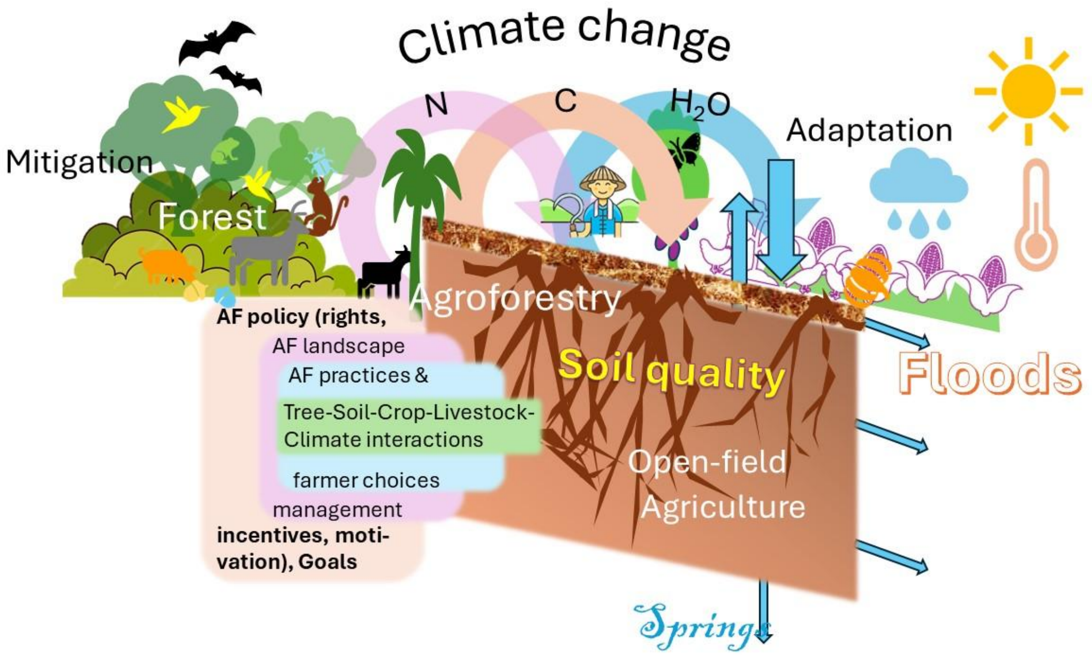
Abstract

Soil health depends on land use, in its forest-agroforestry-(open-field) agriculture continuum, interacting with the nitrogen, carbon and water cycles that shape and respond to a changing climate. The 2023 IPCC Climate Change Synthesis Report, highlights the urgent need for immediate and substantial action to reduce greenhouse gas emissions to prevent catastrophic global warming, increasing droughts and extreme rainfall events, and the fire, floods and landslides that this can cause. Maintaining above- and belowground carbon storage in functional land cover can contribute both to the mitigation (reduced net greenhouse gas emissions) and adaptation (reduced human vulnerability by enhanced buffer and filter functions) part of the climate change agenda. On mountain slopes soil health interacts with the supply of safe drinking water in springs and the destructive power of flash floods. Agroforestry in action needs to link the plot- landscape- and policy interactions between forest and agriculture, with farmer benefits and societal gains, when compared with the current situation.



In November 2021 a flashflood on the slopes of Mount Arjuno killed seven people and destroyed ninety houses in the upper reaches of the Brantas river basin on densely populated Java (Indonesia). Expansion of open-field agriculture (especially vegetable crops), dry-season fires removing soil-covering vegetation and litter, and log-jams where partially burned wood temporarily blocked river channels, together with heavy rainfall after a dry period were jointly responsible for the human+natural disaster that unfolded. Reducing the probability of similar events in future called for a response that involves land cover change and farmer land use rights conditional on improving soil health and better coordination between various government agencies. Can (new forms of) agroforestry contribute to the solutions needed?

The tropical agroforestry research group in Malang was asked to help in te planning and baselines for landscape-scale restoration and carbon storage plans, supported by private-sector carbon finance, and the state-owned forest enterprise. We measured carbon stocks, above- and belowground in the full range of existing land use types: (1) AF in a protected area, (2) Pine-production Forest (HP), (3) multistrata-AF, (4) simple-AF, (5) Tangerine orchard, (6) monocropping-(vegetable) systems. Beyond litter layer and soil carbon stocks in the top 30 cm of soil (matching the IPCC guidelines), we measured soil microbial biomass carbon (MBC) as a soil health indicator.

Results show that Agroforestry in protected areas has the largest total C stock (231 Mg ha^{-1}) where 50% are belowground (roots and soil organic-C), while Multistrata- and simple-AF had 147 – 188 Mg C ha^{-1}, and a 35-year old pine production forests had 162 Mg C ha^{-1}. In areas affected by flash floods microbial biomass carbon (MBC) declined by 40% (from 29.4 to 18.5 μg g^{-1})

A higher standing litter layer was associated ($r = 0.59$) with increased MBC, with indications that both high-quality of litter (high N supply) and low-quality litter (long-lasting soil protection) are needed for a healthy soil and its hydrological functions.

Keywords: Agroforestry, Land use change, Carbon emissions, Volcanic soils

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CURRICULUM VITAE

KRIRK MEEMUNGKIT

Chairman of the Board of Thailand Tree Bank
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Education: Ph.D - Central Luzon State University (CLSU), Philippines

Master's degree - Central Luzon State University (CLSU), Philippines

Bachelor's Degree - 1980, Srinakharinwirot University- Bangsaen Campus, Thailand

Fields of Interest:

An agriculturist, and retired professor, who considers agriculture the most important profession in Thailand and the world.

An agriculturist from Srakaew province, Thailand, who chose to afforest in order to return 'life' to the community.

Work Experience:

Chairman of the Board of Thailand Tree Bank.

Special Instructor at various universities, both public and private.

Assistant Director of Sriracha Technology, Chon Buri, Thailand

Assistant Principal at Dara Samut School, Sriracha, Chon Buri, Thailand

Teacher at Santhiparb School, Chachoengsao, Thailand.

Dr. Krirk Meemungkit

Chairman of the Board of Thailand Tree Bank

Part I: Abstracts

Abstracts of Oral Presentation

Theme A:
Potentials of Agroforestry for Ensuring Food Security

Challenges and Strategies for Preserving Raised-bed Farming: A Traditional Agroforestry System in Nonthaburi Province, Thailand

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Abstract

Raised-bed farming (Suan Yokrong) is a traditional agroforestry system practiced in Thailand's central region, especially Nonthaburi Province, near the Chao Phraya River mouth. Seasonal flooding necessitates elevated planting beds and a network of canals for irrigation, and this system features a diverse mix of crops, focusing on multi-story fruit trees. Historically, Raised-bed farming was once a primary livelihood in the region, with renowned fruits like the durian: Kan-yow variety gaining widespread recognition and commanding high market value.

Managing these farms requires expertise in water level control, understanding plant interactions, and fostering community cohesion among farmers. Raised-bed farming has become an integral part of Nonthaburi's identity, preserving green spaces, a source of food security, and generating income for local communities.

However, raised-bed farming in Nonthaburi faces an existential crisis. Urban expansion has driven up land prices, leading to land sales. Uninformed development policies and a lack of understanding of the area's unique ecosystem and social context have further exacerbated the situation. Climate change, disrupting seasonal patterns and water availability, has compounded these challenges. Additionally, the lack of intergenerational among younger generations in inheriting the family's raised-bed farming tradition has contributed to the decline of this practice.

Adapting to these challenges is crucial for the preservation of raised-bed farming. Strategies include incorporating raised-bed farming areas and traditional communities into urban planning, designating raised-bed farms as urban green spaces, reviving and transmitting knowledge, fostering government and local support, and raising awareness among younger generations. Farmers' groups are encouraged to adapt farming practices to changing environmental and socioeconomic conditions. By implementing these strategies, raised-bed farming can continue to thrive as a unique cultural heritage, a source of sustainable livelihoods, and a contributor to Thailand's sub-urban agricultural biodiversity.

Keywords: Multi-story crops, Nonthaburi province, Raised-bed farming, Traditional agroforestry

A1

Correlation of Community Characteristics to Vegetation Type Preference in Agroforestry Systems in Protected Forests and Community Forests

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Abstract

Government laws on protected forests and community forests have an impact on the forest management and utilization through the agroforestry system. Local community characteristics and preferences for plant species selection in agroforestry systems are crucial to be studied in supporting climate change adaptation. A lot of study has been conducted on the adaptability of kind of plant to soil conditions or planting patterns. The purpose of this study is to analyze the correlation of local community characteristics to preferences in the selection of vegetation types in agroforestry in protected and community forests. A total of 30 members of the Karya Bakti forest farming group participated as research subjects. Another analysis for determining the dominance of plant types in agroforestry systems in protected and community forests based on data from 4 plots each. All community respondents manage community forests as owners and in state forests as members of the social forestry (SF). According to the results, community variables namely age, gender, income level, and land ownership status are correlated with preferences for selecting plant agroforestry vegetation. Young community choose vegetation forms with strong economic value, such as Multipurpose Tree Species (MPTs), but older community prefer vegetation kinds with great cultural value. Communities with high income and land ownership status choose plants with long-term and high economic value. This aims to improve their economic level. In the field, dominance value of MPTs plants in community forests, such as bananas, coffee, and avocados, is higher than in protected forests., This is understandable given the considerable economic worth of this variety, and people are free to plant any type in the community forest. Planting other than trees prohibited by laws in protected forests, woody plant species have greater dominance in these forests.

Keywords: Agroforestry, Community characteristics, Community forests, Important value index, Protected forests

A2

Community-Based Bamboo Production for Sustainable Livelihood and Environmental Protection

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Abstract

Bamboo is a valuable material that is being used as a substitute for wood. It expresses the purpose, safety, and welfare of human society, as well as the health of the environment. Employing the descriptive method of research, this study assessed the community-based bamboo production project in Ansiray, Ilin, San Jose, Occidental Mindoro. Interviews with the members of Ansiray Tree Planters Development Association who were bamboo growers and business owners through home visits, group discussions, and comprehensive research to collect more reliable information on how they intercrop bamboos to trees and fruit trees planted in their land. The identified problems and lessons learned in the previous years in their plantation up to marketing bamboo products led to the enthusiasm of the community through the association to develop their bamboo production. The respondents attended at least one of the four capacity-building activities during project implementation and gave an excellent overall rating to trainings. To test the marketability, the association may participate in more kinds of trade fairs, not only within the municipality that may lead to an increase in market linkages. Strengthening the capacity of the association to document or record data on harvesting, production, and marketing may also be considered.

Keywords: Bamboo production, Capacity-building, Community-based, Intercrop, Market linkages

A3

Do the Farming Futures Desired by Upland Farmers Match the Aims of External Stakeholders in Southeast Asia?

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Abstract

Despite the important role of farming communities in achieving the goals of sustainable land use and management for food security in Southeast Asian upland watersheds, understanding farmers' aspirations in relation to these goals has received little attentions. Understanding farmers' aspirations for well-being will provide an opportunity to achieve land use and food security by supporting them to invest their hard work and assets in activities that meet their aspirations as well as goals of external stakeholders.

In this paper, the concept of aspirations for well-being is explored in the Cabulig watershed, southern Philippines to determine its relevance to the issue of changing farmers' land use and its implication to food security. It uses a mixed method approach where narrative-based data from key informant interviews and farmer group discussions, supplemented by household surveys, were used to elicit preferences. Cognitive mapping was used to represent the factors influencing farmers' desired land use and crop aspirations.

There are two broad types of farmers emerged on analysis of their aspirations: 'prosperous' and 'survivalist'. Most farmers fall into the survivalist category and express a preference for agricultural crops, which reflects their reliance upon household consumption and short-term income. There is a disconnect between farmers and external stakeholders on their land use and crop preference. Decision-makers and researcher key informants are supportive of the farmers' crop preferences but not their preferred agriculture-based land use; external stakeholders would prefer farmers to adopt agroforestry/tree-based systems. Farmers preference in part reflects the current extension activities in the watershed, which are focused on changing crops and not the systems. Extension for agroforestry/tree-based system farming systems is limited and if the government wants to shift farmers agroforestry/tree-based systems, this is a clear gap to address. Geographic location (downstream) as an indicator of their vulnerability to extreme events also influences preferences around tree crops.

Reconciling this land use and crop preferences between farmers and external stakeholders is crucial to ensure food security as well as understanding and responding to the differing aspirations and well-being of the survivalist and prosperous farmers. We argue that understanding farmers' decision-making behavior is of key importance not just for farmers themselves, but also for the government and policymakers to have a more holistic and responsive views in designing and implementing land use programs in upland watersheds. Ignoring how farmers form their preferences and the extent of any mismatch with the priorities of external stakeholders may reduce the likelihood of successful implementation of land use and watershed management interventions for food security.

Keywords: Aspirations, Land use and crop preferences, Prosperous farmers, Stakeholders, Survivalist farmers

A4

Perceived Impacts of Agroforestry Adoption on Livelihood, Income, Farmland Condition, and Equity (LIFE) Among Members of the Liliw Upland Farmers Marketing Cooperative (LUFAMCO) in Liliw, Laguna

Cyrene Jira J. Carbonell[1*] and Lorena L. Sabino[2]

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[2]Asst. Professor, Social Forestry and Forest Governance, College of Forestry and Natural Resources, University of the Philippines Los Baños, Philippines
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Abstract

This study analyzed the perceived impacts of agroforestry (AF) adoption on livelihood, income, farmland condition, and equity (LIFE) among members of the Liliw Upland Farmers Marketing Cooperative (LUFaMCo), a people's organization with 23 years of involvement in Community Based Forest Management (CBFM). The study's objectives included examining the sociodemographic and economic profiles of farmers, typologies of AF systems adopted, perceived impacts on LIFE, and the relationship between these profiles and impacts on LIFE. A mixed methods approach, including full enumeration through survey questionnaires, key informant interviews (KII), focus group discussion (FGD), and farm visits, was conducted from April to May 2024. Findings revealed that out of the 52 respondents, the majority (32.7%) were middle-aged (41 to 50 years old) and in their productive stage. Most husbands (78.3%) earn less than ₱18,200 per month, while most wives (65.9%) earn less than ₱9,100 per month. The primary AF systems adopted were agrisilviculture (88.5%) and agrisilvopastoral (11.5%), particularly vegetable-based intercropping, boundary planting, and multi-storey systems. Results showed that AF adoption generated farming job opportunities and additional income sources for family and community members, helping farmers sustain and secure their daily needs compared to monocropping. Additionally, it improved farmland conditions by creating mini-forests and reducing soil erosion. AF adoption also promoted social cohesion and participation, with each member having equal access to resources and decision-making processes in farm management. Statistical analysis revealed significant correlations between farmers' productive age and impacts on LIFE, highlighting that farmers have more energy in implementing and managing their AF farms. The study recommends providing more livelihood and agroforestry training opportunities, addressing the need for age-specific programs for more effective AF adoption and benefits. Proper AF farm management is also needed, along with increased market linkages and access, and establishment of value-added processing of AF products to diversify and enhance their income.

Keywords: Agroforestry, Agroforestry adoption, CBFM, Equity, Farmland condition, Income, LIFE, Livelihood, LUFAMCO, Perceived impacts

A5

How Resilient are the Agroforestry Farmers in the Community- Based Forest Management Areas in CALABARZON, Philippines?

Leila D. Landicho[1*], Maria Theresa Nemesis P. Ocampo[2], Rowena Esperanza D. Cabahug[2], Roberto G. Visco[3], Venice Jiezzelle C. Nesperos[1], Ma. Armie Janica R. Pleto[2], Mary Anne G. Abadillos[2], Russel Son C. Canilan[2], Arnold Karl A. Castillo[2] and Christine Joy B. Manalo[1]

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Abstract

The Community-Based Forest Management (CBFM) Program was institutionalized to help promote sustainable forest management in the Philippines, putting emphasis on the role of the local communities. The beneficiaries of this program are classified as smallholder farmers who cultivate in marginal forest areas. Their socioeconomic and environmental conditions make them vulnerable to climate and non-climate stressors. This article highlights the resiliency level of the selected CBFM beneficiaries in CALABARZON/Region IVA by measuring their social, natural, financial and human capitals. Data were gathered using farm household survey, focus group discussion, and characterization of their agroforestry farms. Results revealed that the CBFM beneficiaries in CALABARZON had low to moderate levels of resilience with index ranging from 0.27-0.34. Specifically, the CBFM site in Rosario, Batangas exhibited a high level of financial capital (0.28). Meanwhile, the CBFM site in Liliw, Laguna had the highest score in terms of natural capital (0.09). It is important to note that the CBFM site in Magallanes, Cavite had the lowest accumulation of human capital (0.05) and social capital (0.003). Results suggest the need for social, technology and development interventions that would promote a balanced and holistic way of improving the assets and capitals of the four CBFM sites. Appropriate agroforestry systems with a good mix of crop, tree and other perennial, including livestock components, should be co-designed with the farmers to maximize the full economic and ecological benefits of agroforestry systems in CBFM areas. Furthermore, enhancing the capacities of the people's organizations and the individual CBFM beneficiaries is essential to ensure the sustainability of their agroforestry and other livelihood activities

Keywords: Agroforestry, Analytic hierarchy process, Capitals, Resilience, Smallholder farmers

A6

People's Participation in Community Forest Management, Northern Thailand

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Abstract

The objective of this research was to study the process of community participation in community forest management, utilization of community forest and public opinion about community forest, Northern Thailand. The data were collected by using interview from 110 samples. The collected data were analyzed by using descriptive statistics such as frequency, percentage, mean, and standard deviation. The result shown they gained benefits indirectly from community forest at a high level (mean = 3.56) whereas directly gained benefits from community forest at a low level (mean = 2.16). Their positive opinion on community forest was at a high level (mean = 3.51) whereas negative opinion on community forest was at a low level (mean = 1.83). The participation in community forest management was at a high level (mean = 3.36). the participation in planning and processing was at a high level (mean = 3.41), the participation in operation was at a high level (mean = 3.45), the participation in gaining benefits from the forest was at a moderate level (mean = 3.24), and the participation in evaluation was also at a high level (mean = 3.33). The factors related to participation behavior were indirect utilization and negative opinions about community forests.

Keywords: Community forest, Management, Participation

Assessment of Economic Value and Design of Agricultural Crop and Perennial Plant Cultivation in the Agroforestry System at Ban Boonchaem, Namlao Subdistrict, Rong Kwang District, Phrae Province

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Abstract

Agroforestry systems provide many ecosystem services that generate significant economic value to society. The objective of this study was to estimate the economic value of farming in various crops. The study was conducted at Ban Boonchaem, Namlao Subdistrict, Rong Kwang District, Phrae Province. The plants in the study area consisted of teak (*Tectona grandis* L.f), maize (*Zea mays* L.), banana (*Musa sapientum* L.), lime (*Citrus aurantifolia* (Christm.) Swingle), tomato (*Lycopersicon esculentum* Mill) and Chinese cabbage (*Brassica chinensis* (L.) Jusl.). Cost and benefit of each crop were then analyzed. Agroforestry design was then applied based on economic value. The decision criterions including net present value (NPV), benefits-cost ratio (BCR) and internal rate of return (IRR) were calculated. The results found that the economic value per rai for ten years had net present value (NPV), benefits-cost ratio (BCR) and internal rate of return (IRR) at 1,457,210.39 baht, 2.66 and 30.00%, respectively. The economic value per rai for twenty-five years had net present value (NPV), benefits-cost ratio (BCR) and internal rate of return (IRR) at 3,784,303.04 baht, 2.48 and 19.75%, respectively. Principally, net present value (NPV), benefits-cost ratio (BCR) and internal rate of return (IRR) are greater than 0.0 baht, 1.0 and 8%, respectively. Therefore, this project can be concluded that total return was greater than associated cost.

Keywords: Density, Specie, Weed control, Weed diversity

Environmental, Social, and Economic Awareness of Farmers to Tibig *(Ficus nota)* in Selected Barangays of San Jose, Occidental Mindoro

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Abstract

The study assessed the social, economic and environmental level of awareness of farmers in the utilization of Tibig *(Ficus nota)*, a native species of tree in the Philippines. Level of awareness of 95 farmer respondents on the social benefits of Tibig resulted that they are slightly aware of the benefits of Tibig as medicine, housing materials and for recreation. On the other hand, they are not fully aware that the tree can be used in food processing and medicine for animals. The level of awareness on the environmental benefits of Tibig, the respondents are aware of its use in water conservation, controlling soil erosion, as source of organic fertilizer and pesticide. They are also aware that Tibig serves as habitat for birds and other wildlife. On the contrary, respondents are not aware that Tibig can be used as planting material to rehabilitate degraded land. Moreover, the respondents are slightly aware of the economic benefits of Tibig specifically, as source of income. They are not aware that wine,vinegar, jam, can be made out of fruit of Tibig. However, they are aware that this can be source of animal feed and fuel wood. The Key Informant Interview (KII) and Focus Group Discussion (FGD) conducted together with the community leaders and selected respondents revealed the other utilization practices of the residents. The results of the study might serve as reference in conducting similar studies with purpose of further innovation or modification that will come up with a new product and the extension activities to communicate technologies to the farmers.

Keywords: *Ficus nota*, Level of awareness, Utilization practices

A9

Theme B:
Recent Developments in Agroforestry Education and Role of Agroforestry in Climate Change Mitigation and Adaptation

Half Century of Social Forestry in Asia: A Review and Lessons from Sumatra Province

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Abstract

Over the past half-century, social forestry has emerged as a critical approach to natural resource management and sustainable development in Asia, spanning countries as diverse as Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Nepal, the Philippines, Thailand, and Vietnam. This review examines the history, evolution, and current state of social forestry in these 12 key Asian countries, drawing on academic sources. The motivations behind governments' push for social forestry in the region have been complex, encompassing a mix of discourses and rationales, including the desire to alleviate fiscal burdens on the state, improve the management of natural resources through the application of local knowledge, and address the perceived danger of forest resource scarcity and its impact on rural welfare. However, the development of social forestry in these countries has been uneven, reflecting diverse social, political, and economic contexts. While some countries have made significant progress in empowering local communities and integrating their interests into forest governance, in other cases social forestry remains a top-down process that has failed to deliver on promises of equitable and sustainable resource management. This paper synthesizes key lessons and highlights the persistent challenges and emerging opportunities for strengthening social forestry across the region.

Keywords: Asia, Community-based forest management, Environmental justice, Forest governance, Social forestry

B1

Promoting Organic Agriculture Through *Edutourism*: Experience of the UPLB Organic Agriculture Research, Development, and Extension Center (OARDEC)

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Abstract

The agricultural sector faces critical challenges, including ensuring environmental sustainability and the need for effective education on organic farming practices. To address these issues, the University of the Philippines Los Baños implemented the project, Promoting Agroforest Stewardship & Ecological Observations (PASEO), which integrates the “Establishment of Learning Site for Organic Agriculture" project at the Organic Agriculture Research, Development, and Extension Center (OARDEC). This year-long initiative integrates organic agriculture with educational tourism (*edutourism*) and hands-on learning experiences. The project involved setting up seven (7) comprehensive learning modules: an organic vegetable production area, a medicinal garden, an aromatic garden, a section on organic soil amendments, an agroforestry demonstration area, a kids' garden, and a module showcasing the integration of organic crop-animal systems.

The project aimed to showcase organic agriculture technologies, enhance capacity building among stakeholders, and create a platform for sharing best practices and lessons learned in organic farming. Ultimately, the goal was to foster a deeper understanding and adoption of sustainable agricultural practices, contributing to environmental conservation and improved agricultural productivity. Throughout the project, OARDEC welcomed more than 1,400 visitors and harvested more than 300 kilograms of various organic vegetable fresh produce. The project organized an Organic Agriculture Camp for Grade 11 students and their teachers as a culminating activity. This paper highlights the innovative approach of the Learning Site for Organic Agriculture (LSOA) project in promoting organic agriculture education. It explores the project's potential impact on various stakeholders and sustainable food systems.

Keywords: Agroforestry, Capacity-building, Edutourism, Learning site, Organic agriculture

B2

Enhancing Multifunctionality in Cacao Agroforestry: The Role of Climate-Specific Tree Selection and Root Development

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Abstract

The effectiveness of shade trees in climate-resilient cacao systems is largely determined by appropriate tree-site matching, requiring complex, context-specific decisions that can present significant tradeoffs. This study evaluates the benefits and drawbacks of various cacao-based land use systems on multifunctionality and economic performance across different scenarios.

To assess the multifunctionality and economic performance of five cacao-based systems (cacao monoculture, cacao + annual crops, cacao + fruit trees, cacao + fast-growing trees, and cacao + slow-growing trees) under varying conditions, we employed the process-based Water, Nutrient, and Light Capture in Agroforestry Systems (WaNuLCAS) model. These systems were analyzed across three climate regimes (tropical rainforest, monsoon, and savannah), two soil textures, and two sources of cacao root density data (West Africa and Indonesia). Performance was measured using the Land Equivalent Ratio for Production (LERP), multifunctionality (LERM), Net Present Value (NPV), Return to Labour (RtL), and Benefit-Cost Ratio (BCR).

Cacao production per tree, influenced by intercrops, varied with water-limited days. Systems with high root density had higher LERP values (1.15) than those with lower density (0.95), especially in savanna climates. Cacao + annual crops had the highest LERP (1.13), with soil texture not significantly affecting LERP. Tree-based agroforestry systems had higher time-averaged carbon stocks than monocultures or systems with annual crops, though their impacts on other environmental performance aspects were modest, with minor variations in LERM. Economic performance indicators varied: cacao + annual crops and cacao + fruit trees had the highest NPV, cacao + fruit trees had the highest BCR, and cacao + fruit trees had the highest RtL, followed by cacao + slow-growing trees.

This study highlights the importance of robust root development in cacao-based agroforestry systems. High root density enhances the benefits of intercropping, especially in drier climates where lower root length densities (as seen in West Africa) may reduce these advantages. Effective tree-site matching and root development are crucial for optimizing the multifunctionality and economic performance of cacao agroforestry systems

Keywords: Agroforestry, Environmental services, Land equivalent ratio, Net present value, Root density, *Theobroma cacao*

B3

Agroforestry Farmers Intentions, Perceived Impact of Climate Change and Adaptation Strategies in Southern Java, Indonesia

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Abstract

While agroforestry systems are promoted as a climate mitigation-adaptation strategy, an indication of climate change poses challenges to agroforestry management. This paper investigates climate change perception and adaptation to agroforestry systems. The concrete research is to understand agroforestry farmers' intentions, perceived climate change impacts, and adaptation strategies. Finally, the adaptation strategies were classified as active or passive adaptation. The research was conducted in Southern Java Island, using households (n=145) and key informant interviews (n=8). The data were analyzed using descriptive, spearman rank correlation, and economic parameters analysis. Monetary-related considerations were the primary intention in managing agroforestry systems (sig<0.005). Farmers perceived climate change impacts i.e., seasonal changes, landslides, increase in air temperature, and reduced water springs, which were correlated to secondary data. Perceived climate change impacts to agroforestry systems i.e., pest-disease infestation and reduced productivity. In the agroforestry systems, coffee and cocoa were the most climate-sensitive compared to other commodities. The Net Present Value (NPV) and Equal Annual Equivalent (EAE) of the systems decreased by less than 10% due to climate impacts. Farmers predominantly predict the occurrence of climate change impacts using local knowledge and bio-indicators, while also combining with the climate news or announcement. As an adaptation strategy in agroforestry systems, farmers increase the intensity of some regular treatments if farmer experience the indication of climate change impacts. Such treatments i.e., pest control, branch pruning, manual mulching, plant watering, ash fertilization, and manure fertilization. Thus, farmers' adaptation strategies are considered active adaptation strategies.

Keywords: Climate adaptation, Climate smart agroforestry, Farmers adaptation, Nature-based solution, Smart agroforestry

B4

Dynamics of Energy Forest Plantation Development in Jambi Province

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Abstract

The Ministry of Environment and Forestry has targeted the development of Energy Forest Plantations through Industrial Forest Plantation companies as much as 1.29 million hectares to meet the needs of wood biomass. In the General Plan for the fulfillment of electricity (RUPTL) document, the State Electricity Company (PLN) is committed to utilizing wood biomass to be burned together with coal (co-firing) up to a portion of 10% in 52 PLTUs in Indonesia and then claimed as clean energy. This research aims to find out the dynamics of Energy Plantation Forest development in Jambi Province. The research data was collected through several data collection instruments such as field observations, interviews with questionnaires, in-depth interviews, Focus Group Discussions (FGDs) and literature studies. The analysis in this research is descriptive by describing systematically, factually and accurately about the facts, characteristics and relationships between the phenomena investigated. The results of this study indicate that the development of energy plantation forests in Jambi province has encountered various challenges and dynamics in its implementation. Some aspects of the cause include market orientation targeted by business holders more on the fulfillment of export raw materials than the domestic market because it involves price certainty and supply chain guarantees that are unstable and tend to be unfavorable to entrepreneurs, on the other hand the low level of community literacy and government commitment in the framework of HTE development contributed to the slow development of HTE development in Jambi province. Therefore, comprehensive and systematic efforts are needed in the form of strengthening governance and mainstreaming HTE at various levels of actors to optimize the development of HTE in Jambi province.

Keywords: Energy, Forest, Governance

Carbon Sequestration Potential and Leaf Litter Decomposition of Different Forest Stands at Caraga State University, Ampayon, Butuan City

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Abstract

This study investigated the tree species composition, aboveground biomass, carbon storage, carbon sequestration potential and leaf litter decomposition rates within two areas at Caraga State University (CSU) Main Campus, Ampayon, Butuan City, Agusan del Norte: the CSU-Eco Park and the Clonal Nursery Area. In this study, CSU-Eco Park exhibited higher species diversity with 303 trees and had a higher abundance of Kalumpit *(Terminalia macrocarpa)* (79 trees) because the site is a plantation forest. In contrast, the Clonal Nursery Area exhibited lower species diversity with 212 trees, and Bagras *(Eucalyptus deglupta)* being the most abundant (87 trees) since the area is a plantation site as well with a smaller area. Aboveground biomass, carbon storage, and carbon sequestration potential were estimated. The CSU-Eco Park had a higher total aboveground biomass of 433,692.51 Kg, carbon storage of 216,846.25 Kg C and carbon sequestration potential of 795,825.75 Kg C compared to the Clonal Nursery Area having 45,293.86 Kg, 22,646.93 Kg C and 83,114.22 Kg C, respectively. Together, these areas captured an estimated 878.94 tons of carbon dioxide from the atmosphere. Leaf litter decomposition rates were determined using ANOVA (Analysis of Variance), with treatments being used showing significant difference to each plot. The fastest decomposition rate (0.812 g/week) was observed in plot number 5 of the Clonal Nursery Area. The slowest rate (0.484 g/week) was found in plot number 1 of the control area (Organic Agricultural Training Center). Overall, the Clonal Nursery Area exhibited a decomposition rate of 0.655 g/week, while the CSU-Eco Park had 0.633 g/week, in which the different composition of leaf litters affects the decomposition rates.

Keywords: Biomass, Carbon sequestration, Decomposition rate, Leaf litters, Litter bag experiment

B6

Comparison of Overall Carbon Storage between Teak Monoculture and Mixed Plantation of Teak and Eucalyptus in Maesai Village, Phrae Province, Thailand

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Abstract

Carbon storage offers a number of benefits for tackling climate change and global warming. The study carbon storage of teak (*Tecona grandis* Linn.f.) was conducted in Maesai village Phrae Province. The project was aimed to evaluate the effect of different plantations on carbon storage. The assessment of the carbon storage of teak monoculture plantation and mixed plantation of teak and eucalyptus were compared. Sampling plots, 40×40 m, were employed in different plantations. Biomass, carbon sequestration, carbon storage and oxygen emission were analyzed. Diameter at breast height (DBH) and height of tree were measured and used for biomass calculation. Results demonstrated that biomass, carbon sequestration, carbon storage and oxygen emission of teak monoculture plantation were 57.80 tons/ha, 99.10 tons carbon/ha, 27.02 tons carbon/ha, and 71.89 tons oxygen/ha, respectively, while, mixed plantation of teak and eucalyptus were 101.19 tons/ha, 177.37 tons carbon/ha, 47.55 tons carbon/ha, and 126.50 tons oxygen/ha, respectively. This study can be concluded that the mixed plantation of teak and eucalyptus had higher efficiency in overall carbon storage thereby contributing to achieving the sustainable development.

Keywords: Biomass, Carbon sequestration, Carbon storage, Monoculture, Teak

B7

Resilience-Building of Corn Upland Farming Communities in The Province of Isabela, Philippines through Agroforestry

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Abstract

Corn is next to rice as the most important crop in the Philippines. Monoculture farms and the widespread use of hybrid varieties, chemical fertilizers, and pesticides are characteristics of a greater proportion of farms nowadays. Smallholder marginal upland corn farmers in the Philippine are amongst the most vulnerable group to farming shocks such as climate change, natural calamities and recently Covid-19 pandemic. This study highlights the results of an assessment on the level of resiliency of three selected upland corn farming communities in Isabela and recommendations towards community resiliency building. The resiliency level of the farming communities was evaluated through Analytical Hierarchy Process (AHP). The three upland farming communities are mainly engaged in the production of corn through monocropping system and had low levels of resilience, calling for support to strengthen their resilience. Farmer organizations need to be consolidated and capacitated to form collaborations and linkages with various organizations. To establish a shock-resistant upland farming community, it is essential to redesign the production system by diversifying the monocropping production areas in Isabela's upland farming communities. Enhancing the knowledge of smallholder farmers and the technical staff of the local government units on agroforestry and related technologies is crucial. Agroforestry is an effective, science-based response approach and measure for enhancing farming resilience and sustainable resource management. This study express confidence that adoption of appropriate agroforestry systems in the uplands of Isabela will provide an opportunity to build resilience of upland smallholder farmers and the farming community as whole. It is therefore recommended to institute local policies to mainstream agroforestry programs and projects in local government units.

Keywords: Agroforestry, Corn monocropping, Resiliency, Upland farming communities

B8

Theme C:
Ecological Services of Agroforestry

Carbon Storage Potential of Forest Buffer Zones and Banana Plantations in Southern Philippines

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Abstract

Agroecosystems are known to cause high depletion of terrestrial carbon pools that often result in high carbon deficits in the form of net emission. If properly managed, including maintaining forest buffer areas to form agroforest ecosystems, they are potentially an important sink or storage of carbon. This study quantified the carbon stocks of forest buffer zones and banana plantations in Mindanao, Philippines to better understand their contributions to carbon sequestration. Results revealed that the total mean carbon stocks in the biomass of natural forest buffers ranged from 60.3 ± 12.2 Mg C ha-1 to 206.4 ± 47.2 Mg C ha-1, which is comparable to undisturbed forest ecosystems in the country. In contrast, banana plantations had lower C stock (cf. 17.2 ± 1.6 – 56.9 ± 3.1 Mg C ha-1) compared to forest buffer zones despite the absence of biomass burning or removal of plant residues. However, when considering their joint impact as an agroforestry system, including forest buffer zones within banana plantations, the combined effect significantly increased carbon storage of the area. This study highlights the importance of proper and active management of agricultural landscapes, particularly through the integration of woody perennials, to enhance their contribution to carbon sequestration.

Keywords: Agroforestry systems, Banana plantations, Carbon sequestration, Forest buffer zones

Soil Runoff and Erosion Control Potential of Agroforestry

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Abstract

Around 50 percent or almost 15 million hectares of the Philippines total land area is classified as upland. With increasing population, agriculture has expanded into these marginal and environmentally sensitive areas. Due to the country's steep and mountainous terrain, the Philippines' soils are prone to erosion, which is a major source of land degradation. Moreover, adoption of unsustainable production practices in upland areas in the country exacerbates the declining productivity of these lands. Agroforestry systems have been introduced to reduce the destructive “kaingin” or slash-and-burn farming practice in the Philippines. This study was conducted to assess the potential of Sloping Agricultural Land Technology (SALT 1) and Small Agro-Fruit Livelihood Technology (SALT 4) to control or minimize soil erosion for soil conservation management. Runoff plots were installed in each agroforestry system showcased in the Learning Laboratory for Agroforestry, College of Forestry and Natural Resources, University of the Philippines Los Baños, Philippines from July 2019 to December 2020. A total of 311 rain events occurred during the study period with 76 of the said rainfall events producing soil runoffs. The mean soil loss in SALT 1 and SALT 4 was 288.55 and 243.84 kg ha^{-1} yr^{-1} respectively. Soil loss in both agroforestry systems were considered way below the tolerable limit of 10-12 t ha^{-1} yr^{-1}. The tree component in SALT 4 creates a good canopy to help reduce the impact of raindrops to soil erosion. On the other hand, SALT 1 has hedgerows which reduces runoff and soil loss. Both SALT 1 and SALT 4 agroforestry systems are effective in reducing soil erosion in sloping areas in the country.

Keywords: Agroforestry, Erosion, Sloping areas, Soil runoff

C2

Game-Based Analysis of Tree Diversity and Land-use Choices in Agroforestry Systems

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Abstract

Functional diversity is frequently used to manage the trade-offs between economic and ecological aspects of land-use sustainability in uncertain climates and markets. Farmers utilise their expertise, existing (partial) data, and social networks to make decisions on their farms. Instead of enforcing standard economic or ecological justifications for farmer decisions, a participatory method using a simulation game might facilitate the co-creation of knowledge. Observing the way farmers react to technical information and the game's procedures allows academics to comprehend the decisions made by farmers. We employed a recently developed game called Farmer Options, Risks in Complex Ecological-Social system-FORCES to examine diversity management at the plot level. This study was conducted in three different settings in East Java, Indonesia. We examined the decisions made by farmers in the game, the connections between the game and real-life farming practices, and the farmers' reactions to socio-ecological factors such as unpredictable rainfall, changing policies, and fluctuating market prices. We conducted a total of fifty-five separate gaming sessions at the plot level with farmers from different age groups, genders, and types of farms (tree-based and annual crops) across the three settings. The game demonstrated a clear preference between gender when choosing trees and plants species. When selecting trees, individual farmers aim to achieve a synergy between economic and ecological performance. Regarding land-use decisions, older farmers often favoured a tree-based system since it included less risk owing to limited resources. In contrast, younger farmers predominantly opted for annual food crops, despite the increased risk involved, to potentially achieve a better revenue. We observed differences in the degree of consistency in decision-making across different locations, which might be attributed to socio-economic, cultural, and topographical factors. Moreover, agroforest farmers had greater flexibility in their decision-making process as they had access to a larger range of possibilities and combinations. In contrast, annual-crop farmers had fewer choices accessible to them. Individual decision-making is influenced by a combination of social, cultural, and ecological aspects, in addition to economic considerations. It is important to consider the local farmers perspective when formulating agricultural (or forestry) policy, as these ideas cannot be generally applied.

Keywords: Agroforestry, External pressures, Management choices, Sustainability, Watersheds

C3

Diversity and Abundance of Arthropod at an Agroforestry Demonstration Farm in Baybay City, Leyte, Philippines

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Abstract

Agroforestry is a system that combines agricultural crops and forestry products within a piece of land to enhance their productivity, economic, and biodiversity. This study was conducted in the Agroforestry Demonstration Farm at Visayas State University Baybay City, Leyte, Philippines. Generally, the study aims to assess the abundance and diversity of arthropods found both outside and inside habitat of the agroforestry demonstration farm using two collection methods namely: yellow pan trap and sweep netting. Arthropod's diversity was analyzed using the following ecological indices the Shannon, Margalef, Evenness, and Sorenson similarity index fed in the excel program. The results of the study show a total of 1,444 arthropods belonging to nine (9) orders, 68 families, and 79 morphospecies were recorded. The overall percentage of arthropod was found highest in Diptera (44%), followed by Hymenoptera (29%), Orthoptera (8%), Coleoptera and Lepidoptera which have a similar abundance (6%) whereas as the least abundant orders were observed from the Hemiptera (2%) and Blattodea (1%) which were less than one percent in the agroforestry demonstration farm. Inside the farm showed high species abundance (821) individual than outside only (623) individuals but less in terms of diversity indices. Sorensen similarity index in both habitats showed 68% similarity. Diversity of arthropods both sides was very high more than (H=3.337), however, a little bit lower inside than outside the farm. This indicates that the outside habitat has the potential to support arthropod diversity and act as effective refugia for some arthropods from the inside. The lesser abundance of arthropods inside the agroforestry farm is probably due to the effect of disturbance caused by management. Lastly, the total abundance of trophic guilds collected in both habitats revealed that predators contributed to the highest abundance at around (48%) followed by herbivores at (16%), parasitoids at (20%), scavenger (15%), and the very least is phytophagous at only (1%).

Keywords: Evenness, Farm, Morphospecies, Similarity

C4

Influence Differences of Agroforestry Typology in State Forests and Community Forests on Stored Carbon Content

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Abstract

The decrease in the area of state forests and community forests can cause species extinction and have an impact on increasing the greenhouse gas (GHG) effect and will be influenced by an increase in carbon dioxide (CO2) content in the atmosphere. In Indonesia, the status of forests will affects to the type of management, thus will affect to forest ecological function and biodiversity levels, as well as stored carbon content. The aims of this study is to analyze the differences impact of agroforestry typology in state forests and community forests on the content of stored carbon. The number of observation plots in state forests and community forests amounted to 4 plots each. The vegetation analysis use vegetation diversity through the Important Value Index (IVI) and calculating stored carbon using an allometric formula. Based on the research results, the highest INP for vegetation types in the state forests was obtained, namely Coffea arabica at 62.45%, Leucaena leucocephala at 25.91%, Durio zibethinus at 23.34%, and Mangifera indica at 17.03%, while the highest INP value in community forests, namely Coffea arabica at 80.94%, Ceiba petandra at 42.54%, Musa Paradisiaca at 29.00%, and Vernonia amygdalina at 14.87%. In state and community forests, the vegetation type Coffea arabica has the highest IVI. However, the dominance of tree vegetation in state forests has a higher value than in community forests, therefore this condition affect the stored carbon content. Then the total carbon content stored in state forests is 134.12 tons/ha, while in community forests it is 88.81 tons/ha.

Keywords: Agroforestry, Carbon, Community forest, Important value index, State forest

C5

Optimizing Agroforestry-Based Social Forestry Management to Support Water Security and Other Ecosystem Services in Padang City, West Sumatra

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Abstract

The social forestry program is considered capable of balancing economic improvement and forest sustainability in Indonesia. However, land-use changes frequently occur, becoming one of the causes of changes in ecosystem services. In this study, we assess agroforestry-based land management models within the social forestry program and subsequently determine land management models to support ecosystem services, particularly water resilience. The assessment stage covers the period from 2013 to 2022. A combination of Soil and Water Assessment Tools (SWAT) and Dynamic Modeling is used to evaluate the water resilience index and its relationship to changes in land management. Using analysis results from SWAT modeling, the findings show that agroforestry-based land management within Social Forestry areas can maintain water availability and water regulation in disaster mitigation. Furthermore, detailed analysis indicates that ecosystem services related to water resilience can enhance food and energy security, thereby increasing *self-sufficiency levels* under normal and planned community forest conditions. This agroforestry-based land management model can be applied in other locations to evaluate and plan for improvements in water, food, and energy resilience holistically and locally.

Keywords: Agroforestry, Ecosystem services, Social forestry, SWAT, Water, Water security

C6

Agroforestry as a Win-Win Solution: Promoting Biodiversity, Carbon Storage, and Sustainable Livelihoods in Mankayan Watershed, Philippines

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Abstract

This study investigates the potential of agroforestry systems in Mankayan Watershed, Benguet, Philippines, to enhance diversity and carbon sequestration. Field data on plant diversity and carbon storage across different land uses were collected and analyzed. Results revealed that biodiversity in agroforestry systems using Shannon Diversity Index (H’ = 3.39) is higher than in pine forest (H’ = 2.68), grasslands (H’ = 2.45), and vegetation near built-up areas (H’ = 2.99). This high biodiversity in agroforestry systems indicates a resilient ecosystem capable of supporting various plant and animal species. Carbon data showed that the aboveground biomass density (AGB D) in the study area was 13.67 Mg/ha, with a carbon density of 6.83 MgC/ha. Agroforestry practices were found to significantly improve carbon sequestration compared to other land uses, as the integration of trees, agricultural crops, and other fruit tree species in agroforestry systems contributes to higher aboveground biomass and carbon storage, enhancing the overall carbon density of the area. These agroforestry systems not only promote biodiversity but also improve watershed health through soil stabilization, reduced erosion, and enhanced water infiltration. Additionally, agroforestry provides vital ecosystem services in the study area like food, timber, and non-timber products, supporting local livelihoods particularly the indigenous peoples of Mankayan. These findings highlight the significant potential of agroforestry for carbon sequestration, biodiversity enhancement, and watershed conservation in Mankayan. Implementing agroforestry fosters sustainable landscapes, achieving both environmental and socio-economic goals. This study encourages policymakers and land managers to adopt agroforestry as a key strategy for climate change mitigation and rural development.

Keywords: Agroforestry, Biodiversity, Conservation, Sustainability, Watershed

C7

Biodiversity and Carbon Storage Capacity of Different Agroforestry Systems in Sariaya, Quezon, Philippines

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Abstract

Agroforestry has emerged as an alternative land use to address the demand of the increasing population and the provision of environmental benefits and services. Climate change poses significant threats to human resilience affecting both livelihood and overall food security causing increased vulnerabilities especially to upland farmers. The objective of the study was to evaluate the farm diversity and the carbon storage capacity of the three (3) agroforestry farming system in Barangay Concepcion Banahaw, Sariaya, Quezon namely, Coconut-Based Multistory System (CBMS), Multilayered Tree Garden System (MTGS), and Live Trellis System (LTS). Species richness and abundance, Shannon diversity and evenness indices of plants were estimated from 39 plots distributed through probability sampling proportional to farm size of the three systems. Species importance value and carbon storage of the studied agroforestry farms were also evaluated. Results showed that agroforestry systems vary in terms of their species richness and abundance. MTGS recorded higher mean plant species compared to CBMS and LTS. MTGS (2.61) and CBMS (2.35) had significantly higher floral Shannon diversity index than LTS (1.79). For the species evenness LTS recorded the highest value of 0.74 followed by CBMS (0.63) and MTGS (0.57). The findings suggest that agroforestry farm ecosystems where woody perennials are major components like MTGS and CBMS have the potential to maintain biodiversity. In terms of biomass, the CBMS had the highest mean value of AGB (95.48 ton/ha) followed by MTGS (63.64 ton/ha) while LTS obtained the lowest AGB (59.55 ton/ha). The different agroforestry systems vary on their biomass according to their farm structures, species composition and age. The overall total carbon stock was significantly higher in CBMS (152.55 tC/ha) followed by MTGS (119.91 tC/ha) and LTS (109.12 tC/ha). Trees in agroforestry systems capture CO2 from the atmosphere and store it ascarbon in their biomass and in the soil. Agroforestry systems can sequester carbon over long periods, making agroforestry a valuable strategy for achieving carbon neutrality and meeting climate targets. Agroforestry promotes sustainable land use by enhancing productivity on existing agricultural lands, reducing land conversion and providing range of ecosystem services such as carbon sequestration.

Keywords: Agroforestry, Biodiversity, Carbon stock and climate change

C8

Agroforestry for Soil Health and its Effect on Litter Decomposition Rates: Case Study from the Education Forest (UB-Forest), Malang Regency, East Java, Indonesia

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Abstract

Agroforestry provides canopy cover and high litter input to maintain soil health and regulate soil processes, e.g. litter decomposition and mineralization. Objectives: (1) evaluate earthworms abundance and microbial biomass carbon (MBC) in three agroforestry (AF) systems, (2) evaluate decomposition rates of various litter qualities in the same LUS for objective 1.

The research was conducted in 2023 in the Brawijaya University Education Forest (UB Forest) Karangploso District, Malang Regency, East Java Province, Indonesia. Earthworm density was observed in 3 types of AF compared to monocropping systems, the samples were taken from 3 soil depths, while for MBC only taken from a layer of 0-10 cm. The litter decomposition rate was measured based on litter loss per observation time: 2, 4, 6 and 8 weeks after application. Litter types tested: (1) mix-Pine+Coffee (PK); (2) mix-Pine+Banana (PP); (3) mix-Pine+Avocado+Lemon+Vegetables (PALS); (4) Cabbage (KBS). Each litter sample was placed in 4 LUS (land use systems): (1) LUS-PK, (2) LUS-PP, (3) LUS-PALS. (4) LUS-KBS.

There were only 3 genera of earthworms were found (Pontoscolex, Pheretima, Amynthas). Litter input of different quality in AF system can maintain earthworm density and MBC concentration 2x greater than just one type of litter input; meantime those two biological parameters are widely used as indicators of soil health.

The decomposition rate of mix litter PALS placed in LUS-PP shows the fastest (k value = 0.030 with residence time, t50 = 17 weeks), while the lowest showed by a mix litter PP placed in LUSPALS (k value = 0.018, t50 = 28 weeks). The other litter types had an average k value = 0.024, t50 = 21 weeks. As take home message that maintaining diversity of litter inputs and providing a good cover to soil is critical parameters for maintaining environmental services of agroforestry to enhance its resilience to climate change.

Keywords: Earthworm density, Litter decomposition rate, Microbial Biomass Carbon (MBC), Pine-based agroforestry

C9

Plankton Composition and Abundance in Aquasilviculture System in Infanta, Quezon, Philippines

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Abstract

Aquasilviculture (AQS) or silvofishery is a type of coastal agroforestry system that integrates mangrove rehabilitation with raising of aquatic species in net-pens or canals. The study aimed to assess the plankton composition and abundance of the four AQS within a Community-based Forest Management (CBFM) area in Infanta, Quezon. Since plankton is an essential source of food for aquatic organisms and water quality is highly affected by them, it is crucial to know the composition and abundance of plankton for better management of AQS. Surface water sampling with 20 times of horizontal plankton net towing were done in the four AQS. Approximately 20 liters of water were filtered in one tow/haul. Three replications of water sampling were done for each AQS. The results of the study showed that the most dominant group of phytoplankton was diatoms (58.2%), followed by cyanobacteria (33.6%) and green algae (8.3%). There was a numerical difference between the phytoplankton densities of the four AQS. In terms of the number of phytoplankton species, AQS 3 had the most phytoplankton species with 17 species, followed by AQS 1 with 11 species, then AQS 4 with eight species, and AQS 2 with no phytoplankton species observed. Seven zooplankton species were observed in all of the four AQS. Six of the seven reported species were observed to be copepods. Nauplii of copepods dominate the study area with 43% followed by *Pseudodiaptomus marinus* (27.5%), *Acartia tonsa* (12.4%), *Esola* sp. (7.56%), *Arctodiaptomus dorsalis* (4.8%), *Daphnia sp./Ceriodaphnia sp.* (2.7%), and *Acartia edentata* (2.1%). AQS 2 had the most zooplankton species and the highest average zooplankton density among the AQS ponds, followed by AQS 3, AQS 1 and AQS 4. The findings showed the interrelationship of plankton, management practice, and mangrove trees in aquasilviculture system. With monitoring of plankton composition, it can inform environmental management strategies, optimize nutrient inputs, and enhance the sustainability of aquasilviculture practices.

Keywords: Agroforestry, Aquaculture, Community-Based Forest Management (CBFM), Mangroves, Plankton

C10

Building Resilient Communities along Aklan River (BRCAR), Philippines

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Abstract

In recent decades, changing weather can bring many dangers to communities, prompting them to adapt to changing situations. The frequent severe weather, especially floods, made many communities more vulnerable. This program aims to address problems by creating a complete database and assessing the vulnerability of communities along the Aklan River in Western Visayas, Philippines. Its objectives were creating vulnerability maps, implementing adaptation and mitigation measures targeting highly vulnerable populations, developing educational materials, and empowering at-risk groups against flooding hazards. Research findings identified 60 barangays covering seven municipalities along the Aklan River with diverse vulnerability and disaster risk levels, encompassing population density, natural resource distribution, critical infrastructure, lifeline facilities, and land usage patterns. Following the validation of vulnerability assessments, a series of community services were initiated, such as training sessions, workshops, advocacy campaigns, and the establishment of demonstration sites. Further, consultations, dialogues, planning initiatives, and community organizing efforts were undertaken. The establishment of seven demonstration sites showcasing Climate-Smart Agriculture Projects, with the development of seven farmer organizations, emerged as notable outcomes, fostering economic opportunities for beneficiaries. Policy recommendations emphasized risk reduction strategies such as prevention and mitigation measures across various sectors including land use, production, protection areas, infrastructure, and utilities. To sustain and enhance these efforts, partnerships with local and national government entities were prioritized, aligning with the research and extension mandates of the university. These development programs are intended to be institutionalized as integral components of the university's curriculum and activities, ensuring their continuity and long-term impact.

Keywords: Aklan river, Climate change, Flooding, Mitigation

C11

Effectivity of Agroforestry on Soil Fertility Recovery after Logging of Production Forests in Java, Indonesia

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Abstract

This study investigates the effectiveness of agroforestry in restoring soil fertility after logging in production forests. Logging activities often lead to soil degradation, decreased productivity of forest lands. Agroforestry is proposed as a sustainable land management practice that can enhance soil fertility and support ecological recovery. This study investigated the effects of agroforestry on soil functions in a production forest, at State Forest Enterprise, Malang, East Java, Indonesia. The study was conducted on two main plots, one that was two years after a clear-cutting and continuing with planting annual crop and trees (beginning agroforestry establishment) without proper soil conservation and one that was managed under after ten years pine-grass agroforestry establishment. In each main plot also split by different slope with a slope of 0-8%, 8-15%, 15-25%, 25-45%, and > 45%. The natural forest is also determined as control. The measurement of parameters in each plot was using three replications. Soil samples were collected and analyzed for key fertility indicators: soil pH, soil organic matter content, total soil nitrogen, soil availability phosphorus and cation exchanges capacity, soil bulk density, soil porosity, soil aggregate stability, soil infiltration and earthworm. The results showed that agroforestry plots aged 10 years were not significantly different from agroforestry aged 2 years on soil pH, soil availability of phosphorus, soil bulk density, soil porosity, cation exchanges capacity, soil aggregate stability and soil infiltration values. The establishment of agroforestry after 10 years can increase soil organic matter, total nitrogen and biomass of earthworm compared with initial establishment of agroforestry, but still do not achieve the condition in the natural forest. These results indicate that agroforestry has not been effective in improving soil fertility on degraded land if the soil degraded after logging. Therefore, forest management after clear-cutting and continuing with the establishment of agroforestry must apply the proper application of soil conservation measures.

Keywords: Agroforestry, Indonesia, Java, Logging, management, Production forests, Soil fertility, Sustainable land

C12

The Role of Stakeholders in Promoting Agroforestry under Social Forestry Program in West Sumatra, Indonesia

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Abstract

Social forestry program has been implementing for last two decades as the main policy for forestry development of Indonesia. The objectives of the program are improving the healthiness of forest and increasing the prosperity of local communities. Promoting agroforestry is one shot for achieving these two objectives. Agroforestry increases forest cover in high biodiversity with economically valuable trees. So, some stakeholders have been promoting agroforestry in social forestry program. In this paper, we assess the synergically role of each stakeholder in promoting agroforestry under social forestry program in West Sumatra based on the needs of forest villages (*hutan nagari/HN*) and communal forest (*hutan kemasyarakatan/HKm*), schemes of social forestry, management. In addition, we assess the sustainability of HN and HKm institution from the ability of agroforestry continuation when assistances from stakeholders terminated or the willingness of the stakeholders to continue their role in the future. We identify and map the stakeholders and their role at all stage of agroforestry promotion. We do in-depth interview to stakeholders, which are promoting agroforestry. The stakeholders come from government, NGOs, state owned enterprise, private business communities, university and politician with differences motive. The needs of village and communal forest management in agroforestry development are ranging from management and technical capacity, equipment/input both in on-farm and processing, and market for their production. Ministry of forestry provided financial assistance, povincial office of forestry provided seed for on farm activities and equipment for processing, while provincial industry and trade services provided equipment for coffee roasting. Both state-owned and private business assisted in marketing the final products. NGOs played role in strengthening the HN and HKm institution. We found that, there are not all HN and HKm management needs fulfilled by stakeholders' assistance that cause to their less capacity to sustainably continue the agroforestry development in future.

Keywords: Agroforestry, Communal, Forest stakeholders, Social forestry, Sustainability, Village forest

C13

Stewards of the Forest: Arthropods as Bioindicators of an Agroforestry in Mankayan, Benguet, Philippines

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Abstract

Arthropods play an important role in the ecosystem. As bioindicators, their presence or absence can indicate the healthiness of an area. A biodiversity survey was conducted to determine the ecological condition of an agroforestry area in Mankayan, Benguet. It was majorly composed of pine trees and was surrounded with nearby farms, which consist mainly of rice, cucurbits, and crucifers. Specimens were collected by performing soil and leaf litter collection, sweeping, pitfall traps, and opportunistic sampling. The collected arthropods were placed in vials with ethanol then stored in the freezer for preservation and identification. Afterwards, the specimens were identified to the nearest taxa possible using available taxonomic literatures. Results showed that there are numerous kinds of bioindicator species in the area, as represented by several functional guilds which are predators (praying mantis - *Heirodula patellifera*), pollinators (scarlet Mormon swallowtail - *Papilio rumanzovia*), parasitoids (ensign wasp - *Evania appendigaster*), scavengers (field cricket - *Gryllus* sp.), and pests (fruit fly - *Bactrocera dorsalis*). However, due to the thorough use of agrochemical pesticides and improper and unsustainable farming practices, the population of the natural enemies are much dominated by the pest populations, as evidenced by the survey conducted. Because of their ecological and economical importance, long-term arthropod diversity research is recommended to properly establish and designate a sustainable pest management and conservation program.

Keywords: Agroforestry, Arthropods, Benguet, Bioindicators, Philippines

C14

Theme D:
Potential Crop Components of Agroforestry Systems

Effect of Biostimulants and PGRs on the Reproductive Characters of Cacao Under Monocrop and Intercrop Planting Systems

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Abstract

This study was conducted to determine the effects of biostimulants and PGRs on the physiology of cacao cultivated as a monocrop (full sunlight) and as intercrop to coconut (reduced sunlight). Tap water (control), biostimulants (oligocarrageenan and oligochitosan), and PGRs (cytokinin and paclobutrazol) served as foliar spray treatments and were applied as foliar spray onto six-year-old ‘UF 18’ cacao trees with cherelles (BBCH 70-72) in monocrop and intercropped cacao plantations. Regardless of light condition, the foliar spray of biostimulants and PGRs generally improved the leaf chlorophyll index of cacao. Paclobutrazol and oligochitosan reduced the cherelle wilt incidence, irrespective of light condition. Interaction between light condition and foliar treatment revealed that low irradiation is the dominant stress that occurred as can be explained by lower pod retention, lighter pod weight, fewer and lighter beans per pod, and with poor pod index from the cacao in the control. Pod retention did not vary across foliar treatments and light conditions, except for the control under reduced light condition. Moreover, cytokinin, oligocarrageenan, and oligochitosan resulted in heavier cacao pods. The oligocarrageenan also resulted in the production of more full beans and heavier beans per pod, as well as better pod index. In comparison, cytokinin improved the dried bean weight of cacao as well as the pod index in both light conditions. The paclobutrazol treatment also improved the pod index of cacao in both light conditions, while oligochitosan treatment only impacted the pod index of cacao under full sunlight condition. Regardless of the light conditions, the biostimulants and PGRs also regulated the pulp juice quality of cacao such as TSS, TA, and TSS/TA ratio. Overall, the biostimulants and PGRs used in this study have shown positive influence on cacao physiology under varying light conditions.

Keywords: Bio-effectors, Intercropping, Irradiance stress, Photosynthesis, Shade crops

D1

Soil Health and Growth Performance of Red Spanish Pineapple (*Ananas comosus* L.) to Varying Soil Fertility Management on a Contour Farming System in Aklan, Philippines

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Abstract

The uplands are very important landscapes as they influence other ecosystems in various ways. About thirty percent of the land area of the province of Aklan is classified as uplands, protected, and utilized as production forest for crops such as abaca, coconut, banana, tuber crops, fruit trees, and human settlement structures. The recent inscription of the handwoven piña of Aklan province into its List of the Intangible Cultural Heritage (ICH) of Humanity by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) has reverted the demand for the Red Spanish pineapple fiber, which necessitates the use of additional upland areas and viable soil health practices for RS pineapple production. This study aims to evaluate the soil health and growth of RS pineapple applied with different soil fertility management practices under a contour farming system. It was conducted at the Agroforestry Research Site of the Aklan State University, Banga, Aklan, from December 2023 to April 2024. The research was laid out in Randomized Complete Block Design (RCBD) with five treatments designated, respectively, as T1 - Control, T2 - 4 g calcium + IMO + mulch, T3 - 8 g calcium + IMO + mulch, T4 - 4 g calcium + IMO + inorganic fertilizer + mulch, and T5 – inorganic fertilizer + mulch. A one-way analysis of variance was employed, and mean differences were determined through a T-test at the 0.05 level of significance. The findings showed that soil health physical indicators such as aggregate stability, bulk density, and soil structure; biological indicators such as earthworm count; and chemical indicators such as the amount of nitrogen, phosphorus, potassium, and soil organic matter improved after application of calcium and augmentation of indigenous microorganisms. Similarly, the combined use of calcium and the introduction of indigenous microbes enhance the growth parameters of RSP in terms of plant height, length, diameter, and number of leaves in a contoured farming environment.

Keywords: Contour farming, Nutrient management, RS pineapple, Soil health, Upland ecosystem

D2

Disease Spectral Identification and Analysis on the Bark of Gmelina *(Gmelina arborea Roxb)*

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Abstract

This study focuses on disease spectral identification and analysis on *Gmelina arborea* bark using UV-VIS Spectrophotometry. The objective is to generate spectral data from both healthy and unhealthy bark of *Gmelina arborea Roxb* and analyze its spectral characteristics. Bark samples from both healthy and unhealthy bark with canker and death disease were collected on Caraga State University's Main Campus. UV-Vis spectrophotometry was used to measure the absorption of light by the bark samples. Healthy bark exhibited a smooth spectral trend with no peaks or troughs, while bark affected by death-disease showed a drastic decrease in absorption and the presence of troughs in the violet and blue-edge ranges (350 nm to 450 nm). The methodology involved preparing bark extracts and measuring their absorbance over a wavelength range of 350 nm to 800 nm. Specific absorbance peaks and patterns were observed to distinguish between healthy and unhealthy samples with canker and death- disease. The findings revealed distinct spectral signatures of both healthy and unhealthy canker, particularly with death disease, which exhibits a greater alteration in its spectral trend. The spectral trend of death-disease shows a drastic decrease in its absorption and it shows the presence of troughs and peaks. On the other hand, Canker shows a decrease in its absorption. The severity of disease in the bark may potentially affects the behavior of the spectral trend, this is proven in the spectral trend of death-disease. The absorbance decreased causing troughs at specific wavelengths as the presence of those diseases and their severity progressed. These findings show that spectral information from healthy and unhealthy bark can be used as an early detection method for tree diseases or stresses, thereby contributing to the conservation and sustainable use of *Gmelina arborea*.

Keywords: Disease identification, *Gmelina arborea*, Spectral analysis, UV-VIS spectrophotometry

D3

Cultural Management Practices Employed in 'Baligonhon' Yam during Dry Season Cropping

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Abstract

Modifying and enhancing crop resilience is not enough to combat the effect of worsening climatic conditions. Crop managers (farmers) should also gain resilience in order to sustain crop productivity especially during water limiting conditions. Hence, a survey study was conducted in Bantuanon, Lantapan, Bukidnon involving 10 yam (*Dioscorea alata* L.) farmers to assess the cultural management practices employed in 'Baligonhon' yam during dry season cropping. Purposive sampling was used to identify the respondents. Quantitative and qualitative data were gathered through semi-structured interview and collection of crop specimens. Results of the study revealed variable sets of cultural management practices employed in 'Baligonhon' yam across farmers except for the cropping system, harvest and postharvest activities. All of the respondents practice crop rotation, wherein corn is the most common crop planted after yam. Further, actual production volume (yield per hectare), yield per plant, and tuber anthocyanin content of 'Baligonhon' yam differed across yam farmers. This indicates potential influence of different cultural management practices employed. Nonetheless, there are specific and unique cultural management practices during dry season cropping that potentially favor production volume and tuber anthocyanin accumulation. These include the use of heavier minisetts (>100 g) as planting material, longer growth duration (8 MAP), crop rotation, and installation of water impounding. Results of this study can be used as baseline information to formulate recommendations on appropriate cultural management practices to stabilize 'Baligonhon' yam production while maintaining its anthocyanin content in times of water scarcity.

Keywords: 'Baligonhon' yam, *Dioscorea alata* L., Dry season, Resilience

D4

Intercropping Effects of Cocoa Seed Clones with *Neolamarckia cadamba* on Root Traits under Controlled Conditions

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Abstract

Malaysia has great potential to integrate into the global cocoa market. The cocoa seed clone (UIT1 X NA33) was chosen as the best seed cocoa clone for root stock because of its high resistance to pests and diseases and good rooting systems. Today, demand for cocoa has led to a lack of availability to find cocoa seed clones that have good characteristics for root stocks that have the same competitiveness quality as cocoa seed clones (UIT1 X NA33). The aim of this study was to evaluate the growth performance of a selected group of commercial cocoa clones through tree intercropping under controlled conditions. The five best cocoa seed clones from a previous study of six-week-old seedlings, including KKM 1, PBC 123 QH 22, MCBC 1, and UIT × NA33 (control clone), were selected for intercropping with one-month-old *Neolamarckia cadamba* (Laran) seedlings. The total number of rhizotrons used was 33, with five seed clones used for monocropping, five seed clones intercropped with *N. cadamba* seedlings, and three replicates for each. A completely randomised design (CRD) was employed in this study. Two-way ANOVA was employed, followed by Tukey's HSD. The results showed that root biomass, root intensity, and root depth were significantly different, whereas shoot biomass, height increment, root length density, and specific root length were not. In conclusion, the root traits of KKM 1, QH22, and MCBC 1 were higher in intercropping than in monocropping, even though they were not as significant as those of the control cocoa seed clone.

Keywords: Agroforestry, Cocoa seedlings, Competition, Complementarity, Facilitation, Root growth

Stand Structure, Morphology, and Bio Physico-Chemical Characteristics of Soils in Maganhop (*Albizia lebbekiodes D.C.*) and Abaca (*Musa textiles L.*) Production Systems

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Abstract

The stand structure and morphology of Maganhop as a nurse tree for Abaca and some soil physicochemical characteristics of Maganhop-Abaca production systems were evaluated. One-hectare sampling areas were selected and replicated three times. A complete enumeration of all Maganhop found within these areas was conducted. Height (m), diameter at breast height (DBH), crown diameter (m), crown depth(m), uncompacted live crown ratio, root diameter (cm and length were determined from sample trees with DBH 10 cm and above for 100 trees. Soil samples for biophysico-chemical characteristics were collected from areas with Abaca and Maganhop and without Maganhop. Maganhop trees with diameters at breast height (DBH) ranging from 30 to 50 cm have an average merchantable height of 10.35 m, an average total height of 20 m, a crown span of 10.36 m², a crown depth of 10.36 m, and an uncompacted live crown ratio of approximately 50%. The average root span, diameter, and length of Maganhop trees were recorded as 3.65 meters, 17.44 centimeters, and 2.99 meters, respectively. An average of 32 Maganhop trees with a diameter at breast height (DBH) of 10 centimeters or more were observed per hectare. Soil texture analysis indicated that both surface and subsurface soils are clay loam, with a bulk density of 1.59 g/cm³ and a moisture content of 55.15%. The soil bacterial population and fungal colony count were higher in areas with both Abaca and Maganhop trees. Initial results showed that the association of Maganhop with Abaca positively influenced soil chemical properties, such as soil pH (5.78), organic matter content (1.5%), nitrogen (0.075%), available phosphorus (14 ppm), and exchangeable potassium (619 ppm), compared to Abaca production areas without nurse trees. These initial findings suggest that the presence of Maganhop as nurse trees enhances the biophysical and chemical properties of the soil, improving the productivity and sustaining the soil health of Abaca production areas.

Keywords: Abaca, Bio physico-chemical, Characteristics, Maganhop, Morphology, Soils, Stand structure

D6

Social Return on Investment (SROI) Analysis of Multi-Stakeholder Support for Agroforestry Development Under Social Forestry Program in West Sumatra

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Abstract

The Social Forestry national program in Indonesia aims to provide legal rights to forest communities in managing forest area within their living space sustainably. The program is in line with the objective of Agroforestry approach, which enhances forest cover and community prosperity with economically valuable forest-based commodities and supports biodiversity. Given the close relationship between agroforestry and social forestry, this analysis aims to evaluate the Social Return on Investment (SROI) of the Social Forestry program in West Sumatra by assessing the funding and non-funding support from government and other related stakeholders to forest community within Social Forestry program. WRI Indonesia, a non-profit organization, partners with the West Sumatra Government in 10 key Social Forestry areas across five districts. The SROI analysis is conducted under 3 distinct scenarios in the key Social Forestry areas. Scenario 1 focuses on inputs from WRI Indonesia for the specific Social Forestry groups supported by WRI. Outcome indicators include increased income, improved community capacity, newly developed business partnerships, and carbon sequestration. Scenario 2 includes inputs from multiple stakeholders (government agencies, private sector, academia, and local communities) but remains focused on the WRI-supported Social Forestry groups. Scenario 3 encompasses all Social Forestry groups in West Sumatra, with inputs from all related stakeholders. The SROI for each scenario is ranging from 0.6 to 2.5, reflecting a direct impact but limited scale, indicating significant regional benefits but potential disparities in impact across groups. This study highlights agroforestry's role within social forestry programs, demonstrating how stakeholder collaboration can amplify social and environmental returns. However, it also emphasizes the need for balanced resource distribution to ensure sustainable agroforestry development in forest communities.

Keywords: Agroforestry, Social forestry, Social return on investment, Stakeholder, West Sumatra

D7

Enhanced National Greening Program Implementation on Selected Indigenous People Organization in San Jose and Rizal Occidental Mindoro

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Abstract

The general objective of Enhanced National Greening Program (eNGP) is to expand the coverage of NGP to rehabilitate all the remaining unproductive and denuded forestlands by planting forest trees, fruit trees and high-valued crops such as coffee, cacao and rubber. This program of the government implemented in the country is a response to the sustainable development goal focusing on for poverty alleviation, food security, biodiversity conservation, environmental stability, and climate change adaptation and mitigation. Using descriptive-correlational method, five selected indigenous people organization composed of 15 to 30 members has been gauged the knowledge and awareness on the implementation strategies of the program. Based on the analyzed responses from the members to the given statements in the survey questionnaire, majority of the respondents agree and aware on the site validation, assessment and planning and also on the site preparation related activities. The financial and incentives related question got neutral answers and they are not aware in activities related to planning and value-chain analysis to match species planted with site and markets. These results are associated with the socio demographic information of the respondents. Reinforcement activities to program facilitator should be enhanced to properly implement activities to achieve the objectives and have a standard, orderly and effective implementation of the program.

Keywords: Enhanced National Greening Program, Indigenous people organization, Rehabilitate

D8

Theme E:
Agroforestry System and Practices

A Shift in Farming Systems and Practices Among Upland Farmers in Buhi, Camarines Sur, Philippines

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Abstract

The shift in farming systems and practices among upland farmers is essential in bridging the knowledge gap and enhaces local knowledge on agroforestry. This study utilized mixed method, such as focus group discussion using participatory tools and techniques, key informant interview, participant's observation and survey. Thirty-five members of the Namurabod Upland Corm Farmers Association in Buhi, Camarines Sur participated in the study. Primarily, the study analyze the shift in farming practices of the local NUCFA farmers. The upland farmers decision to shift in farming systems and practices aims to sustain income generation and optimize farmland.The study also reveals that their own understanding of agroforestry primarily revolves on the economic benefits. Currently, farming systems involve the intercropping of yellow corn and coconut or cultivating abaca and coconut as windbreakers. The interventions of Local Government Units, Department of Agriculture and Department of Environment and Natural Resources play a significant role by providing them seeds, conducting trainings and support for agricultural diversification. The farmers expressed a need for more knowledge-sharing and hands-on learning, indicating an opportunity for more targeted and adaptive interventions in the future as the current farming systems and practices is the start of agroforestry.

Keywords: Agroforestry systems and practices, Intercropping, Multiple crops, Namurabod, Upland farmers

E1

Factors of Adoption of Smallhold Agroforestry-based Farmers in Silang, Cavite, Philippines

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Abstract

The adoption levels and factors affecting sustained adoption and/or non-adoption of agroforestry smallholder farmers were studied in the Municipality of Silang, Cavite, Philippines. The study employed the sustainable livelihoods approach by looking into the human, physical, natural, social, and financial aspects of the farmers and the community. As well as their access to these assets and identified potential vulnerabilities. A household survey and focus group discussions were employed to determine the change in adoption level of agroforestry among the farming communities.

A total of 152 farmer respondents were interviewed. Based on the survey, the agroforestry adoption pattern of the most farmer respondents was classified as innovators. This implies that the majority of the farmers are appreciative of new interventions for adoption and are more risk-takers. In giving weight to the five capitals, such as human, physical, natural, social, and financial aspects, most of the farmer respondents give all the capitals an equal weight of 20%. This means that all capitals mentioned have an equal importance for the farmers that affects their adoption. As for the continuance of adoption, 13.16% are certain to adopt agroforestry, 36.84% are very likely to adopt, 49.34% are likely to adopt and only 0.66% are unlikely to adopt.

The most common practices being employed by the Silang farmers are agrisilvicultural and agrosilvipastoral farming systems, where planting annual crops, such as root crops and various vegetables, are mixed with fruit trees, while several others also raised livestock. This practice has given them higher income, better yield and more diversified products. Facing various struggles such as the pandemic, aging farmers, climate change, high cost of labor, low market price of products, and threats of land conversion, farmers are still willing to adopt, maintain and practice agroforestry as their main farming system.

Keywords: Agroforestry adoption, Farming community/system, Sustainable livelihood

E2

Vulnerabilities, Challenges and Opportunities of Socio-Ecological Production Landscapes (SEPLs): Case of Sta. Cruz Sub-Watershed in the Philippines

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Abstract

This study was conducted in Sta. Cruz Sub-Watershed, covering the river system that traverses from high-elevation in Brgy. Luquin, Liliw, mid-elevation in Brgy. Banaan, Magdalena, to the low-elevation community, which is in Brgy. Patimbao, Sta.Cruz. These communities represent the Socio-Ecological Production Landscape (SEPL) in Laguna, Philippines. The majority of the population in these SEPLs depend on agriculture as their main livelihood, which is highly exposed to shocks and uncertainties such as climate change, market uncertainties, policy shifts, natural hazards, and, more recently, the COVID-19 pandemic. The data was gathered using mixed methods. These include household surveys, key informant interviews, focus group discussions, and farm visits. Data gathered includes the general socioeconomic conditions, livelihood activities, and the major issues and challenges being faced by these communities. Transect and village walks were used as tools in assessing the biophysical conditions of the communities across the SEPLs. Results revealed that majority of communities depend on farming as their main source of livelihood. However, farming systems are vulnerable to natural hazards such as typhoons, drought, and climate change. The pandemic also hampered agricultural production and marketing. Monocropped rice dominates the low elevation while patches of fruit trees, vegetables, and monocropped rice are common in mid- elevation community. The upstream community, which is prone to soil erosion is dominated by vegetables and some fruit trees. Agricultural intensification is observed in high and mid-elevation communities while land use change is prevalent in the low-elevation community. Unstable market prices of produce, and declining farm income are among the socioeconomic issues. These findings highlight the need for technology and social interventions that address these interconnected challenges and promote sustainable development within SEPL communities to increase their resiliency against vulnerabilities.
.

Keywords: Livelihood and governance, Socio-ecological production landscape communities, Sub-watershed

E3

An Overview of Farming Systems' Characteristics of Barangay Tala, Rizal, Laguna, Philippines

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Abstract

Understanding the general characteristics of farming systems play a significant role in providing effective management strategies to enhance productivity, ensure food security and achieve environmental resiliency and sustainability. This study aims to characterize the various farming systems in Barangay Tala, Rizal, Laguna. A biophysical assessment was conducted to determine the typology of the farming systems, and a household survey was used to gather information on farmers' knowledge and practices. Results revealed that the major farming systems are "pure agriculture", "live trellis system" and "multistorey system". The farms are generally rain-fed and relatively rolling to steep terrain. Majority of the farmers used a combination of synthetic and organic fertilizers. Soil assessment revealed that the soil texture across the three farming systems is sandy loam. The pH level of pure agriculture and live trellis system were strongly acidic while multistorey was moderately acidic. Organic matter level is lowest at the pure agriculture system. There were variations in the soil nutrient content (N, P, K) of the three farming systems. In terms of eliciting knowledge, most of the farmers are aware of climate change and experienced its impacts such as extreme heat, drought, prolonged rainy season and occurrence of strong typhoons. However, many farmers are unaware on the concept of agroforestry. Given these findings, there is a clear opportunity to promote and improve agroforestry practices in Barangay Tala, Rizal, Laguna, Philippines. By facilitating the adoption of agroforestry systems, researchers aim to support farmers in developing more sustainable and resilient farming practices that can better withstand the challenges of climate change and environmental degradation.

Keywords: Agroforestry, Climate change, Farming systems, Soil characteristics

Pest Management in Agroforestry: Evaluating Practices in Mankayan, Benguet, Philippines

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Abstract

Benguet is a highland area in the Northern Philippines and is known to be one of the most conducive areas for plantations of agricultural crops due to its cold climate. In addition to its agricultural productivity, this province also boasts its diverse forests, with some trees, being endemic to the location. An agroforestry survey was conducted in selected areas in Mankayan, Benguet focusing on the pest management practices of the farmers. Data gathering methods include sampling of arthropods through the use of traps, handpicking and use of forceps, processing of secondary data, and face-to-face interview with the farmers themselves. Based on the results, it was found that the farmers rely heavily on the use of agrochemical pesticides as their primary method in controlling pests, especially arthropods. This practice greatly affects the nearby forests by harboring more pest species, making the trees more vulnerable and susceptible to pests and diseases. The researchers recommend the use of Integrated Pest Management (IPM) for a more sustainable pest management program to ensure stable and effective practices and to plant more native trees to promote a more diverse ecosystem for the betterment of our agricultural lands and forests.

Keywords: Arthropods, Benguet, IPM, Pests, Pesticides

E5

Kaingin Farming Practices of Alangan Farmers in the Indigenous Community of Sta. Cruz, Occidental Mindoro

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Abstract

The study aimed to understand the kaingin farming practices of 88 Alangan farmers in Sta Cruz, Occidental Mindoro, using a validated questionnaire as an interview schedule. Frequency and percentage distribution, weighted mean were used. The Alangan farmers were young aged (mean=37 years old), mostly female, no formal schooling, no affiliated organization and had short farming experienced in a small owned kaingin farm of 1.94-hectare. Their household annual income is low, primarily from producing rice, corn, cassava, sweet potato, yam, banana, jackfruit and ginger. Alangan farmers adopted permanent and shifting culture called "kaingin" as farming system. They practice monocropping, intercropping, crop rotation, mixed cropping and diversified cropping. Minimum, zero and conventional tillage, direct sowing and transplanting of crops, hand weeding mechanical and chemical herbicides used in controlling weeds. They applied basal, broadcasting, side dressing, foliar and no fertilization methods. Rainwater, deep well and water pump were source of water for crops. They used different pest control methods such as chemical, physical, cultural, botanical and no pest control applications. Manual harvesting of crops using yatab and sickle, sun drying and air drying of seeds as method of seed conservation. Alangan farmers recognize the social, economic, and environmental benefits of kaingin farming as their culture, and advocate for solutions through social dialogues, economic livelihoods, and environmental protection training. Low production and income challenges require technical support from local government units and agencies to boost farm productivity and sustainability, including agroforestry technology training and resource conservation education.

Keywords: Alangan farmers, Cultural practices, Kaingin farming

Indigenous Agroforestry Practices of Gubatnon Farmers in Purnaga, Magsaysay, Occidental Mindaro

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Abstract

The study determined the "kaingin" farming practices of Gubatnon farmers in Purnaga, Magsaysay, Occidental Mindoro using descriptive method of research. Developed and validated questionnaires were used as interview schedule to 100 respondents and focused group discussion was also conducted to validate the data gathered. Majority of the respondents are young Gubatnon farmers. They produce diverse traditional crops for food and income. The cultural practices in the "kaingin" farms of these indigenous people are shifting cultivation, using indigenous seeds, adopting mixed cropping system, employing zero tillage, planting direct seeding, controlling weeds manually, nothing do in soil fertilization, applying surface irrigation, employing physical control for pest, performing manual harvesting, sun drying of seeds and utilizing traditional seed storage. Ensuring indigenous peoples communities to become climate-resilient is vital for they are believed to be essential in enhancing food systems' resilience as well. Provision of technical support services, linkages, and partnerships with the Gubatnon farmer's organization for sustainable upland development programs are suggested for these indigenous people are the steward of environment.

Keywords: Cultural practices, Gubatnon farmers, Kaingin farming

Abstracts of Poster Presentation

Effect of Drying Condition on Quality of Robusta Coffee Blossom Tea

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Abstract

The objective of this research was to study the effect of drying conditions on the quality of Robusta coffee blossom tea. The commercial tea produced by a local small enterprise at Ban Natong, Phrae province (control) was compared to a laboratory prototype. Both conditions were prepared using pan roasting then sun drying. The commercial tea produced by a local small enterprise at Ban Natong, Phrae province (control) was compared to a laboratory prototype. Both conditions were prepared using pan roasting then sun drying. The commercial tea was prepared under condition without control of temperature and time. The prototype was prepared using pan roasting at 75-80 °C for 20 minutes then sun drying for 3 days (average temperature of daytime was 40°C and night time was 24 °C). The chemical properties of Robusta coffee blossom were analyzed and found that the blossom contained moisture content and total phenolic contents of 83 % and 30.07 mg GAE/g, respectively. The DPPH inhibition of the blossom presented at 71.19 %. The color vales (L*, a* and b*) and moisture content of tea from both conditions were compared. The results found that there were no significant differences in color values and moisture content. The L*, a* and b* values of control were 8.06, 8.51 and -2.69, respectively, and the L*, a* and b* values of the prototype were 7.81, 9.72 and -2.33, respectively. Moisture contents of control and prototype were 2.14 and 2.24%, respectively. The moisture contents of tea from both conditions were lower than the Thai Community Product Standard (120/2546). The drinking tea was prepared by soaking 1.6 g dried tea in 110 mL. hot water at 85°C for 4 minutes. The results presented that the drinking tea from control and prototype showed phenolic contents of 504.41 mg GAE/L and 644.60 mgGAE/L, respectively and DPPH inhibition of 45.69 and 54.26 respectively. The results revealed that drying process control was a critical aspect of production systems, playing a pivotal role in maintaining and providing high quality products.

Keywords: Bioactive compound, Coffee blossom, Drying, Roasting, Robusta

P1

The Effect of Xanthan Gum and Swamp Algae Incorporation on Properties of Banana Flour Substituted Noodles

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Abstract

Traditional noodles are claimed to lack essential nutritional components due to the main ingredients consisting of wheat flour, water and salt. Therefore, application of banana flour which is rich in dietary fiber has gained attention. However, the limitation of banana flour usage is poor in viscoelastic properties which affect cooking quality. The purpose of this study is to evaluate the effects of xanthan gum and swamp algae addition on the properties of banana flour substituted noodles. The wheat noodles supplemented with 30% banana flour were prepared. The first study, the addition of xanthan gum at 0, 1, and 2% (based on flour content) was investigated. The incorporation of xanthan gum resulted significantly ($p \leq 0.05$) increased in moisture content and cooking yield and decreased cooking time and cooking loss of noodles. The optimum level of xanthan gum was 1%. The second study, the incorporation of swamp algae at 0, 10, 20, and 30% (based on flour content) was conducted. The results presented that addition of swamp algae influenced significantly ($p \leq 0.05$) increased in cooking time and cooking yield and decreased cooking loss. Sensory evaluation demonstrated that the most acceptance from panelists was the noodle enriched with 10% swamp algae. This study can be concluded that the optimum condition for preparation of the wheat noodles supplemented with 30% banana flour was 1% xanthan gum and swamp algae at 10% of flour content which could be an alternative product for consumers who pay attention to healthy food.

Keywords: Banana flour, Cooking quality, Noodle, Swamp algae

P2

Evaluation of Total Phenolic Content, Antioxidant Activity and Chlorophyll Content of *Murraya siamensis* Leaf Extract

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Abstract

The objective of this research was to evaluate total phenolic content, antioxidant activity and chlorophyll content of ethanolic extract of *Murraya siamensis* leaves. Young and mature leaves were collected from the Crop Production Technology farm, Maejo University-Phrae campus. The leaves were then oven dried at 50°C for 20 hours. Four treatments consisted of fresh young (FY), fresh mature (FM), dried young (DY) and dried mature (DM) leaves were then extracted for analysis. The estimation of total phenolic content was done by using the Folin-Ciocalteu method. The antioxidant efficacy of extract was evaluated using (DPPH) 2,2-Diphenyl-1-picrylhydrazylradical scavenging activity. Chlorophyll contents were measured using spectrophotometer at 645 and 663 nm. Total chlorophyll, chlorophyll a, and b were calculated. The results presented that total phenolic content of FY, FM, DY and DM leaves were 7.53, 6.22, 16.64 and 12.73 mg GAE/g, respectively, while, DPPH inhibition were 74.63, 72.83, 90.32 and 91.00%, respectively. Chlorophyll a of FY, FM, DY and DM leaves were 0.475, 0.447, 1.214 and 1.147 mg/g, respectively, while, chlorophyll b were 0.051, 0.078, 0.366 and 0.478, respectively. Therefore, total chlorophyll of FY, FM, DY and DM leaves were 0.526, 0.525, 1.580 and 1.634 mg/g, respectively. The results can be concluded that the oven dried young leaves had maximum total phenolic content, while oven dried mature leaves had maximum total chlorophyll. The results of these bioactive compounds will be important for decision of application of the extract from *Murraya siamensis* leaves in agricultural products.

Keywords: Chlorophyll, DPPH inhibition, *Murraya siamensis*, Total phenolic content

Development of Sauce from Reject Gros Michel Banana (*Musa sapientum*) Cultivated for Exporting

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Abstract

The purpose of this project was to optimize the amount of Gros Michel banana for production of sauce. The poor quality bananas cultivated in Chumphon Province which did not pass for export were used. The effects of banana amounts at 40, 45 and 50 % (w/w) on the quality of sauces were conducted. The chemical properties including total soluble solid (TSS), pH, titratable acidity (TTA), total sugar and reducing sugar, and physical properties including viscosity, flow rate and color values (L*, a*, b*) were measured. The results showed that the amount of banana influenced significantly ($p \leq 0.05$) on TSS and all physical properties. An increase in the amount of banana provided a significant ($p \leq 0.05$) increase in TSS and viscosity but decreased flow rate. For color values, an increase in the amount of banana decreases L* value indicating lower lightness but increases a* (redness) and b* (yellowness) values. The sauces prepared using 40, 45, 50% (w/w) had TSS at 39.00, 39.90 and 40.30 °Brix, respectively, and viscosity at 1,904, 2,000 and 2,800 cPs, respectively, while flow rate at 0.13, 0.11 and 0.08 cm/s, respectively. The sauces contained banana at 40, 45, 50% (w/w) had L* value at 30.70, 31.05 and 29.81, respectively, while, b* value at 4.07, 4.30 and 4.98, respectively and b* value at 6.44, 6.39 and 7.04, respectively. There was no significant ($p > 0.05$) difference on pH, TTA, total sugar and reducing sugar. The sauces presented pH, TTA, total sugar and reducing sugar in a range of 3.59-3.61, 0.87-0.89 % (as acetic acid), 33.58-35.24% and 7.25-8.02 %, respectively. Basically, viscosity is an important rheological property of sauce. Therefore, based on a commercial product which has a viscosity of approximately 2,000 cPs, the formula containing 40% and 45% (w/w) of banana could be used for the development of the product in the next sensory evaluation.

Keywords: Banana, Sauce, Viscosity

P4

Study of Weed Diversity and their Population Density in Different Fields

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Abstract

Weed interference is a major problem in the agricultural system. The biodiversity of and their density in different fields were observed. The research was conducted in four fields including palm, teak, eucalyptus and emblica at Maejo University-Phrae campus. Specie and density of weed were collected. The results showed that amount of weed speices found in palm, teak, eucalyptus and emblica fields were 8, 4, 13 and 6 species. The highest density weed found in palm, teak, eucalyptus and emblica fields were *Tridax procumbens* L. (11,300 plant per rai), *Ageratum conyzoides* L. (405, 600 plant per rai), *Leptochloa chinensis* (L.) Nees (60,800 plant per rai) and *Mimosa pudica* L. (187,360 plant per rai), respectively. Meanwhile, the lowest density weed found in palm, teak, eucalyptus and emblica were *Mimosa pudica* L. (50 plant per rai), *Eleusine indica* (L.) Gaertn (7,200 plant per rai), *Eleusine indica* (L.) Gaertn (2,880 plant per rai) and *Gomphrena celosioides* Mart.(11,200), respectively. In addition, the morphological properties of weeds found in three fields were also recorded related data of size, shape and structure. The collection of these data of specie and density of weed in plant field will be important for weed control management for farmer.

Keywords: Density, Specie, Weed control, Weed diversity

P5

The Effect of Shading on Growth of Young Arabica Coffee Plant

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Abstract

Productivity of coffee plantations is threatened by climate change. The use of shading might protect against temperature variability and excessive radiation. The aim of this study was to evaluate the effect of shading on growth of young Arabica coffee plants. Completely randomized design (CRD) was used for the experiment. The young Arabica coffee plants were grown under non-shading condition (T1) compared to shading conditions at 25(T2), 50(T3),75(T4) %. Stem diameter, plant height and leaf number were measured at 15, 30,45 and 60 days. The results showed that all treatments presented growth of young Arabica coffee increased continuously during 60 days. Shading influenced significantly ($p \leq 0.05$) different stem diameter and height compared to non-shading. However, there were no significant differences ($p > 0.05$) of stem diameter and height affected by level of shading. The shading conditions had higher values of stem diameter and height compared to non-shading condition. The maximum stem diameters at 15, 30, 45 and 60 days were 1.74, 2.03, 2.17 and 2.21 mm., respectively, which were grown under shading 75% (T4). The highest plant height at 15, 30, 45 and 60 days were 10.52(T2), 12.66(T2), 13.88(T4) and 14.31(T4) mm., respectively. It was found that there were significant differences ($p \leq 0.05$) on leaf number influenced by shading. The leaf number of plants increased with increased level of shading especially after 15 days. The maximum leaf numbers at15, 30, 45 and 60 days were 7.92(T4), 10.53(T4), 11.04(T3, T4) and 7.78(T4) leaves per plant, respectively. The results revealed that using shading could increase growth of young Arabica coffee plants.

Keywords: Arabica coffee, Photosynthesis, Shading, Young plant

P6

The Effect of Slope Aspect on Growth of Plants in Nan Province Highland

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Abstract

Three plants include *Zanthoxylum limonella* (Dennst.) Alston. and *Perilla frutescens* (L.) Britton and *Musa sapientum* L. have been cultivated in Nan Highland in area of Moo.9 Ai Na Lai sub-district, Wiang Sa District, Nan Province for replacement of maize plantation. The effect of two slope aspects (south and north) on growth of plants was evaluated. Height, stem base diameter, number of leaf, canopy diameter of four plants were measured. The results of *Zanthoxylum limonella* (Dennst.) Alston. at 3 months found that there were no significant differences ($p>0.05$) on height and stem base diameter. The height of plants collected from south and north slope aspects were 84.59 and 73.63 cm., respectively, while, stem base diameters were 14.14 and 10.85 mm., respectively. The results of *Perilla frutescens* (L.) Britton at 2 months showed that slope aspect affected significant ($p\leq0.05$) difference on height and canopy diameter but there was no difference ($p>0.05$) on stem base diameter. The height of plants collected from south and north slope aspects were 75.15 and 50.49 cm., respectively, while, stem base diameters were 10.59 and 9.26 mm., respectively and canopy diameters were 57.20 and 31.72 cm., respectively. The results of *Musa sapientum* L. at 3 months demonstrated that there were no significant differences ($p>0.05$) on height, stem base diameter and number of leaf. The height of plants collected from north and south slope aspects were 130.59 and 145.20 cm., respectively, while, stem base diameters were 84.82 and 91.74 mm., respectively and number of leaves were 9.18 and 10.58 leaves per plant, respectively. It can be concluded that slope aspects of south and north did not significantly influence on growth of *Zanthoxylum limonella* (Dennst.) Alston. and *Perilla frutescens* (L.) Britton and *Musa sapientum* L. which indicating that farmers can grow plants for replacement of maize on both slope aspects.

Keywords: *Musa sapientum* L. *Perilla frutescens* (L.) Britton, Plant growth, Slope aspect, *Zanthoxylum limonella* (Dennst.) Alston

P7

Part II: Full Paper

Full Paper

How Resilient are the Agroforestry Farmers in the Community- Based Forest Management Areas in CALABARZON, Philippines?

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Abstract

The Community-Based Forest Management (CBFM) Program was institutionalized to help promote sustainable forest management in the Philippines, putting emphasis on the role of the local communities. The beneficiaries of this program are classified as smallholder farmers who cultivate in marginal forest areas. Their socioeconomic and environmental conditions make them vulnerable to climate and non-climate stressors. This article highlights the resiliency level of the selected CBFM beneficiaries in CALABARZON/Region IVA by measuring their social, natural, financial and human capitals. Data were gathered using farm household survey, focus group discussion, and characterization of their agroforestry farms. Results revealed that the CBFM beneficiaries in CALABARZON had low to moderate levels of resilience with index ranging from 0.27-0.34. Specifically, the CBFM site in Rosario, Batangas exhibited a high level of financial capital (0.28). Meanwhile, the CBFM site in Liliw, Laguna had the highest score in terms of natural capital (0.09). It is important to note that the CBFM site in Magallanes, Cavite had the lowest accumulation of human capital (0.05) and social capital (0.003). Results suggest the need for social, technology and development interventions that would promote a balanced and holistic way of improving the assets and capitals of the four CBFM sites. Appropriate agroforestry systems with a good mix of crop, tree and other perennial, including livestock components, should be co-designed with the farmers to maximize the full economic and ecological benefits of agroforestry systems in CBFM areas. Furthermore, enhancing the capacities of the people's organizations and the individual CBFM beneficiaries is essential to ensure the sustainability of their agroforestry and other livelihood activities

Keywords: Agroforestry, Analytic hierarchy process, Capitals, Resilience, Smallholder farmers

1. Introduction

The Community-Based Forest Management (CBFM) Program was adopted in 1995 primarily as the main strategy for sustainable forest management. This program came into law by Presidential Executive Order No. 263, Series of 1995. CBFM is anchored on the premise that the upland dwellers are important stewards in forest management. The CBFM beneficiaries generally are smallholder farmers and are cultivating in forestlands with marginal conditions, making them vulnerable to land degradation due to biophysical, climatic, and socioeconomic threats. Consequently, the agricultural production of these smallholder farmers is exposed to various risks such as pests and diseases, extreme weather events, policy and market variabilities, and land degradation. These risks undermine household food, income security, and ecological stability.

Several literatures point out the vulnerability of the agriculture and forestry sectors, particularly the smallholder farmers and forest-dependent communities to climate change impacts in Southeast Asia (Evangelista et al., 2015; Landicho et al., 2015). and many parts of the world (Roshani, 2022). Landicho et al. (2015) and Tolentino and Landicho (2013) noted increased use of farm inputs and reduced crop yield and farm income. Meanwhile, Harvey et al. (2018) reported food insecurity after extreme weather events. In particular, the vulnerability of forest-dependent communities to climate change and natural hazards is determined by their socioeconomic status (Chechina et al., 2018), their marginalized environment, and the lack of basic services (Tapia, Peras & Pulhin, 2014). The basic question is how resilient are the CBFM areas in the Philippines? This article highlights the resiliency level of four CBFM areas in CALABARZON or Region IVA using the Local Adaptive Capacity (Jones et al., 2017) and Sustainable Livelihoods Framework (DFID, 2000) as theoretical foundations. These two frameworks emphasize assets and capitals as measures of resilience and adaptive capacity. These include human, social, natural, and financial capital. Human capital refers to the skills and competencies of people to undertake a particular livelihood. Meanwhile, the land, other agricultural, water, and other natural resources, comprise the natural capital. These provide livelihoods and ecosystem services. Financial capital refers to the financial resources used to achieve livelihood objectives, and social capital refers to relationships that people draw to carry out their livelihood activities. Social capital is classified into two types: the bonding capital, or the relationships between the community members, and the bridging capital, which refers to the community's relationship with external institutions and organizations.

This article highlights the resiliency levels of four CBFM areas in CALABARZON, Philippines, considering their natural, financial, social and human capitals.

2. Methodology

2.1 Study sites

The study was conducted in four selected CBFM areas in CALABARZON. These include Barangay Nasi in Rosario, Batangas; Barangay Ramirez in Magallanes, Cavite; Barangay Luquin in Liliw, Laguna; and, Barangay Binonoan in Infanta, Quezon. The study sites were selected based on a st of criteria. These include the presence of active CBFM people's organizations; type of agroforestry systems being practiced; climatic type; willingness of the farmers and people's organization to participate in the study; and, peace and order conditions. Barangay Luquin/Novaliches/Ilayang Sungi in Liliw, Laguna has a CBFM area of 360 hectares and whose dominant farming system is a vegetable-based agroforestry system. It has an existing people's organization, Liliw Upland Farmers' Multi-Purpose Cooperative (LUFAMCO), composed of 65 members. Barangay Ramirez, Magallanes, Cavite has a total of 291 hectares of CBFM area, and farmers are engaged in fruit tree-based agroforestry system. The CBFM is managed by the Ramirez Upland Farmers' Association Inc. (RUFAI) with 32 members. Meanwhile, Barangay Nazi, Rosario, Batangas has a total CBFM area of 68 hectares under the management of Mt. View Upland Farmers' Association, Inc. (MUFAI) with 56 members. The farmers are generally engaged in fruit tree-based agroforestry systems. Lastly, Barangay Binonoan, Infanta, Quezon is a coastal community engaged in mangrove plantation establishment and management and was awarded 17.45 hectares of CBFM area. Farmers are engaged in ecotourism development and aquasilviculture. This area is being managed by the Binonoan Producers' Cooperative (BiPCO) with 33 members.

2.2 Data gathering techniques

The data were gathered through household surveys, key informant interviews, and focus group discussions. For the household survey, the respondents were sampled using the formula as follows:

$$N = N/(1 + Ne^2)$$

Where N refers to the total population of the CBFM beneficiaries, and e refers to a sampling error of 5 %

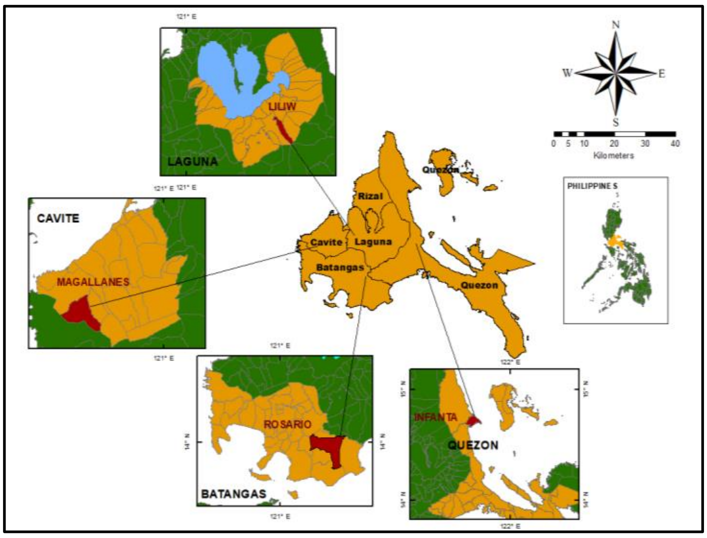

Figure 1. The study sites

Respondents represented the CBFM beneficiaries and were selected using simple random sampling (Table 1). To validate the survey data, one focus group discussion (FGD) was conducted in each site. Key officials of the people's organizations, barangay officials, and staff from the local government units participated in the FGDs. The biophysical characteristics of the agroforestry farms were validated through actual farm visits. The research team organized a feedback workshop in which farmers and representatives from the local government units and field offices of the Department of Environment and Natural Resources (DENR) presented and validated results from the data-gathering methods.

Table 1. Distribution of respondent-CBFM beneficiaries by project site.

Study sites	Number of respondents
Ramirez, Magallanes, Cavite	51
Nasi, Rosario, Batangas	56
Binonoan, Infanta, Quezon	37
Luquin, Liliw, Laguna	72

2.3 Scoring and prioritization of resiliency indicators

DFID (2000) argues that social capital, human capital, natural capital, and financial capital shape the sustainability of a livelihood project. Different variables were identified under each of the four indicators of sustainability and resilience, as shown in Table 2. The corresponding weights of each indicator and variable were calculated using the Analytical Hierarchy Process (AHP) of Saaty (1990). AHP enables users to provide weights and scores through pairwise comparisons between all options.

In this study, a participatory scoring of the different indicators of resiliency was done using the AHP. One AHP session was conducted in each site, where different stakeholders provided weights based on the importance of the different parameters of resiliency. The weights of each of the indicators and sub-indicators (Figure 1) were computed using the pairwise comparison variables, computing the criteria weight and checking on the consistency ratio. Average weights of the variables were then computed.

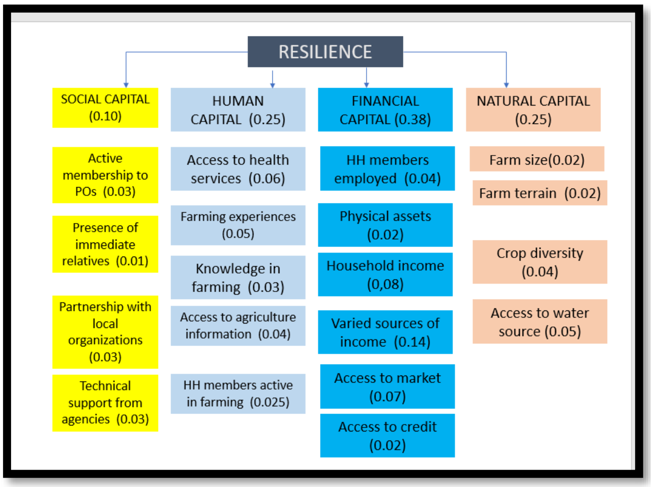

Figure 2. Weights/scores of indicators and variables of resiliency in the four CBFM sites.

2.4 Data analysis

Descriptive statistics such as frequency and percentages were utilized to analyze the data gathered from the farm household survey. Meanwhile, findings from the FGDs were analyzed into themes. Resiliency index was measured based on the weights and scores of the four indicators and their corresponding variables.

3. Results and Discussion

3.1 Socioeconomic and biophysical characteristics of the study sites

The CBFM Program in the Philippines espouses agroforestry as the main production technology to ensure sustainable forest management. FGD and biophysical characterization results revealed that the CBFM sites in Rosario, Batangas and Magallanes, Cavite practiced fruit-tree based agroforestry systems (Figures 3 and 4). These were dominated by fruit trees such as papaya (*Carica papaya*), coffee (*Coffea* sp.), lanzones (*Lansium domesticum*), and cash crops such as banana (*Musa* sp.) and coconut (*Cocos nucifera*) along with annual crops such as cassava (*Manihut esculenta*), ginger (*Zingiber officinale*) and varied vegetable crops. The CBFM site in Infanta, Quezon was dominated by 15 hectares of mangrove plantation (Figure 5). The CBFM beneficiaries were engaged in aquasilviculture. As shown in Figure 6, the CBFM site in Liliw, Laguna was dominated by vegetable-based agroforestry system, comprised of high-value vegetable crops such as tomato (*Solanum lycopersicum*), radish (*Raphanus sativus*), lettuce (*Lactuca sativa*), beans (*Phaseolus vulgaris*), ampalaya (*Momordica charantia*), cabbage (*Brassica oleracea*), root crops such as sweet potato (*Ipomoea batatas*); and, strawberry (*Fragaria ananassa*), among others.

The household survey results showed that most (67%) of the CBFM beneficiaries in CALABARZON were male, with a mean age of 50, representing mostly second-line farmer-beneficiaries. Their mean household size was four (4), whose source of income was a combination of farming and non-farm employment, from which the household generated an average monthly income of Php12,112.25. This indicates that the CBFM beneficiaries live below the Philippine poverty threshold at least Php13,797 per month to meet the basic food and non-food needs of a family with five members (PSA, 2023).

As shown in Table 2, the CBFM beneficiaries in Liliw, Laguna had the highest farm income of Php19,524 compared to the other sites. This could be attributed to the type of crops that are being cultivated by the CBFM beneficiaries. In Liliw, Laguna, the CBFM beneficiaries cultivated high-value vegetable crops that were primarily grown for the market. These were also short-term crops, which farmers produced all throughout the year. The farmers also practiced intercropping and crop rotation, and thus, maximum utilization of the farmlands. In other sites, particularly those engaged in fruit tree-based agroforestry systems, fruits and other produce were harvested on a seasonal basis.

Most of the beneficiaries had been farming for more than 15 years with an average farm size ranging from 1.18 hectares up to 4.00 hectares. It may be noted, however, that of these farm sizes, the cropped or cultivated areas ranged from 0.83-2.35 hectares only. This is because of the limited financial resources to invest in the full utilization of the lands, and/or the constraints in the biophysical characteristics of the farms. Table 2 shows that half (51%) of these farms were situated in rolling areas, while some were in steep areas (33%) and flat (34 %). These farms were highly dependent on rainfall and rivers as sources of their irrigation.

In general, the socioeconomic and biophysical characteristics of the CBFM beneficiaries reflect the characteristics of smallholder farmers in the Philippines (Baliton, et al., 2022; Baliton et al., 2017; Landicho & Dizon, 2020).

Table 2. Major findings from household survey and community needs assessment.

Category	Study sites				Average
	Rosario	**Infanta**	**Magallanes**	**Liliw**	
		Sex			
a) Male	80%	54%	64%	70%	67%
b) Female	20%	46%	36%	30%	33 %
Mean age (years)	54	47	47	52	50
Mean household si	5	4	4	4	4
Mean monthly HH income (in Php)	12,921	14,510	14,415	19,524	12,112.25
		Primary sources of household income			
a) Farming	27%	38%	26 %	52 %	36 %
b) Farming +non-farm	73%	60%	74 %	48 %	64 %
Mean farm size	1.18	2.45	4.00	1.56	2.29
Mean cropped/developed area from the total farm size	0.83	2.01	2.35	0.99	1.54
		Farm topography			
a) Flat	0.50 %	100 %	17 %	20 %	35 %
b) Rolling	90 %	-	43 %	20 %	51 %
c) Steep	0.50 %	-	40 %	60 %	35 %
		Sources of irrigation water			
a) Rainfall	-	100 %	35 %	25 %	53 %
b) Rivers, sprin		-	65 %	75 %	70 %
Agroforestry system	Fruit tree-based agroforestry	Aquasilvi culture	Fruit tree-based agroforestry	Vegetable-based agroforestry	

Figure 3. Fruit tree-based agroforestry system in Rosario, Batangas

Figure 4. Fruit tree-based agroforestry system in Magallanes Cavite

Figure 5. Aquasilviculture system in Infanta, Quezon

Figure 6. Vegetable-based agroforestry system in Liliw, Laguna

3.2 Strengths, Weaknesses, Opportunities and Threats (SWOT) of the CBFM Areas

Major findings from the community needs assessment and focus group discussions are reflected in Table 3. The strengths, weaknesses, opportunities, and threats of the different CBFM areas were likewise identified. The practice of crop diversification is one of the strengths of the three sites representing the terrestrial ecosystem. Crop diversification ensures food security among the farm households because of multiple harvests, and available food and income sources throughout the year. According to Houben, Verstand & Noren (2022), a diverse cropping system in time and space can lead to a resilient farming system because of better soil health and slower pest outbreaks. Crop diversification increases farmers' resilience by significantly improving income stability (Kujawska, Strzelecka & Zawadzka, 2021), and thus, it reduces uncertainties in farmers' income particularly among the smallholder farmers (Feliciano, 2019).

CBFM beneficiaries also noted their edge in terms of their established partnership with the forestry sector—the Department of Environment and Natural Resources (DENR). This agency is primarily responsible in the implementation of the CBFM Program, among others, to ensure sustainable forest management in the country, as stipulated in Executive Order No. 263 in 1995. Respondents also considered the active people's organizations in their respective areas as one of their strengths. As CBFM is centered on people-oriented forest protection and management, the formation of POs plays a crucial role in the program implementation. The DENR and other support groups tap the POs to channel livelihood projects and capacity development opportunities. As such, some POs have already established networks with other institutions, particularly with the local government units and state universities, as in the case of POs in Liliw, Laguna and Infanta, Quezon. The respondents also confirmed availing of various training programs offered by various agencies, particularly DENR. Nevertheless, these opportunities are primarily utilized by the officers, resulting in a significant lack of training opportunities for the younger generation of PO members. Notably, the farmers' produce across the four CBFM areas have assured markets, but these are negotiated with the local traders or middlemen. This results in lower prices for their produce. Lack of marketing facilities and infrastructure also constrains the marketing of agricultural produce. These include poor farm-to-market roads, lack of efficient transportation, lack of post-harvest facilities that could be used for perishable crops, oversupply, and competition. In general, these are the marketing constraints that are being faced by smallholder farmers as noted by Onifade et al. (2021); ILO (2017); Manaomzor & Mamudu (2017).

Demographic change is also seen as a challenge, particularly the aging farmer-beneficiaries. This issue poses risks to farm sustainability, including efforts on sustainable forest management. The aging farming population also hinders ecological restoration for technology adoption (Yu et al, 2023), and reduces investments in agriculture (Akdemir et al., 2021). There are also factors that pose threats to the sustainability of the CBFM areas. These include natural hazards, including strong typhoons, pests, and diseases, as well as climate change that would affect their livelihoods.

However, could some opportunities could be tapped to overcome their weaknesses and threats. These include the potential of value-adding and processing of their agricultural produce, particularly perishable crops, through technical assistance from DOST and the Department of Trade and Industry. The respondents also recognized the strong support of the local agencies and institutions for community development.

Table 3. SWOT Analysis in the four CBFM sites in CALABARZON

Strengths	Weaknesses	Opportunities	Threats
- Farmer-beneficiaries practice crop diversification - Timber trees are integrated in the farms - Farmers' knowledge on farming passed onto them by ancestors - Established partnership with DENR and other agencies - Diverse sources of household income - Active people's organization - Assured market of produce through the traders - Produce have direct buyers - Active people's organizations - Capable PO Leaders - Accessibility of training programs for officers and members	- Crops are vulnerable to climate change and pests - Occurrence of soil erosion particularly in sloping areas - Limited means of product transport - Poor farm-to-market road - Limited training opportunities for other PO members - Poor water source for crop irrigation - Timber production is bound by DENR policies; - Fluctuating market price for AF produce - Oversupply of produce - Produces are perishables	- Potential value-adding for agricultural produce - Potential support from national government agencies involved in the processing of agricultural produce - Networks with DENR, other CBFM people's organizations and other stakeholder groups	- Climate change - Crop infestation - Declining market prices - Competition with other vegetable producers -Potential selling and renting-out of farms within CBFM area

Strengths	Weaknesses	Opportunities	Threats
- Climate is suitable for fruit tree production	- Lacks post-harvest facilities - Low farm income because of high cost of farm labor and inputs - Lower prices of produce taken by traders' inactive members - Occurrence of soil erosion - Lacks training for younger generation of farmers - Only few beneficiaries are PO members - Aging PO members and leaders		

3.3 Analysis of the current resiliency level

The CBFM site in Rosario, Batangas exhibited a moderate level of resiliency (0.43), while those in Magallanes, Cavite; Infanta, Quezon; and Liliw, Laguna had low levels of resiliency of 0.28, 0.36 and 0.33, respectively. This was based on the scores of the four indicators, namely: social capital, human capital, financial capital, and natural capital as shown in Table 4.

Social capital refers to the social resources that people draw to carry out their livelihood activities (DFID, 2000). It may be developed through network and connectedness, membership to formalized groups, and relationships of trust and exchanges. It could be built from among the community members (bonding capital) or from establishing partnerships with other entities (bridging capital). Social capital is an important indicator of resiliency, as social relationships serve as the safety nets regarding disaster, emergency, and other problems related to farm and community development. Social capital plays an important role in disaster resilience and recovery (Islam & Walkerden, 2014; Xiang, Welch & Liu, 2021; Volker, 2022), adapting to climate change impacts.

Results of this study indicate, however, that among the four capitals, social capital had the lowest score across the four sites with a mean score of .007. This finding is similar to Grefalda, Pulhin and Santos (2018), where social capital of CBFM areas in selected areas in Bicol Region was recorded lowest. In this study, social capital had three sub-indicators, namely: active membership to people's organization, relationship with relatives and community members, and partnership and linkages with external organizations. Although there were existing POs in the four sites, one of the problems faced by these POs was inactive members as highlighted in Table 4. In most cases, only officers were actively engaged in organizational activities. Furthermore, table 4 highlights that the criteria weight obtained by social capital using AHP was 0.08, the lowest weight among the four capitals. This suggests that the CBFM stakeholders view social capital as the least indicator and contributor to their resiliency.

However, it is important to note that the CBFM site in Magallanes, Cavite had the lowest rating in social capital (0.003). This is because most of the CBFM beneficiaries are not members of their existing people's organization and do not actively participate with development organizations, except DENR. Meanwhile, the CBFM sites in Batangas and Quezon scored better regarding social capital. These sites have relatively active POs and have established partnerships with the Department of Environment and Natural Resources, local government units, and state colleges and universities. Meanwhile, human capital refers to the accumulation of knowledge and competencies of the farm households through attendance to training, access to agriculture information, experience in farming, knowledge in agriculture/farming, and active involvement of the household members in farming. Human capital is an essential indicator of resiliency, considering that the farmers are the main actors in farming/agriculture. Their physical involvement, as well as knowledge and experiences, help shape their farm and, at the same time, serve as a mechanism to address emerging problems and concerns related to farm development and improvement.

In this study, human capital refers to the number of family members involved in farming, farmers' training experiences, and farming experience. Results revealed that three sites shared similar scores on human capital (0.07), which were higher than their social capital scores. This could be due to the training/capability-building programs that are being organized by DENR on topics related to sustainable forest management; local government units in ecotourism as in the case of the CBFM site in Quezon, and livelihoods as in the case of the CBFM site in Laguna.

Generally, the agroforestry farmers in the four CBFM sites had been farming for 15 years. As such, they may have accumulated learnings from their farming experience, which allowed them to address farm-related problems. The respondents noted the availability of training programs for the people's organizations from the government agencies, particularly DENR. Nevertheless, some PO members noted that not all CBFM beneficiaries were given the opportunity to attend trainings. In most cases, only the officers were sent for training. Regarding farm labor, results indicate that the household head and the spouse were involved in farm activities across the four CBFM sites.

Financial capital serves as an equally important indicator of farm and community resiliency. It refers to the financial resources that people use to achieve their livelihood objectives (DFID, 2000). Financial capital becomes a critical asset in farming as it serves as the source of farmers' investments. It also provides a buffer for farm households in case agricultural production fails because of pest infestation, natural calamities such as drought and typhoons, and market failure (Landicho et al., 2017). In this study, financial capital refers to the physical assets of the farmers, household income, varied sources of income, number of households employed, and their access to credit services.

It was also noted that financial capital obtained the highest score among the four capitals across the four CBFM sites (Figure 7). Specifically, the CBFM site in Rosario, Batangas had a high level of financial capital (0.28) as shown in Table 4. This could be attributed to the farm households' varied income sources. In addition to agroforestry farming, several farm households have members engaged in non-farm employment, which could have contributed to the accumulation of physical assets and household income, which are among the sub-indicators of financial capital. Houben, Verstand & Noren (2022) asserted that non-farm income is a measure of the existence of alternative avenues for income and livelihood in rural areas. If there is non-farm income, the enterprise is less vulnerable to highly variable production and income from the farm. The CBFM site in Cavite had the lowest financial capital (0.15), as farmers are mainly engaged in fruit tree-based agroforestry, whose produce is seasonal.

Natural capital refers to the natural resource stocks (DFID, 2000), where livelihoods are derived and which provide ecological services such as nutrient cycling, soil erosion control, among others. Natural capital is, therefore, the backbone of farming. In this study, natural capital refers to the land that is being cultivated by the farmers, particularly soil condition, access to water sources, crop diversity, presence of perennial crops, and soil and water conservation measures.

Additionally, the CBFM site in Liliw, Laguna had the highest score in natural capital (0.09). This could be attributed to the maximum utilization of their CBFM areas/farm for crop production, which is dominated by agricultural crops. Hence, their farms are cropped throughout the year. The farm households also integrate perennial crops (fruit trees and forest trees). The CBFM Program led to improved forest conditions as evidenced by the increased area of natural forests and the establishment of tree plantations. Furthermore, Lasco and Pulhin (2006) found that integrating trees on farms and landscapes provided ecological services such as soil and water conservation, carbon sequestration and biomass production. These contribute to the accumulation of the natural capital.

These results suggest the need for a balanced and holistic way of improving the resiliency level of the four CBFM Sites, taking into consideration the current conditions of the four resiliency indicators.

Table 4. Resiliency level of the selected CBFM sites in CALABARZON, 2020

CBFM sites	Indicators								Resiliency Index[c]
	Social Capital		Human Capital		Financial Capital		Natural Capital		
	Weight [a]	Score[b]	Weight [a]	Score[b]	Weight [a]	Score[b]	Weight [a]	Score[b]	
Barangay Ramirez, Magallanes, Cavite	(0.10)	0.003	(0.25)	0.05	(0.38)	0.15	(0.26)	0.08	0.28 (Low)
Barangay Luquin/ Ilayang Sungi, Liliw, Laguna	(0.10)	0.005	(0.25)	0.07	(0.38)	0.20	(0.26)	0.09	0.36 (Moderate)

CBFM sites	Indicators								Resiliency Index[c]
	Social Capital		Human Capital		Financial Capital		Natural Capital		
	Weight [a]	Score[b]	Weight [a]	Score[b]	Weight [a]	Score[b]	Weight [a]	Score[b]	
Barangay Nasi, Rosario, Batangas	(0.10)	0.01	(0.25)	0.07	(0.38)	0.28	(0.26)	0.07	0.43 (Moderate)
Barangay Binonoan, Infanta, Quezon	(0.10)	0.01	(0.25)	0.07	(0.38)	0.18	(0.26)	0.07	0.33 (Low)

[a]Weights computed using the Analytic Hierarchy Process (AHP); average weights of the four sites were taken
[b]Computed using the actual data (in scale) from the farmer-respondents multiplied by the weight of each of the sub-indicators of the four resiliency indicators
[c]Average of the total scores of the four resiliency indicators. The resiliency index is scaled as follows: 0.00-0.33 (low); 0.34-0.66 (moderate); and, 0.67-1.00 (high)

4. Conclusion and recommendations

Research results indicate that the CBFM beneficiaries in CALABARZON who practice agroforestry are smallholder farmers who cultivate in marginal areas. Their socioeconomic and environmental conditions make them vulnerable to climate and non-climate stressors. Results further revealed that these CBFM beneficiaries have low to moderate levels of resilience with an index ranging from 0.27-0.34 based on the four indicators of resilience: social capital, human capital, financial capital, and natural capital. Specifically, the CBFM site in Rosario, Batangas, had high economic capital (0.28). Meanwhile, the CBFM site in Liliw, Laguna, had the highest score in natural capital (0.09). Notably, the CBFM site in Magallanes, Cavite, had the lowest accumulation of human capital (0.05) and social capital (0.003). Results suggest the need for social, technological, and development interventions to promote a balanced and holistic way of improving the assets and capital of the four CBFM Sites. Appropriate agroforestry systems with a good mix of crop, tree, and other perennials, including livestock components, shall be co-designed with the farmers to maximize agroforestry systems' economic and ecological benefits in CBFM areas. Building the capacities of the people's organizations and the individual CBFM beneficiaries is necessary to help sustain their agroforestry and other livelihood activities.

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Promoting Organic Agriculture Through *Edutourism*: Experience of the UPLB Organic Agriculture Research, Development, and Extension Center (OARDEC)

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Abstract

The agricultural sector faces critical challenges, including ensuring environmental sustainability and the need for effective education on organic farming practices. To address these issues, the University of the Philippines Los Baños implemented the project, Promoting Agroforest Stewardship & Ecological Observations (PASEO), which integrates the "Establishment of Learning Site for Organic Agriculture" project at the Organic Agriculture Research, Development, and Extension Center (OARDEC). This year-long initiative integrates organic agriculture with educational tourism (*edutourism*) and hands-on learning experiences. The project involved setting up seven (7) comprehensive learning modules: an organic vegetable production area, a medicinal garden, an aromatic garden, a section on organic soil amendments, an agroforestry demonstration area, a kids' garden, and a module showcasing the integration of organic crop-animal systems.

The project aimed to showcase organic agriculture technologies, enhance capacity building among stakeholders, and create a platform for sharing best practices and lessons learned in organic farming. Ultimately, the goal was to foster a deeper understanding and adoption of sustainable agricultural practices, contributing to environmental conservation and improved agricultural productivity. Throughout the project, OARDEC welcomed more than 1,400 visitors and harvested more than 300 kilograms of various organic vegetable fresh produce. The project organized an Organic Agriculture Camp for Grade 11 students and their teachers as a culminating activity. This paper highlights the innovative approach of the Learning Site for Organic Agriculture (LSOA) project in promoting organic agriculture education. It explores the project's potential impact on various stakeholders and sustainable food systems.

Keywords: Agroforestry, Capacity-building, Edutourism, Learning site, Organic agriculture

1. Introduction

Organic Agriculture is vital to achieving Sustainable Development Goals (SDGs). It addresses the agricultural sector's environmental, social, and economic challenges (FAO, n.d.). Organic farming may encompass the following SDGs: Zero Hunger (SDG 2), Good Health and well-being (SDG 3), Clean Water and Sanitation (SDG 6), Decent Work and Economic Growth (SDG 8), Responsible Consumption and Production (SDG 12), Climate Action (SDG 13), and Life on Land (SDG 15). Recognizing its importance, the Philippines institutionalized organic farming through Republic Act No. 10068, the Organic Agriculture Act of 2010. This legislation promotes the widespread adoption of organic farming by improving soil health, reducing pollution, and supporting biodiversity. To enhance accessibility for small farmers, Republic

Act No. 11511 amended RA 10068 in 2020, introducing the Participatory Guarantee System (PGS), a community-based certification approach that fosters trust, knowledge exchange, and inclusivity. Despite these efforts, the adoption of organic agriculture remains limited (Philippine Legal Research, 2021). As of 2023, only about 7,278 hectares of land in the Philippines have been certified as organic, with many small farmers struggling due to high certification costs and limited awareness. This highlights the critical need for innovative educational initiatives to bridge the knowledge gap and promote sustainable practices (NOAP, 2023).

The UPLB, as an academic and research institution, and in support of the OA act, established the Interdisciplinary Studies Center on Organic Agriculture (IdSC-OA) to promote the development of a globally competitive and sustainable organic agriculture sector in the Philippines. This center focuses on interdisciplinary research, development, and extension activities to promote organic farming practices. IdSC-OA aims to contribute to the country's food security and environmental sustainability goals by fostering innovation and knowledge sharing. IdSC-OA falls into the Food Security and Sovereignty development thrust of the UPLB's Accelerating Growth Through One Research and Extension in Action (AGORA). Additionally, the university offers undergraduate organic agriculture courses through the Agricultural Systems Institute under the College of Agriculture and Food Science (ASI-CAFS). Furthermore, the institute manages OARDEC, a learning laboratory for research, development, extension, instruction, and capacity building. The Center provides immersive learning experiences through educational tours, allowing visitors to witness firsthand the practices and benefits of organic farming systems. In 2023, the program Promoting Agroforest Stewardship and Ecological Observations (PASEO), funded by the Commission on Higher Education (CHED) under the StudyPH Program, was approved and being implemented by the UPLB Office of the Vice Chancellor for Community Affairs, designated OARDEC as the Learning Site for Organic Agriculture (LSOA), combining educational tourism with organic farming to create meaningful and engaging experiences for the community.

Edutourism emerges as a powerful tool to foster a deeper understanding of organic agriculture's benefits, inspiring individuals to adopt sustainable practices. It plays a significant role in local development by connecting educational initiatives with community engagement and economic activities. Programs hosted by universities or research institutions often provide local stakeholders new opportunities for cultural exchange, skill enhancement, and economic benefits through partnerships with educational tourists. These interactions help to boost the local economy while creating meaningful experiences for participants (Tomasi, 2020).

This study explores how the UPLB OARDEC integrates *edutourism* in promoting organic agriculture to various stakeholder groups. Specifically, OARDEC *edutourism* emphasizes the different organic agriculture technologies, capacity building of stakeholders, and on creating a platform for sharing best practices and lessons learned in organic farming.

2. Methodology

OARDEC edutourism centers on the development of learning materials, guided farm tours, and training of teachers and other stakeholder groups.

2.1 Study Site

OARDEC is strategically situated within the Science and Technology Park of UPLB, nestled at the base of the iconic Mt. Makiling. The land was used as an experimental banana and sugarcane area before shifting to an organic agriculture system. It is a 7-hectare land showcasing different learning modules that integrate the principles of organic agriculture.

2.2 Establishment and improvement of the learning modules

Seven (7) modules at OARDEC were established and improved. These modules provide a structured framework for delivering organic farming education, making complex agricultural concepts accessible and engaging for learners at all levels. These include the aromatic garden, medicinal garden, vegetable garden, organic soil amendments, crop-animal system, agroforestry, and kids' garden.

2.3 Development of learning guides tailored for organic agriculture

The learning guides help enrich and ensure an engaging educational journey for OARDEC's clients. These guides are thoughtfully designed to present key principles, techniques, and benefits of organic farming in a way that is easy to understand and apply. Aligned seamlessly with the learning modules, they ensure consistency and flow in teaching and hands-on activities.

Topics like the proper preparation of organic soil amendments, the 5Cs of organic vegetable production, and organic pest disease and management control are presented clearly, making the content practical and relatable. The learning guides were tailored to suit diverse audiences, including students, teachers, and farmers, ensuring usability across different educational levels and settings.

2.4 Conduct of training sessions

Training sessions were organized to empower students, teachers, farmers, and other stakeholders with the knowledge and skills needed to champion organic agriculture. These sessions were facilitated by experienced agriculture professionals and organic farming practitioners, who shared practical, real-world insights based on their expertise. Through these hands-on and interactive trainings, participants gained the ability to implement organic farming practices in their houses, schools, farms, and communities. The program equipped them with technical skills and inspired them to take on active roles as advocates for organic agriculture, driving positive change toward more sustainable farming methods.

2.5 Organization of Student Immersion and Organic Agriculture Camp

The Organic Agriculture Camp was designed as an interactive and enriching experience where students could immerse themselves in nature. It offered them a chance to put their learning into practice while gaining a deeper appreciation for the role of organic agriculture in sustainability.

3. Results and Discussion

3.1 Showcase of Organic Agriculture Technologies

The OARDEC has successfully improved and implemented a variety of learning modules showcasing organic agriculture technologies. The learning modules cover seven thematic areas, including an aromatic garden, a medicinal plants garden, vegetable production area, organic soil amendments, agroforestry systems, a kids' garden, and crop-animal integration modules. Each module combines theoretical knowledge with practical application, ensuring participants can see and experience the benefits of organic farming firsthand. For instance, the aromatic garden not only teaches plant cultivation but also highlights their culinary and ecological importance; the agroforestry systems, integrated with high value crops, that serves as windbreaker or natural barrier to the Kids' Garden; the organic soil amendments and concoctions that protect the soil from extreme use of synthetic fertilizers and pesticides. These modules provide a platform for the community to connect with nature and learn the environmental benefits of organic agriculture, fostering both awareness and appreciation for sustainable practices. During the implementation of the project, the Center welcomed about

1,400 students and have harvested 300 kilograms of various organic crops. Shown in figure 1 is the top view of the Center locating its various modules.

Figure 1. UPLB Organic Agriculture Research, Development, and Extension Center *(photo courtesy of Dr. Jabez Flores)*

3.1.1 Aromatic Garden: This module showcases a diverse array of aromatic herbs and ornamental plants, including dill, basil, oregano, lemongrass, and tarragon. Also featured are garlic vine and blue ternate for added aesthetic value. Many of these plants not only possess delightful aromas but also offer culinary uses. Citronella, a natural insect repellent, is also cultivated within this module.

Figure 2. Aromatic Garden at OARDEC

3.1.2 MedicinalGarden: this module was established in collaboration with UP Manila – Institute of Herbal Medicine and the National Integrated Research Program on Medicinal Plants (NIRPROMP). This initiative supports a larger goal of producing and distributing affordable, plant-based medicines to enhance public health and contribute to the growth of the Philippine pharmaceutical industry. The OARDEC hosts the experimental and demonstration area where research and cultivation of medicinal plants are conducted. Among the ten medicinal plants under study, Lagundi *(Vitex negundo)* and Sambong *(Blumea balsamifera)* have already reached the market and are now widely available for use. These plants, known for their efficacy in treating respiratory conditions and kidney health respectively, highlight the project's success in bridging scientific research and community health needs. Medicinal plants garden module not only showcases the potential of medicinal plants but also underscores the collaboration between research institutions and agricultural hubs in advancing health and sustainability initiatives.

Figure 3. Medicinal Plants Garden at OARDEC: (a) Experimental/Production Area, and (b) Demonstration area

3.1.3 Vegetable Production Area: this module demonstrates the basic considerations for improving soil health. These include crop diversification, crop rotation, conservation tillage/minimum tillage, cover cropping/mulching, and composting. The vegetable production area used a chessboard plot design for various vegetables, root crops, herbs, and agronomic crops. In addition to serving as an educational tool, this area functions as an experimental and demonstration site for both externally-funded and core-funded projects. Researchers and practitioners use it to test and refine organic farming techniques, ensuring their practical applicability and scalability. The diverse planting strategy also highlights the economic and ecological benefits of crop integration, demonstrating how smallholder farmers can maximize yield and resilience through organic methods.

Figure 4. Vegetable production area of OARDEC

3.1.4 Organic Soil Amendments: this module highlights sustainable practices for enriching soil fertility and reducing dependency to synthetic fertilizers and pesticides. It focuses on using natural inputs such as plant-based compost, organic concoctions, coco coir, vermicast, and other organic matter. These organic amendments improve soil structure, boost nutrient retention, and support beneficial microorganisms, creating an ideal environment for healthy crop growth. It also served as a platform for hands-on learning, where students, teachers, and farmers actively prepared and applied these amendments. The module empowered stakeholders to adopt and advocate for environmentally friendly farming techniques by integrating theoretical knowledge with practical applications.

3.1.5 Crop-Animal Integration: this mini-module demonstrated the synergistic relationship between crops and livestock in an organic agriculture system. This approach focuses on resource recycling, where the residues serve as feed for animals, minimizing farm waste. The stingless bees help in the pollination of the plants and at the same can maximize productivity.

Figure 4. Organic Soil Amendments learning module at OARDEC

Figure 5. Crop-Animal Integration learning module at OARDEC

3.1.6 Agroforestry Systems: This module showcases the integration of trees with agricultural crops to create diverse, sustainable farming landscapes. This system promotes soil improvement because of the nitrogen-fixing trees like *Gliricida sepium;* it enhances biodiversity by providing habitats for various organisms and thus supporting pollinators for and predators of root crops, herbs, and plantation crop; if agroforestry is diverse pests and diseases is more manageable; the canopies of the trees also help in maintaining water retention in the soil leading to sustainable water use; and lastly, agroforestry serves as natural barrier or wind breaker to extreme weather events reducing effects of natural disaster.

3.1.7 Kids' Garden: this module served as a dynamic space where children could learn by doing, engaging in activities like planting seeds, watering plants, and exploring various organisms at OARDEC. The recent addition of a butterfly garden further enriched the module, teaching children about the vital role of pollinators in maintaining ecological balance. It is designed to introduce children to organic farming in a fun, interactive, and educational manner and inspire them to pursue agricultural courses or life sciences in the future. Their appreciation for nature at an early age may instill a sense of responsibility for organic agriculture and environmental stewardship, ensuring that the importance of sustainability resonates with the next generations.

Figure 6. Agroforestry System learning module at OARDEC

Figure 7. Kids' Garden learning module at OARDEC

3.2 Enhanced Capacity Building Among Stakeholders

OARDEC places a strong emphasis on empowering stakeholders through targeted capacity-building programs. These efforts are designed to provide participants with the skills, knowledge, and capacity needed to implement and advocate for organic agriculture in their institutions, communities, and even within their homes. In April 2024, the PASEO-OARDEC project provided the Grade 12 students of Los Baños Senior High School (LBSHS) with an 80-hour student immersion. The immersion program allowed the students to witness and take part at OARDEC operations. They were taught how to plant, harvest, and make organic soil amendments and organic concoctions. They also had the opportunity to develop their skills as tour guides, with guiding tours serving as their final exam. This hands-on task allows them to demonstrate what they have learned from the immersion. Meanwhile, the Teachers' Capability Training on Organic Agriculture (TEACH-OA) teacher-trainees underwent hands-on training on organic concoctions and plant-based fertilizer as a requirement for acquiring a National Certificate in Organic Agriculture Production. The training sessions empowered educators and students to actively promote organic farming, equipping them with the skills and confidence to apply sustainable practices.

Figure 3. 80-hour immersion of Grade 12 students at OARDEC, April 2024

3.3 Created a Platform for Sharing Best Practices and Lessons Learned in Organic Farming

OARDEC established dynamic platforms such as the Organic Agriculture Camp to encourage knowledge exchange and foster collaboration among stakeholders. Held in May 2024, the camp brought together a diverse group of participants, including the PASEO program leader, project staff from the Office of the Chancellor, former OARDEC-ASI staff, and the project's beneficiaries. Attendees included Grade 11-12 students from LBSHS, Bayog Senior High School, and TEACH-OA trainees.

The camp celebrated students' and teachers' dedication and hard work in learning about organic agriculture and *edutourism.* Activities were thoughtfully designed to make the experience both educational and engaging. Highlights included competitions such as jingle-making, poster-making, and best organic vegetable garden, alongside a guided farm tour. These activities tested participants' creativity and knowledge and reinforced their understanding of organic farming principles.

The Office of the Chancellor sponsored prizes for various categories, including Best OA Vegetable Garden, Best OA Poster, Best OA Jingle, and Best OA Tour Guide to further motivate participants. These recognitions acknowledged the participants' efforts and fostered a sense of achievement and pride. Moreover, the camp provided a platform for meaningful interactions among UPLB experts, researchers, teachers, and students. This exchange of ideas and experiences cultivated a spirit of collaboration and mutual learning, strengthening the community’s commitment to advancing organic agriculture. By bridging diverse perspectives and expertise, the camp successfully established a culture of innovation and shared purpose in sustainable farming practices.

Figure 4. Organic Agriculture Camp held at OARDEC on 23 May 2024

4. Conclusion

The success of the project, Promoting Agroforest Stewardship and Ecological Observations (PASEO) program highlights the transformative efforts of integrating agroforestry, *edutourism*, and organic agriculture to address pressing challenges in the agricultural sector. By establishing interactive learning modules and leveraging immersive educational experiences, OARDEC has demonstrated how sustainable practices can be effectively promoted among diverse stakeholders. *Edutourism* is vital in fostering deeper engagement and understanding of sustainable practices provided in OARDEC. Activities like educational tours, event platforms, and practical demonstrations enriched the learning experience while building a sense of sustainability and collaboration among the stakeholders. The agroforestry systems showcased in the program illustrate the synergy between trees, crops, and livestock in creating diverse and sustainable farming landscapes. These systems not only enhance soil health and biodiversity but also serve as natural barriers against extreme weather events, exemplifying their potential to mitigate the impacts of climate change. The agroforestry module also emphasized the ecological and economic benefits of integrating trees with agricultural production, offering valuable lessons for resilience and sustainability.

At the core of these efforts lies organic agriculture. Through modules on organic soil amendments, crop-animal integration, and vegetable production, among others, the program demonstrated the practical benefits of sustainable farming, including reduced reliance on synthetic inputs, a circular economy, and enhanced environmental stewardship.

Ultimately, the PASEO program exemplifies how integrating agroforestry, organic agriculture, and *edutourism* can create a holistic approach to sustainable development. By fostering innovation, collaboration, and knowledge-sharing, these initiatives contribute to the global goals of food security, environmental conservation, and community empowerment, ensuring that sustainability principles resonate across generations.

Acknowledgment

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Carbon Sequestration Potential and Leaf Litter Decomposition of Different Forest Stands at Caraga State University, Ampayon, Butuan City

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Abstract

This study investigated the tree species composition, aboveground biomass, carbon storage, carbon sequestration potential and leaf litter decomposition rates within two areas at Caraga State University (CSU) Main Campus, Ampayon, Butuan City, Agusan del Norte: the CSU-Eco Park and the Clonal Nursery Area. In this study, CSU-Eco Park exhibited higher species diversity with 303 trees and had a higher abundance of Kalumpit *(Terminalia macrocarpa)* (79 trees) because the site is a plantation forest. In contrast, the Clonal Nursery Area exhibited lower species diversity with 212 trees, and Bagras *(Eucalyptus deglupta)* being the most abundant (87 trees) since the area is a plantation site as well with a smaller area. Aboveground biomass, carbon storage, and carbon sequestration potential were estimated. The CSU-Eco Park had a higher total aboveground biomass of 433,692.51 Kg, carbon storage of 216,846.25 Kg C and carbon sequestration potential of 795,825.75 Kg C compared to the Clonal Nursery Area having 45,293.86 Kg, 22,646.93 Kg C and 83,114.22 Kg C, respectively. Together, these areas captured an estimated 878.94 tons of carbon dioxide from the atmosphere. Leaf litter decomposition rates were determined using ANOVA (Analysis of Variance), with treatments being used showing significant difference to each plot. The fastest decomposition rate (0.812 g/week) was observed in plot number 5 of the Clonal Nursery Area. The slowest rate (0.484 g/week) was found in plot number 1 of the control area (Organic Agricultural Training Center). Overall, the Clonal Nursery Area exhibited a decomposition rate of 0.655 g/week, while the CSU-Eco Park had 0.633 g/week, in which the different composition of leaf litters affects the decomposition rates.

Keywords: Biomass, Carbon sequestration, Decomposition rate, Leaf litters, Litter bag experiment

1. Introduction

Forests serves as the habitat of most of the wildlife species and considered as the most important place where biodiversity conservation is implemented. Trees, as one of the basic components of forest, has an important role in conserving, protecting, and sustaining the ecosystem. Trees also play an economic and ecological role as source of food, provides shelter, supplies oxygen, helps in the above-ground carbon sequestration and, water and nutrient cycling. Trees drop their leaves and other physiological parts, as a natural response to changing seasons and environmental conditions, this process known as abscission. And leaves dropping due to aging is known as senescence, leaves dropped by these processes are called leaf litter (Amendolare, 2023).

Carbon sequestration occurs in different ecosystems including wetlands, oceans, and soils, but most importantly, in forests. It is a crucial process that plays a pivotal role in mitigating the impacts of climate change by capturing and storing atmospheric carbon dioxide in natural or artificial reservoirs. This process is vital for reducing the concentration of greenhouse gases in the atmosphere, which helps to combat global warming and its associated environmental and societal challenges. (Prajapati et al., 2023). Carbon sequestration is a critical and innovative approach to addressing the escalating challenge of global climate change (Intergovernmental Panel on Climate Change 2021).

Plant leaf litter decomposition provides a source of energy and nutrients in forest ecosystems (Zhao et al., 2022). The rate of leaf litter decomposition is affected by factors like temperature, moisture content etc., together with the presence of microorganisms in the soil also affects the rate decomposition (Krishna & Mohan, 2017). Leaf litter decomposition rates are a function of litter quality, biota, and microclimate, as well as edaphic properties (Heneghan et al., 1998). In litter decomposition, it undergoes with different methods and approaches that can be applied to test its decomposition rate. The most applicable method for this experiment is the Litter-Bag Experiment. According to the study conducted by Palosuo et al. (2005), litterbag experiments provide valuable data for testing the accuracy of the predictions of decomposition. Litterbag experiments are used to study the decomposition of organic matter, such as plant material in various ecosystems, which helps researchers understand the dynamics of nutrients cycling and carbon sequestration (Moorhead et al., 2013).

Caraga State University-Main Campus is situated at Barangay Ampayon, Butuan City, which has a 17-year-old Biodiversity Demonstration Forest used for attraction and home to Philippine premium species and a clonal nursery area for macro-propagation and seedling production. The forest is about 1.5 hectares in area which showcases Philippine Dipterocarp species, it was established before 2006 with more than 300 trees comprising around 10 dipterocarp tree species were planted. And a clonal nursery area of about 0.62 hectares. Trees in CSU-Eco Park offer invaluable services not only to the instructors and students in the academe, but also, to the wildlife that inhabits there. On the other hand, the clonal area offers not only for propagation of different sorts but also has a designated area for tree stand establishment, which in this case, the Bangkal *(Nauclea orientalis)* and Bagras *(Eucalyptus deglupta)* stands. Above all, these trees have a significant impact in sequestering aboveground carbon dioxide while at the same time naturally drops leaf litters. These two areas were man-made forests and are used for field laboratory activities of forestry students. CSU-Eco Park is composed of Philippine native tree species while the clonal nursery host plantation species of *N. orientalis* and *E. deglupta.* To date, there are no studies conducted in CSU-Eco Park and clonal nursery regarding carbon sequestration potential and decomposition rates. Hence, this study was conducted to determine the aboveground biomass of trees, their carbon stored, and their potential amount of carbon stored, while at the same time investigate the rate of leaf litter decomposition of the different tree stands within CSU-Eco Park and clonal nursery area respectively. This also generated a list of tree species found in CSU- Eco Park and clonal nursery area, together with the tree information that can be utilized for carbon sequestration potential computation. Furthermore, the findings of this study can be utilized to craft better conservation and development plans for the site for the institution's future endeavors.

2. Methodology

2.1 Location of the study

The Eco Park and clonal nursery resides within the premises of Caraga State University-Main Campus which lies at N8.95506, E125.596718 and N8.9529013, E125.5986900 respectively, which are located at Barangay Ampayon, Butuan City, Agusan del Norte in the northern part of Mindanao, Philippines. CSU-Eco Park has an estimated land area of 1.5 hectares which constitutes 0.86% of the total land area of Caraga State University-Main Campus, which is 232 hectares, considered as an artificial forest. Clonal nursery area has an estimated area of about 0.62 hectares, which constitutes about 0.27% of the total land area of CSU-Main Campus which is a tree plantation forest. Barangay Ampayon is one of the 86 barangays covered by the administrative boundary of Butuan City which has a land area of 642.62 hectares. The study site (CSU-Eco Park and Clonal Nursery) belongs to a region that has no pronounced wet and dry season which has heavy rains occurring in the months of November to February (PAGASA, 2016). The study was conducted during the Philippine dry season from March to April 2024.

Figure 1. Map showing the study area within CSU-Main Campus, Eco Park (Orange bordered area) and clonal nursery (Red bordered area), Ampayon, Butuan City

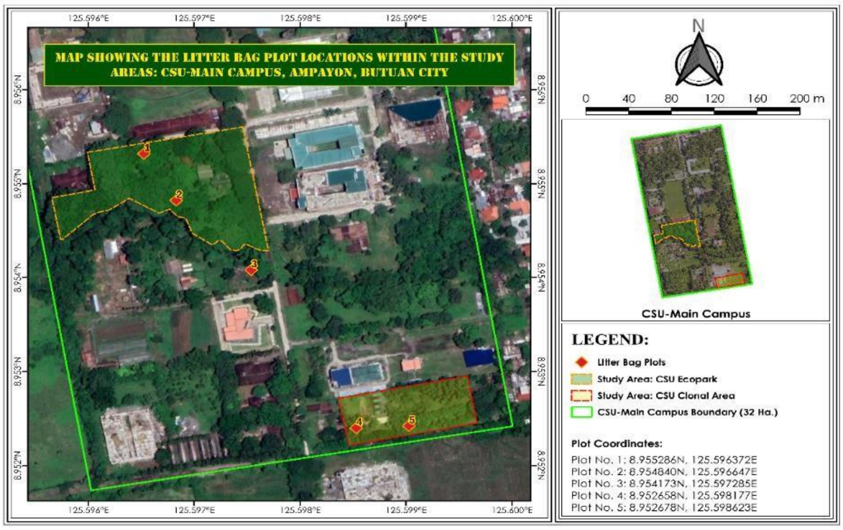

Figure 2. Map showing geotagged leaf litter plots location within the study sites, CSU-Main Campus, Ampayon, Butuan City.

2.2 Research instruments and data gathering procedure

2.2.1 Species Composition and Distribution, Aboveground Biomass, Carbon Stored and Carbon Sequestering Potential

In this study, the researchers used a variety of tools and/or instruments. For studying aboveground biomass of different forest stands in CSU-Main which then be used as the main element to compute for the carbon stored and carbon sequestration potential, the researchers used: tree caliper and/or calibrated diameter tape to obtain the Diameter at Breast Height (DBH) and Diameter Above Buttress (DAB) of standing trees; electronic hypsometer to determine the precise total height of trees; GPS receiver to obtain tree and plot coordinates; field notes for recording data. The CSU-Main Campus Eco-Park and Clonal Nursery Area were chosen as the study site. The researchers conducted a one hundred (100) percent inventory of all trees within the chosen study sites in accordance with the qualification of DENR FMB Technical Bulletin No.3. All identified trees were measured according to its Diameter at Breast Height (DBH) and/or Diameter Above Buttress (DAB), Tree Height (total height) and tree species wood. Density was identified as well. Using the best model formula for estimating Above Ground Biomass (AGB) developed by Aabeyir et al. (2020).

2.2.2 Rate of Leaf Litter Decomposition

For the determination of the rate of decomposition, the materials used are Straw thread that serves as a safety measure and serves as boundary of the sampling plot; litter bags; tape measure for measuring plot dimensions and field notes are used for data recording.

The researchers established 5 (five) sampling plots measuring 1 meter by 1 meter. Each sampling plot was utilized in collecting leaf litter and were placed in 5 (five) litter bags, excluding other debris, for a total of 25 (twenty-five) litter bags. Leaf litter collected in the sampling plots was washed first to remove adhering soil and undergoes 1 day of air drying. Those air- dried leaves were placed inside the litter bags with the size of 20 cm by 20 cm weighing 10 grams each (Trofymow & CIDET Working Group, 1998).

Twenty-five (25) leaf litter bags were grouped in which each group consists of 5 (five) leaf litter bags. Each group of litter bags were placed according to which sampling plots it was collected. Litter bags were coded by placing a number of tapes in tie-wires to easily identify which group it belongs to and then left in the plots over the course of three (3) weeks. After which, it was then collected. Litterbags being collected were washed first to remove the adhering soil. Furthermore, the clean and dry litter is wrapped in aluminum foil and oven dried at temperature of eighty (80) degrees Celsius for forty-eight (48) hours (Darmawan, 2021). After oven drying, those samples of leaf litter were weighed and recorded and analyzed.

The letter to conduct for this study was sent personally to the College Dean's Office and coordinated with the College of Forestry and Environmental Sciences, for assistance regarding the research instruments that are used.

2.3 Quantification of Data

The following are the formula used to quantify the data:

All trees according to the qualification of DENR FMB Technical Bulletin No. 3 should measure in terms of DBH, 1.3 meters above the ground and DAB 0.3 meters above the buttress using tree caliper. The tree height was measured using hypsometers. All trees were identified, marked, and tallied which then subjected to analysis and discussion.

2.4 Aboveground Biomass:

According to Aabeyir et al. (2020), that the best model for estimating AGB (Above Ground Biomass) in the tropical woodlands is:

$$\text{AGB} = 0.0580\ \rho\ [(dbh)^2(H)^{0.999}]$$

where ρ is specific density of the wood, *dbh* is diameter of the tree at breast height and *H* is the total height of the tree

2.4.1 List of wood density within CSU-Main Eco Park and Clonal Nursery

Table 1 below shows the list of trees species found within the selected study area. Through the works of Reyes et al. 1992, World Agroforestry Organization and Izabal Wood Co. Member of the Izabal Group, identified tree species have the following corresponding wood densities.

Table 1. Lists of trees species found within the selected study area and their identified corresponding wood densities.

Tree No	Common Name	Scientific Name	Family Name	Specific Density (ρ)
1.	Agoho	*Casuarina equisetifolia*	Casuarinaceae	0.83
2.	Anislag	*Flueggea flexuosa*	Phyllanthaceae	0.81, 0.96
3.	Antipolo	*Artocarpus blancoi*	Moraceae	0.43
4.	Bagras	*Eucalyptus deglupta*	Myrtaceae	0.34
5.	Bagtikan	*Parashorea malaanonan*	Dipterocarpaceae	0.51
6.	Balobo	*Diplodiscus paniculatus*	Malvaceae	0.63
7.	Baluno	*Mangifera caesia*	Anacardiaceae	0.52 *(Mangifera sp.)*
8.	Bangkal	*Nauclea orientalis*	Rubiaceae	0.56
9.	Bani	*Milletia pinnata*	Fabaceae	0.72 *(Militia sp.)*
10.	Brazilian Firetree	*Schizolobium parahyba*	Fabaceae	0.32
11.	Caimito	*Chrysophyllum cainito*	Sapotaceae	0.70
12.	Coconut	*Cocos nucifera*	Arecaceae	0.50
13.	Dao	*Dracontomelon dao*	Anacardiaceae	0.52
14.	Eugenia	*Syzygium myrtifolium*	Myrtaceae	0.69, 0.76+ *(Syzygium sp.)*
15.	Ficus sp.	-----	Moraceae	0.39
16.	Gisok-gisok	*Hopea philippensis*	Dipterocarpaceae	0.64 *(Hopea sp.)*
17.	Hagakhak	*Dipterocarpus validus*	Dipterocarpaceae	0.61 *(Dipterocarp sp.)*
18.	India Rubber Tree	*Ficus elastica*	Moraceae	0.39 *(Ficus sp.)*
19.	Jackfruit	*Artocarpus heterophyllus*	Moraceae	0.60
20.	Kalamansanai	*Terminalia calamansanai*	Combretaceae	0.50, 0.51, 0.58+ *(Terminalia sp.)*
21.	Kalumpit	*Terminalia microcarpa*	Combretaceae	0.53
22.	Kamagong	*Diospyros blancoi*	Ebenaceae	0.70 *(Diospyros sp.)*
23.	Lamog	*Planchonia spectabilis*	Lecythidaceae	0.58

Table 1. (Continued)

Tree No	Common Name	Scientific Name	Family Name	Specific Density (ρ)
24.	Large Leaf Mahogany	*Swietenia macrophylla*	Meliaceae	0.42, 0.55
25.	Malaboho	*Sterculia oblongata*	Malvaceae	0.61
26.	Mangga	*Mangifera indica*	Anacardiaceae	0.52, 0.59+
27.	Manggasinoro	*Shorea assamica*	Dipterocarpaceae	0.41
28.	Manila Palm	*Adonidia merrillii*	Arecaceae	0.50 *(Cocos sp.)*
29.	Marang Banguhan	*Artocarpus odoratissimus*	Moraceae	0.58 *(Artocarpus sp.)*
30.	Molave	*Vitex parviflora*	Lamiaceae	0.70
31.	Paper mulberry	*Broussonetia papyrifera*	Moraceae	0.51
32.	Rain Tree	*Samanea saman*	Fabaceae	0.45, 0.46+
33.	Sampalok	*Tamarindus indica*	Fabaceae	0.75
34.	Santol	*Sandoricum koetjape*	Meliaceae	0.44
35.	Smooth Narra	*Pterocarpus indicus f. indicus*	Fabaceae	0.52
36.	Talisay Dagat	*Terminalia catappa*	Combretaceae	0.50, 0.51, 0.58+ *(Termanilia sp.)*
37.	Tanguile	*Shorea polysperma*	Dipterocarpaceae	0.47
38.	Tibig	*Ficus nota*	Moraceae	0.39 *(Ficus sp.)*
39.	Tuai	*Bischofia javanica*	Euphorbiaceae	0.54, 0.58, 0.62+
40.	White Lauan	*Pentacme contorta*	Dipterocarpaceae	0.44
41.	Yakal Kaliot	*Hopea malibato*	Dipterocarpaceae	0.73
42.	Yemane	*Gmelina arborea*	Lamiaceae	0.41, 0.45+
43.	Ylang-ylang	*Cananga odorata*	Annonaceae	0.29

2.4.2 Carbon Stored

The carbon stored in each tree, expressed by the weight of tree, called tree biomass, it is defined as the amount of standing organic matter per unit area. Biomass is converted to carbon by using conversion factors. The amount of carbon in each tree is approximately 50% from the total aboveground biomass (Hirata et al., 2012). With that, the conversion of biomass to carbon was calculated by applying the conversion factor of 0.5 based on the following equation:

$$C_{(kg/tree)} = AGB * CF$$

where C is the carbon stock in kilogram per tree, where AGB is the aboveground biomass (kg/tree), and CF is the carbon fraction

2.4.3 Carbon Sequestration Potential

The weight of CO_2 produced in burning carbon is determined by the factor of CO_2 unit in every carbon equivalent released to the atmosphere which is C_{eq} unit = CO_{2eq} unit= 3.67 (44/12, respectively). When carbon is converted into carbon dioxide the factor is 3.67.

Carbon has molecular weight of 12.01 and oxygen has a molecular weight of 15.999, since carbon if burned is transformed into CO_2 which has a molecular weight of 44, then 44/12=3.67. This was also adapted from Fransen (2019).

$$W_{CO2} = 3.67 * W_{carbon}$$

2.4.4 Mass Loss of Litter and Rate of Decomposition

According to Darmawan (2021), the calculation of the mass loss of litter uses the following formula:

$$L\ (\%) = \frac{(Wo - Wt)}{Wo} \times 100$$

where L is the mass loss of litter (%), W_o is the litter weight before the study started (gram) and W_t is the dry weight of litter left after time (t) (gram)

The litter decomposition rate is calculated using the following formula:

$$R = \frac{Wo - Wt}{T}$$

where R is the decomposition rate (g/week), T is the time of observation (week), W_o is the initial dry weight of litter (gram), W_t is the final dry weight of litter (gram).

The formula for litter mass remaining rate (R%) is as follows:

$$MR = \frac{Wt}{Wo} \times 100$$

where MR is the litter mass remaining rate (gram/week), W_o is the initial dry weight of litter (gram), W_t is the final dry weight of litter (gram)

2.5 Data Analysis

The data gathered for Aboveground Biomass, Carbon Stored and Carbon Sequestration Potential were recorded and analyzed in MS Excel. The researchers used Analysis of Variance (ANOVA) test to examine the differences in mass loss and rate of decomposition between plots (Zhao et al., 2022), and proceeded to do a post-hoc test to determine the significant difference of each plot through the use of STAR (Statistical Tool for Agricultural Research) software.

3. Results and Discussion

3.1 Species composition and Distribution of Tree species

Table 2 shows that within CSU-Eco Park, the study recorded three hundred three (303) total tree species, where Kalumpit (*Terminalia microcarpa*) has the highest total number of trees (79 tree species), than other tree species, this is due to the fact that the area was an initial plantation site, whereas the lowest numbers are: Baluno (*Mangifera caesia)*, Eugenia (*Syzygium myrtifolium)*, India Rubber Tree (*Ficus elastica)*, Manila Palm (*Adonidia merrillii*) Marang Banguhan (*Artocarpus odoratissimus)*, Sampalok (*Tamarindus indica)*, Talisay Dagat (*Terminalia catappa)*, Tibig (*Ficus nota)*, White Lauan (*Pentacme contorta)*, Yakal-Kaliot (*Hopea malibato)*, and Ylang-ylang *(Cananga odorata)* with only 1 (one) species present in the area.

Table 2. Tree species found within CSU-Eco Park and their corresponding species composition.

Species	Scientific Name	Number Trees
Antipolo	*Artocarpus blancoi*	3
Bagtikan	*Parashorea malaanonan*	37
Balobo	*Diplodiscus paniculatus*	14
Baluno	*Mangifera caesia*	1
Brazilian Firetree	*Schizolobium parahyba*	2
Caimit	*Chrysophyllum cainito*	30
Coconut	*Cocos nucifera*	19
Dao	*Dracontomelon dao*	27
Eugenia	*Syzygium myrtifolium*	1
Gisok-gisok	*Hopea philippinensis*	2
Hagakhak	*Dipterocarpus validus*	5
India Rubber Tree	*Ficus elastica*	1
Jackfruit	*Artocarpus heterophyllus*	3
Kalumpit	*Terminalia microcarpa*	79
Kamagong	*Diospyros discolor*	2
Lamog	*Planchonia spectabilis*	2
Large Leaf Mahogany	*Swietenia macrophylla*	7
Mangga	*Mangifera astylosa*	10
Manggasinoro	*Shorea assamica*	3

Table 2. (Continued)

Species	Scientific Name	Number Trees
Manila Palm	*Adonidia merrillii*	1
Marang Banguhan	*Artocarpus odoratissimus*	1
Miscellaneous	*Ficus sp.*	1
Molav	*Vitex parviflora*	27
Paper mulberry	*Broussonetia papyrifera*	2
Rain Tree	*Samanea saman*	4
Sampalok	*Tamarindus indica*	1
Santol	*Sadoricum koetjape*	5
Smooth Narra	*Pterocarpus indicus*	2
Talisay Dagat	*Terminalia catappa*	1
Tanguile	*Shorea polysperma*	2
Tibig	*Ficus nota*	1
White Lauan	*Pentacme contorta*	1
Yakal Kaliot	*Hopea malibato*	1
Yemane	*Gmelina arborea*	4
Ylang-ylang	*Cananga odorata*	1
TOTAL		**303**

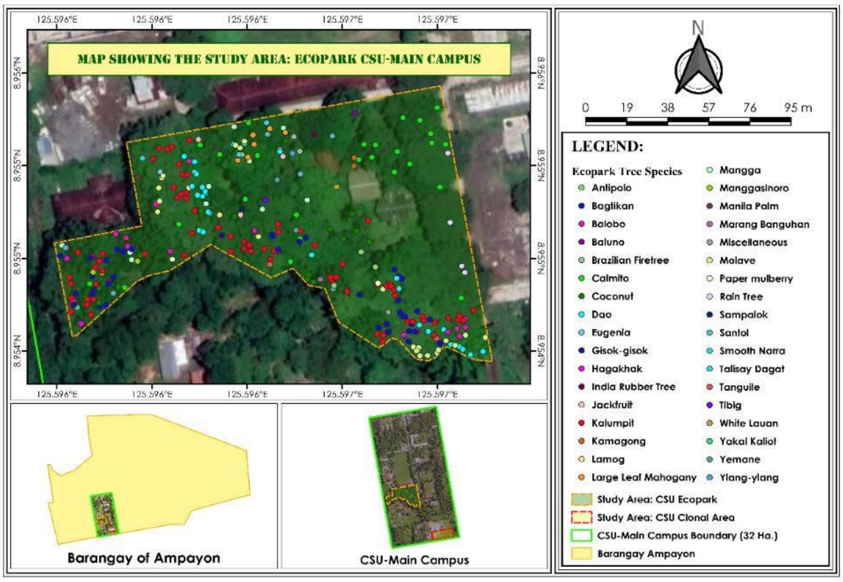

Figure 3. Map showing geotagged tree species within the study site, CSU-Eco Park.

In this study, table 3 shows that within the Clonal nursery area, there are two hundred twelve (212) total tree species where Bagras *(Eucalyptus deglupta)* has the highest number of 87 tree species, due to the reason that the area is a plantation site were undesirable tree species are removed favoring Bagras. Whereas, Anislag (*Flueggea flexuosa)*, Balobo (*Diplodiscus paniculatus)*, and Malabuho (*Sterculia oblongata)* with only 1 (one) species present in the area.

Table 3. Tree species found within Clonal nursery area and their species composition.

Species	Scientific Name	Number of Trees
Agoho	*Casuarina equisetifolia*	3
Anislag	*Flueggea flexuosa*	1
Antipolo	*Artocarpus blancoi*	2
Bagras	*Eucalyptus deglupta*	87
Balobo	*Diplodiscus paniculatus*	1
Bangkal	*Nauclea orientalis*	59
Bani	*Pangamia pinnata*	3
Kalamansanai	*Terminalia calamansanai*	2
Kalumpit	*Terminalia microcarpa*	6
Large Leaf Mahogany	*Swietenia macrophylla*	6
Malabuho	*Sterculia oblongata*	1
Smooth Narra	*Pterocarpus indicus*	10
Tuai	*Bischofia javanica*	19
Yemane	*Gmelina arborea*	12
TOTAL		**212**

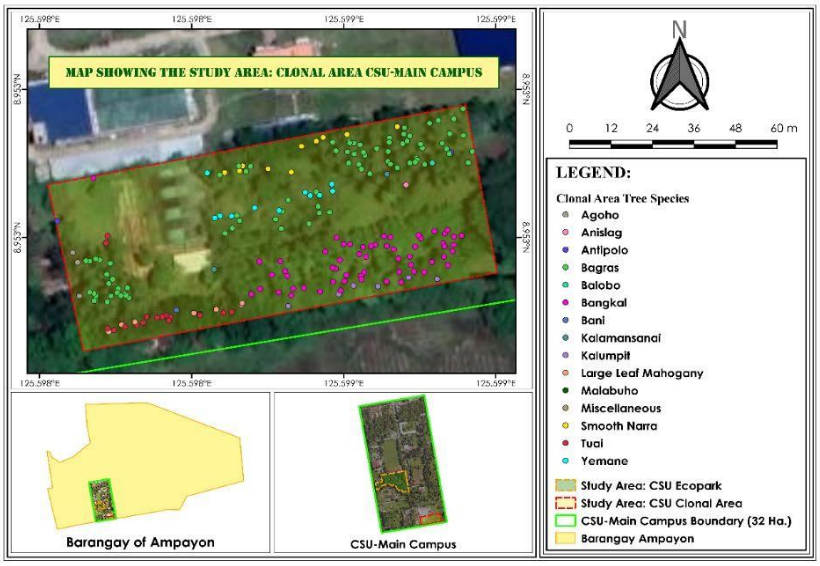

Figure 4. Map showing geotagged tree species within the study site, Clonal Nursery Area.

3.2 Aboveground Biomass, Carbon Stored and Carbon Sequestration Potential

This study recorded three hundred three (303) total number of tree species within the CSU-Eco Park as shown in table 4. The computations show that the area has a total aboveground biomass of 433,692.51 Kg, which has a total carbon stored of 216,846.25 Kg C, and has a total carbon sequestration potential of 795,825.75 Kg C.

Table 4. Tree species found within CSU-Eco Park and their corresponding total aboveground biomass, total carbon stored and total carbon sequestration potential.

Species	Scientific Name	Number of Trees	Total Aboveground Biomass (Kg)	Total Carbon Stored (Kg C)	Total Carbon Sequestration Potential (Kg C)
Antipolo	*Artocarpus blancoi*	3	2,768.79	1,384.39	5,080.73
Bagtikan	*Parashorea malaanonan*	37	17,885.26	8,942.63	32,819.44
Balobo	*Diplodiscus paniculatus*	14	2,584.61	1,292.30	4,742.76
Baluno	*Mangifera caesia*	1	6,168.03	3,084.01	11,318.33
Brazilian Firetree	*Schizolobium parahyba*	2	392.16	196.08	719.62
Caimito	*Chrysophyllum cainito*	30	46,817.56	23,408.78	85,910.23
Coconut	*Cocos nucifera*	19	12,071.43	6,035.71	22,151.07
Dao	*Dracontomelon dao*	27	46,203.38	23,101.69	84,783.20
Eugenia	*Syzygium myrtifolium*	1	160.23	80.12	294.03
Gisok-gisok	*Hopea philippinensis*	2	219.65	109.83	403.06
Hagakhak	*Dipterocarpus validus*	5	1,787.83	893.92	3,280.67
India Rubber Tree	*Ficus elastica*	1	5,264.82	2632.41	9,660.95
Jackfruit	*Artocarpus heterophyllus*	3	1,071.97	535.99	1,967.07
Kalumpit	*Terminalia microcarpa*	79	220,211.92	110,105.96	404,088.86
Kamagong	*Diospyros discolor*	2	304.49	152.24	558.74
Lamog	*Planchonia spectabilis*	2	186.62	93.31	342.45

Table 4. (Continued)

Species	Scientific Name	Number of Trees	Total Aboveground Biomass (Kg)	Total Carbon Stored (Kg C)	Total Carbon Sequestration Potential (Kg C)
Large Leaf Mahogany	*Swietenia macrophylla*	7	4,949.66	2,474.83	9,082.63
Mangga	*Mangifera astylosa*	10	14,884.56	7,442.28	27,313.16
Manggasinoro	*Shorea assamica*	3	201.63	100.82	369.99
Manila Palm	*Adonidia merrillii*	1	66.48	33.24	121.98
Marang Banguhan	*Artocarpus odoratissimus*	1	581.27	290.63	1,066.63
Miscellaneous	*Ficus sp.*	1	1,663.35	831.68	3,052.26
Molave	*Vitex parviflora*	27	8,156.82	4,078.41	14,967.77
Paper mulberry	*Broussonetia papyrifera*	2	448.59	224.30	823.16
Rain Tree	*Samanea saman*	4	1,6638.69	8,319.34	30,531.99
Sampalok	*Tamarindus indica*	1	832.29	416.15	1,527.25
Santol	*Sadoricum koetjape*	5	7,147.02	3,573.51	13,114.78
Smooth Narra	*Pterocarpus indicus*	2	5,608.99	2,804.50	10,292.50
Talisay Dagat	*Terminalia catappa*	1	88.19	44.09	161.82
Tanguile	*Shorea polysperma*	2	917.14	458.57	1,682.95
Tibig	*Ficus nota*	1	94.30	47.15	173.04
White Lauan	*Pentacme contorta*	1	90.51	45.25	166.08
Yakal Kaliot	*Hopea malibato*	1	168.42	84.21	309.05
Yemane	*Gmelina arborea*	4	5,788.82	2,894.41	10,622.49
Ylang-ylang	*Cananga odorata*	1	1,267.02	633.51	2,324.98
TOTAL		**303**	**433,692.51**	**216,846.25**	**795,825.75**

Additionally, at clonal nursery area, this study has recorded two hundred twelve (212) tree species as shown in table 5. Findings showed that the clonal nursery area have a total aboveground biomass of 45,293.86 Kg, which has as total carbon stored of 22,646.93 Kg C, and has a total carbon sequestration potential of 83,114.22 Kg C.

Table 5: Tree species found within Clonal nursery area and their corresponding total aboveground biomass, total carbon stored and total carbon sequestration potential.

Species	Scientific Name	Number of Trees	Total Aboveground Biomass (Kg)	Total Carbon Stored (Kg C)	Total Carbon Sequestration Potential (Kg C)
Agoho	*Casuarina equisetifolia*	3	2,681.21	1,340.61	4,920.02
Anislag	*Flueggea flexuosa*	1	127.64	63.82	234.22
Antipolo	*Artocarpus blancoi*	2	357.63	178.82	656.25
Bagras	*Eucalyptus deglupta*	87	16,069.07	8,034.53	29,486.74
Balobo	*Diplodiscus paniculatus*	1	80.32	40.16	147.37
Bangkal	*Nauclea orientalis*	59	9,184.57	4,592.29	16,853.69
Bani	*Pangamia pinnata*	3	257.29	128.65	472.13
Kalamansanai	*Terminalia calamansanai*	2	2,202.99	1,101.49	4,042.48
Kalumpit	*Terminalia microcarpa*	6	2,628.69	1,314.34	4,823.64
Large Leaf Mahogany	*Swietenia macrophylla*	6	2,578.05	1,289.02	4,730.73
Malabuho	*Sterculia oblongata*	1	44.98	22.49	82.53
Smooth Narra	*Pterocarpus indicus*	10	2,353.50	1,176.75	4,318.68
Tuai	*Bischofia javanica*	19	3,179.26	1,589.63	5,833.94
Yemane	*Gmelina arborea*	12	3,548.67	1,774.33	6,511.80
TOTAL		**212**	**45,293.86**	**22,646.93**	**83,114.22**

From the study conducted by Adair et al., (2020) showed that a rise in plant diversity led to a significant increase in aboveground biomass by 51%. The study found that forests with greater species richness and diversity stored more carbon in their biomass compared to those with lower diversity.

The results indicate that, CSU-Eco Park has the highest number of aboveground biomass, carbon stored and carbon sequestration potential (433,692.51 Kg, 216,846.25 Kg C, 795,825.75 Kg C, respectively), this is because, the area is initially a plantation site and has an area of approximately 1.5 hectares with 303 recorded tree species. Compared to the clonal nursery area which is an established plantation site and has an estimated area of 0.62 hectares with only 212 recorded tree species thus gives 45,293.86 Kg, 22,646.93 Kg C, 83,114.22 Kg C, accordingly.

From the study of Agbelade & Onyekwelu (2020), tree species diversity has greater impact on biomass accumulation which determines carbon sequestration. Altogether, the CSU-Eco Park and Clonal nursery area is 2.12 hectares in total, its combined Aboveground Biomass is 478,986.37 Kg, while its Carbon stored is 239,493.18 Kg C and its carbon sequestration potential is 878,939.98 equivalent Kg of Carbon. According to Ecometrica (2011), a one-ton carbon tree locks up around 3.67 tons of carbon dioxide from the atmosphere. If 878,939.98 Kg of C is converted to tons, then, CSU-Eco Park and Clonal nursery area therefore holds 878.94 tons of CO_2 in the atmosphere.

3.2 Rate of Decomposition of Tree Leaf Litters Between Plots

Table 6 below shows the different rate of decomposition of each plot. Plot number 5 (a) had a higher decomposition rate across all plots (0.812 grams/week), which is then followed by plot number 2 (ab) of 0.71 grams/week, plot number 3 (bc) with 0.550 grams/week, plot number 4 (c) with 0.498 grams per week, and lastly, plot number 1 with 0.484 grams per week (c). The different composition of leaf litter affects the rate of decomposition on each plot which leads to the recording of different rate of decomposition. Leaf decomposition varies depending on the type of leaf which the litter bag is composed of (Liu et al., 2015). This is also supported with the study of Schmidt et al. (2011) discussed how the chemical composition of litter, including the C:N ratio and lignin content, can affect decomposition rates. Chemical makeup of organic matter significantly influences its decomposition rate in soil (Liu and Sun, 2013). And particle size can affect on decomposition rate of organic matter in soil (Angers and Recous, 1997).

Plot number 1 in the control area, located at Organic Agricultural Training Center (OATC) communal garden, composed of tree species of Sablot (*Litsea glutinosa*), Santol (*Sandoricum koetjape*) and Alangas (*Ficus heteropoda*). Plot number 2 with the same location as plot number 3 located at CSU-Eco Park is dominated/surrounded by Narra (*Ptercarpus indicus)*, Large Leaf Mahogany (*Swietenia macrophylla)* and Kalumpit (*Terminalia macrocarpa)*. Plot number 3 isdominated/surrounded by Hagakhak *(Dipterocarpus validus)*, Bagtikan (*Parashorea malaanonan)* and Dao (*Dracontamelon dao)*. Plot number 4 with the same location as plot number 5 is composed and perfectly dominated by Bagras *(Eucalyptus deglupta)* stand. Finally, plot number 5 is composed/surrounded by the tree species of Talisay-dagat (*Terminalia catappa)*, and mostly dominated by Bangkal (*Nauclea orientalis)*. The treatments used shows a significant difference across plots with a p-value of 0.0147, except for plot number 1 (c) of Control area and plot number 4 (c) of Clonal nursery area, which shows no significant difference between the two plots as shown in the table below.

Table 6. Summary table of leaf litter decomposition rates across the study sites, in grams within 3 weeks-time (March 17 – April 10, 2024) and ANOVA test result.

Study Sites	Plot no.	Samples (g)					Mean (g)	N Group
Control area	1	8.76	8.42	8.92	8.50	8.15	0.4840	5c
CSU-Eco Park	2	7.27	7.57	7.58	8.80	8.04	0.7160	5ab
	3	8.56	9.10	7.62	8.11	8.34	0.5500	5bc
Clonal Nursery Area	4	8.37	8.59	8.77	8.24	8.55	0.4980	5c
	5	7.68	7.87	7.03	8.09	7.15	0.8120	5a

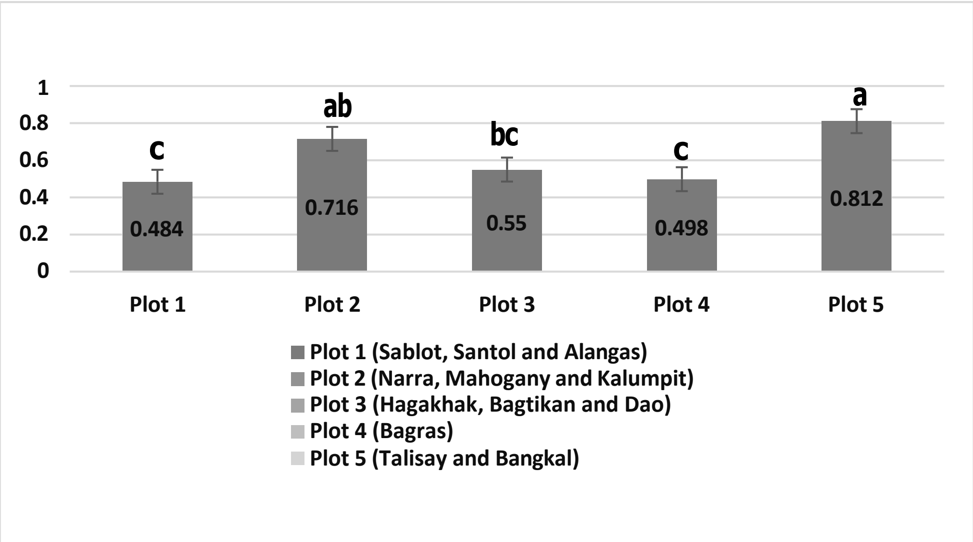

Figure 5. Decomposition rate between plots

3.3 Rate of Decomposition of Tree Leaf Litters Between Study Areas

Figure 6 below shows the individual average decomposition rates between the study sites: CSU Eco Park, clonal nursery area, and the control area. The decomposition rates are as follows: 0.655 grams/week was recorded in Clonal nursery area. The Clonal nursery area is composed of plot numbers 4 and 5; CSU-Eco Park plots have a rate of decomposition of 0.633 grams/week which is composed of plot numbers 2 and 3; Finally, the control area has recorded484 grams/week rate of decomposition, which is represented by plot number 1. The leaf litter composition affects the decomposition rate. Study of Wu et al., (2013), stated that tree species composition and decomposition duration should be considered in determining the rate of decomposition. Decomposition of organic matter in soils is an important part of ecological processes. According to Lin (2012) leaf litter is an important component of healthy soil. Decomposing leaf litter releases nutrients into the soil and keeps it moist. It also serves as great nesting material, hiding places and protected spots for animals and microorganism.

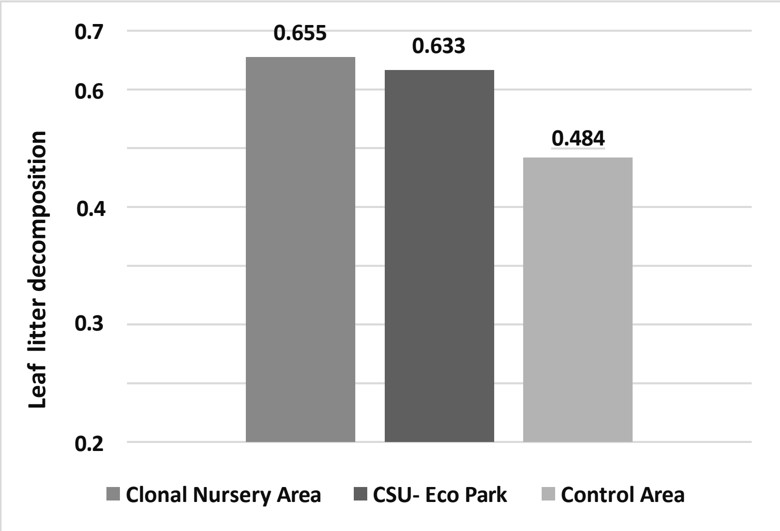

Figure 6. Average Rate of Decomposition of Leaf litter, CSU-Eco Park, Clonal Nursery Area, and Control area OATC.

4. Conclusion and Recommendation

Trees are the best carbon capture technology in the world, consequently forests capture and store different amounts of carbon at different speeds depending on the average age of the trees and the number of trees in the stand. In this study, the researchers came up with a conclusion that the greater the tree biomass of an area, the higher its carbon stored and carbon sequestration potential than a forest area composed with almost similar tree species. However, calculation based only on the carbon sequestration potential of a particular area does not provide a comprehensive notion about the overall ecological service of an area. Altogether, the CSU-Eco Park had a higher tree species composition and distribution than the Clonal nursery area. These study sites have a combined carbon sequestration potential of 878,939.98 Kg of C, which can therefore hold 878.94 tons of CO_2 in the atmosphere. On the other hand, the researchers were able to identify the rate of decomposition of the study areas in which plot number 5 located at clonal nursery area has the fastest rate of decomposition than all other plots, with plot number 1 at OATC communal garden the slowest decomposition rate. Relatively, the clonal nursery area also exhibits a faster decomposition rate across all study sites. However, it did not explicitly examine the relationship between carbon sequestration and leaf litter decomposition because of certain limitations of the study. To further enhance the understanding of this interplay, future research should specifically focus on examining the impact of varying decomposition rates on the carbon sequestration capacity of different forest ecosystems.

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Agroforestry as a Win-Win Solution: Promoting Biodiversity, Carbon Storage, and Sustainable Livelihoods in Mankayan Watershed, Philippines

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Abstract

This study investigates the potential of agroforestry systems in Mankayan Watershed, Benguet, Philippines, to enhance diversity and carbon sequestration. Field data on plant diversity and carbon storage across different land uses were collected and analyzed. Results revealed that biodiversity in agroforestry systems using Shannon Diversity Index (H’ = 3.39) is higher than in pine forest (H’= 2.68), grasslands (H’ = 2.45), and vegetation near built-up areas (H’ = 2.99). This high biodiversity in agroforestry systems indicates a resilient ecosystem capable of supporting various plant and animal species. Carbon data showed that the aboveground biomass density (AGB D) in the study area was 13.67 Mg/ha, with a carbon density of 6.83 MgC/ha. Agroforestry practices were found to significantly improve carbon sequestration compared to other land uses, as the integration of trees, agricultural crops, and other fruit tree species in agroforestry systems contributes to higher aboveground biomass and carbon storage, enhancing the overall carbon density of the area. These agroforestry systems not only promote biodiversity but also improve watershed health through soil stabilization, reduced erosion, and enhanced water infiltration. Additionally, agroforestry provides vital ecosystem services in the study area like food, timber, and non-timber products, supporting local livelihoods particularly the indigenous peoples of Mankayan. These findings highlight the significant potential of agroforestry for carbon sequestration, biodiversity enhancement, and watershed conservation in Mankayan. Implementing agroforestry fosters sustainable landscapes, achieving both environmental and socio-economic goals. This study encourages policymakers and land managers to adopt agroforestry as a key strategy for climate change mitigation and rural development.

Keywords: Agroforestry, Biodiversity, Conservation, Sustainability, Watershed

1. Introduction

Agroforestry has emerged as a promising strategy for promoting biodiversity, enhancing carbon storage, and fostering sustainable livelihoods in ecologically sensitive areas like the Mankayan Watershed in Benguet, Philippines. Compared to traditional upland farming practices such as *Kaingin* or slash-and-burn (Calitang and Orpiano, 2023) —known for contributing to deforestation and soil degradation— agroforestry systems offer an environmentally friendly alternative. Integrating trees with crops not only supports biodiversity and carbon storage but also contributes significantly to watershed health by stabilizing soil, reducing erosion, and enhancing water infiltration (Lasco et al., 2016).

Agroforestry approach is particularly relevant for Mankayan, a mineral-rich watershed with existing large- and small-scale mining activities, and home to Indigenous Cultural Communities (ICCs) and Indigenous Peoples (IPs). Mining operations can severely degrade the environment, further intensifying the need for practices like agroforestry that mitigate land degradation and support ecosystem recovery.

While research has demonstrated the benefits of agroforestry for biodiversity and carbon storage (Kristiansen et al., 2023; Khan et al., 2024), few studies have focused on watersheds with mining operation, particularly in the context of enhancing local ecosystem resilience and community well-being. Typical agroforestry areas within the Mankayan Watershed include forested slopes and terraces cultivated with highland or temperate vegetable crops. Along the hedges, farmers grow various fruit trees and shrubs, such as coffee and citrus, which contribute to biodiversity and offer additional income sources. This agroforestry system or arrangement enhances both ecological and economic sustainability, providing a "win-win" solution by supporting biodiversity conservation, carbon sequestration, and local livelihoods in the watershed (Jiang et al., 2021; McDonald et al., 2024).

This study aims to investigate the plant composition and diversity, carbon sequestration potential, and economic importance of agroforestry systems in Mankayan, especially compared to other land uses in the watershed. As a critical component of the Abra River Basin and housing a Protected Area, the Mankayan Watershed holds unique ecological and cultural significance. Assessing agroforestry's role in this landscape will highlight its potential to balance conservation goals with the needs of local communities, particularly in regions vulnerable to environmental degradation from mining activities. Through this research, we hope to demonstrate that agroforestry not only aligns with biodiversity conservation and carbon storage but also serves as a viable, sustainable livelihood option, making it an ideal land-use approach for the Mankayan Watershed.

2. Methodology

2.1 Study area

The study area is located in the Mankayan watershed, in Benguet, Philippines. Mankayan is the upstream area of the Abra River Basin in Luzon Island. The town is known as a mining town with large and small-scale mining operations.

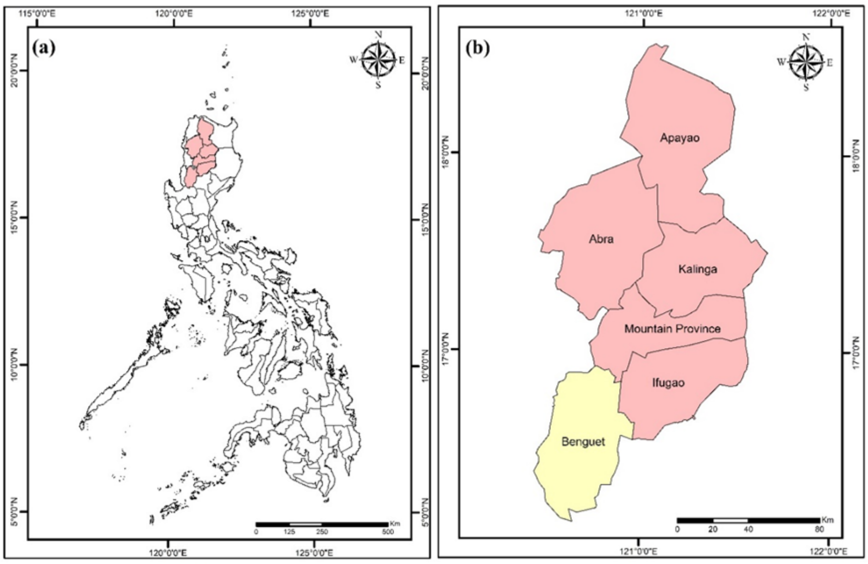

Figure 1. Map showing the location of study site: (a) The Philippines; (b) the Cordillera Administrative Region highlighting the Province of Benguet where Mankayan is located.

2.2 Plant Diversity Analysis

This study utilized a stratified quadrat sampling method to assess plant diversity values and index (Table 1) across different agroforestry sites and other land uses in the Mankayan Watershed. Sampling was conducted in three main zones— upstream, midstream, and downstream—to capture spatial variation in species composition and diversity. In each zone, nested quadrat plots measuring 20m x 20m were established, following the biodiversity assessment guidelines by the Biodiversity Management Bureau and GIZ (BMB-GIZ, 2017).

Table 1. Parameters used in analyzing the plant diversity in the study area.

Parameters	Description	Formula	References
Species Abundance (Ab)	The total number of individuals of a particular taxon or taxa in a given area, population (e.g. trees, shrubs, ferns, grass, among others) or community (e.g. agricultural area, forest, grassland).	$Ab=\sum_{i=1}^{n} a_i$ Where: *Ab* = total number of individuals of the taxon; a_i = number of individuals of the taxon in the *i*th group; and *n* = total number of groups/categories.	Hassan et al. (2005)

Parameters	Description	Formula	References
Species Density (D)	The measure of the number of plant individuals per unit area.	$D=\frac{\sum N}{\sum A}$ Where: D = species density; $\sum$N = the total number of individuals of a species found; $\sum$A = total area examined.	BMB-GIZ, (2017)
Relative Density (RD)	Expressed as a percentage value. The RD is totally independent of area and is actually a relative term.	$RD=\frac{D}{\sum D}x100$ Where: RD = relative density; D = species density; and $\sum$D = total density of all species.	BMB-GIZ, (2017)
Species Frequency (F)	The species frequency or quadrat frequency, is the number of samples or plots in which a species occur.	$F=\frac{Ps}{\sum Np}$ Where: F = species frequency; Ps = number of plots where species occur; and $\sum$Np = total number of plots sampled.	BMB-GIZ, (2017)
Relative Frequency (RF)	To obtain the relative frequency (RF) (in percentage), the F of a species is divided by the sum of the frequencies of all species, multiplied by 100.	$RF=\frac{F}{TF}x100$ Where: RF = relative frequency; F = species frequency; and TF = frequency of all species	BMB-GIZ, (2017)
Species Dominance (Dom)	It represent the species with the largest presence. The dominance of a species is determined by the value of its basal cover	$Dom=\frac{BA\ or\ V}{A}$ Where: Dom = species dominance; BA = basal area of a species; V = volume of a species; and A = area sampled.	Pulhin et al. (2020)
Relative Dominance (RDom)	It is the dominance value of a species with respect to the overall dominance of the rest of the species found in the study area	$RDom=\frac{Dom}{TDom}x100$ Where: RDom = relative dominance;	Pulhin et al. (2020)

Parameters	Description	Formula	References
		Dom = dominance of a species; and TDom = dominance of all species.	
Importance Value (IV)	It is a measure of how dominant a species is in a given area. The IV is calculated by adding the RD, RDom, and RF values	IV =RD + RF + RDom Where: IV = importance value; RD = relative density; RF = relative frequency; and Rdom = relative dominance.	Pulhin et al. (2020)
Shannon-Wiener Diversity Index (H')	It is one of the most commonly used measure to characterize the species diversity in a community. This index considers both species abundance and evenness. The Pi is calculated first and then it is multiplied by the (ln pi). The resultant product is summed across species and then multiplied by -1	$H' = \sum_{i=1}^{S} (Pi)(\ln Pi)$ Where: H' = Shannon-Wiener diversity index; S = total number of species; Pi = the proportion of individuals found in the ith species; and ln = natural logarithm	Bollarapu et al. (2021)

In this study, each plant species encountered across the agroforestry sites in the different elevation zones was classified according to its ecological class or endemism. Species were categorized into one of the following groups: endemic (found only in the Philippines), native (found in the Philippines but also occurring in other countries), introduced or cultivated (brought to and cultivated in the Philippines), naturalized (introduced species that now grow in the wild without cultivation), and invasive (species that negatively impact native biodiversity). These classifications were based on the Co's Digital Flora of the Philippines (CDFP) (Pelser et al., 2011).

2.3 Carbon Storage Analysis

The carbon storage analysis in this study combines satellite-based data and field measurements to estimate the aboveground (AGB), belowground biomass (BGB), undergrowth and forest litter (UFL), and soil organic carbon (SOC) in the agroforestry area. Two global datasets were utilized: (1) NASA's Global Aboveground and Belowground Biomass Carbon Density Maps (Spawn and Gibbs, 2020), with 300m spatial resolution, which provided AGB and BGB carbon (C) densities; and (2) ESA's Biomass Climate Change Initiative (Biomass CCI) Earth observation satellite (Santoro and Cartus, 2023), which used optical, LiDAR, and radar data at a 100m resolution. Geospatial analysis through QGIS software involved clipping the dataset to the study area, converting raster files to vector format, and computing carbon stock per elevation zone in the mining site.

Field-based data were gathered from 20m x 20m plots within the sampling sites to measure AGB, UFL, and SOC. Tree diameter at breast height (DBH) and height were recorded, and AGB was calculated for trees over 10 cm DBH. Biomass density of UFL was determined by oven-drying plant samples from subplots, and soil samples were collected and analyzed for organic content.

Specific allometric equations, based on tree type and DBH, were used to estimate AGB for coniferous and broadleaved trees (Brown, 1997). BGB was estimated using a regression model (Pearson et al., 2005) as a function of AGB, while UFL biomass density was calculated based on dry weight. Carbon content in each biomass type was determined by assuming a 50% carbon conversion (Brown, 1997).

SOC was calculated from soil bulk density and organic carbon concentration, with soil depth and bulk density measured using standard procedures. Equations were used to derive soil volume per hectare, weight, and final SOC content, which was computed based on %C specific to elevation levels. This multi-source approach provided an assessment of carbon stock and density across elevation zones, leveraging both global datasets and localized measurements.

2.4 Economic Importance/Uses

In this study, the economic importance or uses for the identified species in the sampling plots was based on the 12 categories of economic uses from the World Economic Plants database as mentioned in the paper of van Kleunen et al. (2020). The 12 categories include the following: 1 Invertebrate food; 2. Gene sources; 3. Social; 4. Bee plants; 5. Non-vertebrate poisons; 6. Animal food; 7. Fuels; 8. Food additives; 9. Materials; 10. Human Food; 11. Environmental; and 12. Medicines. Various sources and databases were also utilized (Merlin-Franco, 2021) to further evaluate the economic importance and/or uses of each species documented in the sampling plots of the mining site.

3. Results and Discussion

3.1 Plant Diversity Analysis

The agroforestry areas surveyed in upstream, midstream, and downstream locations revealed a total of 37 plant species and 50 individual plants, distributed across 18 plant families and 32 genera (Table 2). The upstream zone showed the highest diversity with 11 families, 16 genera, and 17 species, reflecting a broad mix of crop plants and invasive species. Notably, the presence of *Pinus kesiya*, alongside crops like *Manihot esculenta* and invasive species such as *Chromolaena odorata*, suggests a dual focus on reforestation and mixed cropping, likely aimed at soil stabilization on sloped terrain (Figure 1). The midstream zone displayed slightly less diversity, with 9 families, 11 genera, and 11 species. This zone is notable for its abundance of soil-enriching legumes such as *Alnus japonica* and *Cajanus cajan*, highlighting an agroforestry strategy centered on soil fertility and productivity with economically valuable crops. The downstream zone, with the lowest family diversity (7 families) but similar genus and species counts as midstream (11 each), featured a mix of herbaceous and weedy species such as

Lantana camara and *Brachiaria mutica*, indicating periodic disturbances, likely from burning. The downstream presence of fast-growing trees like *Eucalyptus camaldulensis* suggests an approach focused on erosion control and biomass production.

In terms of land use and vegetation structure, agroforestry areas achieved a high Shannon Diversity Index (H') of 3.39, classifying them as highly diverse ecosystems. This high diversity contrasts with adjacent land covers such as pine forests (H' = 2.68, moderate diversity), grasslands (H' = 2.45, low diversity), and built-up areas (H' = 2.99, moderate diversity). The overall diversity for the area was calculated at H' = 3.27, also classified as high. This indicates that the agroforestry areas contribute substantially to local biodiversity, promoting resilience and ecological balance.

The species diversity across the zones reflects agroforestry's benefits in balancing productivity and ecological health. In the upstream area, a combination of crop and tree species aids in soil stabilization, while in the midstream, soil fertility and food production are prioritized through leguminous crops. Downstream efforts are focused on erosion control with species like *E. camaldulensis* but are challenged by invasive plants, necessitating ongoing management to sustain crop productivity and ecological stability. Collectively, the agroforestry areas demonstrate a robust capacity to support high biodiversity and contribute to landscape resilience, with sustainable land-use practices to address the specific needs of each zone.

A total abundance of 50 plants was recorded, with an average density of 11.26 individuals per area unit. Rd and Rf were both calculated at 2.7%, indicating consistent distribution across plots. The average frequency of 0.38 suggests moderate dispersion of species, reflecting a balanced spread within the surveyed zones. Notably, *P. kesiya* emerged as a dominant species based on basal area, alongside several other species such as *Ageratina riparia*, *Ageratina adenophora*, *Miscanthus sinensis*, and *Tithonia diversifolia*. This dominance underscores their ecological role in the agroforestry system, contributing to soil stabilization and potentially affecting understory light and moisture availability. Species importance was highest for *P. kesiya*, *M. esculenta*, and *C. odorata*, with other species like *Gmelina arborea* and *E. camaldulensis* also ranking highly. These species' high importance values reflect their adaptability, ecological contributions, and potential utility within the agroforestry context, supporting both environmental stability and community benefits such as timber production.

Table 2. The list of species in the agroforestry areas in Mankayan watershed.

No.	Common/ Local Name	Family Name	Scientific Name	Importance Value (IV)
1	Benguet Pine	Pinaceae	*Pinus kesiya* Royle ex Gordon	91.77
2	Sipa-sipa	Asteraceae	*Ageratina riparia* (Regel) R.M.King & H.Rob.	8.76
3	Crofton weed	Asteraceae	*Ageratina adenophora* (Spreng.) R.M.King & H.Rob.	4.38
4	Rono	Poaceae	*Miscanthus sinensis* Andersson	4.38
5	Sunflower	Asteraceae	*Tithonia diversifolia* (Hemsl.) A.Gray	8.76
6	Kamote	Convolvulaceae	*Ipomoea batatas* (L.) Lam.	8.76
7	Pinya	Bromeliaceae	*Ananas comosus* (L.) Merr.	4.38

No.	Common/ Local Name	Family Name	Scientific Name	Importance Value (IV)
8	Laya	Zingiberaceae	*Zingiber officinale* Roscoe	4.38
9	Bugos	Euphorbiaceae	*Acalypha amentacea* Roxb.	4.38
10	Lemon	Rutaceae	*Citrus × limon* (L.) Osbeck	4.38
11	Malunggay	Moringaceae	*Moringa oleifera* Lam.	4.42
12	Guyabano	Annonnaceae	*Annona muricata* L.	4.41
13	Dap-dap	Fabaceae	*Erythrina variegata* L.	4.41
14	Kiling	Poaceae	*Bambusa vulgaris* Schrad. ex J.C.Wendl.	4.38
15	Hagonoy	Asteraceae	*Chromolaena odorata* (L.) R.M.King & H.Rob.	10.76
16	Alnus/Japanese Alder	Betulaceae	*Alnus japonica* (Thunb.) Steud.	8.61
17	Falcata	Fabaceae	*Falcataria falcata* (L.) Greuter & R.Rankin	6.52
18	Cassava	Euphorbiaceae	*Manihot esculenta* Crantz	14.76
19	Gmelina	Lamiaceae	*Gmelina arborea* Roxb. ex Sm.	9.96
20	Lantana	Verbenaceae	*Lantana camara* L.	4.38
21	Eucalyptus	Myrtaceae	*Eucalyptus camaldulensis* Dehnh.	8.94
22	Para Grass	Poaceae	*Brachiaria mutica* (Forssk.) Stapf	4.38
23	Makahiya	Fabaceae	*Mimosa pudica* L.	4.38
24	Paragis	Poaceae	*Eleusine indica* (L.) Gaertn.	4.38
25	Malatabako	Asteraceae	*Elephantopus mollis* Kunth	4.38
26	Weed 1	Asteraceae	*Crassocephalum crepidioides* (Benth.) S.Moore	4.38
27	Weed 2	Urticaceae	*Gonostegia hirta* (Blume) Miq.	4.38
28	Taro	Araceae	*Colocasia esculenta* (L.) Schott	4.38
29	Kalunay	Amaranthaceae	*Amaranthus spinosus* L.	4.38
30	Napier	Poaceae	*Cenchrus purpureus* (Schumach.) Morrone	4.38
31	Banana	Musaceae	*Musa acuminata* Colla.	4.38
32	Billy-goat Weed	Asteraceae	*Ageratum conyzoides* L.	4.38
33	Weed 3	Rubiaceae	*Spermacoce ocymoides* Burm.f.	4.38
34	Okra	Malvaceae	*Abelmoschus esculentus* (L.) Moench	4.38
35	Pink Pin Heads	Polygonaceae	*Persicaria capitata* (Buch.-Ham. ex D.Don) H.Gross	4.38
36	Santing	Fabaceae	*Calopogonium mucunoides* Desv.	4.38
37	Kardis	Fabaceae	*Cajanus cajan* (L.) Huth	8.38

The biodiversity inherent in agroforestry systems contributes to ecological resilience by creating complex, multilayered ecosystems that are more resistant to pests, diseases, and extreme weather conditions (Dissanayaka et al., 2024). For Mankayan watershed, which is susceptible to landslides and heavy rainfall, tree species with strong root systems help stabilize soil, thereby reducing the risk of soil erosion. Economically, plant diversity within agroforestry enhances resilience for farmers by reducing dependency on a single crop and offering various products such as food, fuelwood, timber, and medicinal plants. In Mankayan, this diversification provides income alternatives and buffers against market fluctuations, which is crucial for communities relying on agricultural production. By integrating both local and economically valuable species, agroforestry in Mankayan can help alleviate poverty and foster economic growth while conserving biodiversity, making it a powerful, multifunctional land-use strategy.

3.2 Carbon Storage Capacity

The analysis of carbon storage capacity within the agroforestry areas of Mankayan Watershed highlights agroforestry's role as a supplementary, though modest, carbon reservoir when compared to other land uses such as forests, built-up areas, and grasslands. Agroforestry systems in the Mankayan watershed exhibit an aboveground biomass density of 13.67 Mg/ha, corresponding to a carbon density of 6.83 MgC/ha, which, while lower than forests, still contributes to the watershed's overall carbon pool (Table 3). Agroforestry areas store 498 Mg of carbon, representing only 0.09% of the total carbon storage across the watershed. However, agroforestry’s impact extends beyond immediate carbon sequestration: the system enhances soil health through notable levels of soil organic carbon (SOC), averaging 152.08 MgC/ha at a 0-30 cm depth. This SOC enrichment is crucial for maintaining soil fertility and long-term carbon storage, showing agroforestry's potential in promoting sustainable land use that supports both agricultural productivity and environmental resilience. Agroforestry also contributes 1,829.78 Mg of CO_2e, a relatively low emission level, reflecting its low-impact nature. While forests dominate in carbon storage, agroforestry complements these areas by providing a sustainable and productive option for carbon sequestration, especially in lands less suited to traditional forestry, such us in the mining area of the study site. The findings suggest that agroforestry is a valuable practice for enhancing carbon storage and supporting soil health within multi-functional landscapes, offering an integrated approach to land use that can diversify carbon sequestration strategies within the watershed.

Table 3. The quantified biomass and carbon storage potential in the study site.

LULC	Biomass (Mg)	%	Carbon (Mg)	%	CO2e (Mg)	Average SOC (MgC/ha)
Agroforestry	1,004	0.09	498	0.09	1,829.78	152.08
Built-up	143,342	12	71,464	12	262,274.90	168.37
Grassland	723	0.07	325.55	0.06	1,194.77	167.89
Pine Forest	964,982	86	481,270	86	1,766,263.09	160.60
Total	1,110,052	100	553,559	100	2,031,562.53	162.24

3.3 Economic Importance/Uses

The agroforestry area of the Mankayan Watershed supports a diverse range of plants, fulfilling numerous economic, ecological, and social roles that benefit both the community and the environment. Analysis of plant uses shows that the majority of species serve medicinal purposes, with 31 plants utilized for health-related applications, reflecting the reliance on traditional remedies within the community (Figure 1). Environmental applications are the next most significant category, with 19 species contributing to ecosystem functions such as erosion control and soil stabilization, essential for watershed health. Human food is also a major category, with 18 plant species, including *Abelmoschus esculentus* (okra), *Ipomoea batatas* (sweet potato), and *Musa acuminata* (banana), providing critical nutrition to local diets. Materials (15 species) and food additives (11 species) further enhance the area's resource diversity, with plants like *Bambusa vulgaris* (bamboo) providing building materials and *Moringa oleifera* (moringa) contributing both as a food additive and a fuel source.

Additionally, 10 species serve as fuels, and 8 are used as animal food sources, such as *Brachiaria mutica* (pará grass), which supports local livestock. Other functions include non-vertebrate poisons (6 species) and bee plants (4 species) like *Erythrina variegata* (coral tree), which support pollinator populations and biodiversity. Though some plants have unknown uses and categories like gene sources and invertebrate food are currently unrepresented, the varied functions of these agroforestry plants underscore the system's adaptability and importance. Collectively, the presence of species serving in areas from healthcare to fuel, food security, and environmental stability illustrates agroforestry's multifaceted contributions to the Mankayan Watershed's sustainable land use.

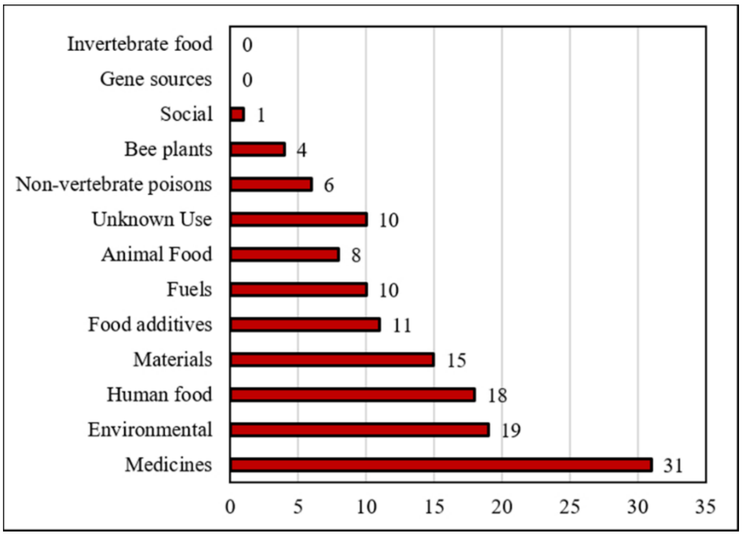

Figure 2. The economic importance/uses of the species encountered in the agroforestry areas of Mankayan watershed.

4. Conclusion

In the Mankayan watershed, where underground mining predominates, agroforestry emerges as a win-win solution, promoting biodiversity, carbon storage, and sustainable livelihoods. Agroforestry areas within the watershed demonstrate notably higher species richness and diversity than other land uses, including the pine-dominated forest areas, where *Pinus kesiya* prevails, leading to relatively low biodiversity. Although the overall carbon storage contribution from agroforestry is modest, these areas still function as important carbon sinks, contributing to climate change mitigation efforts. Additionally, agroforestry supports sustainable livelihoods by harboring a variety of economically valuable plant species that serve as sources for food, medicine, building materials, and fuel. This diversity highlights the significant economic potential of agroforestry, offering opportunities to boost local income while enhancing ecological resilience. Given its many benefits, agroforestry holds promise as a sustainable land-use strategy that aligns biodiversity conservation with carbon storage and economic development. Further research and investment in agroforestry within the Mankayan watershed could optimize its contributions, supporting long-term sustainability goals and community well-being in the Philippines.

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Vulnerabilities, Challenges and Opportunities of Socio-Ecological Production Landscapes (SEPLs): Case of Sta. Cruz Sub-Watershed in the Philippines

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Abstract

This study was conducted in Sta. Cruz Sub-Watershed, covering the river system that traverses from high-elevation in Brgy. Luquin, Liliw, mid-elevation in Brgy. Banaan, Magdalena, to the low-elevation community, which is in Brgy. Patimbao, Sta.Cruz. These communities represent the Socio-Ecological Production Landscape (SEPL) in Laguna, Philippines. The majority of the population in these SEPLs depend on agriculture as their main livelihood, which is highly exposed to shocks and uncertainties such as climate change, market uncertainties, policy shifts, natural hazards, and, more recently, the COVID-19 pandemic. The data was gathered using mixed methods. These include household surveys, key informant interviews, focus group discussions, and farm visits. Data gathered includes the general socioeconomic conditions, livelihood activities, and the major issues and challenges being faced by these communities. Transect and village walks were used as tools in assessing the biophysical conditions of the communities across the SEPLs. Results revealed that majority of communities depend on farming as their main source of livelihood. However, farming systems are vulnerable to natural hazards such as typhoons, drought, and climate change. The pandemic also hampered agricultural production and marketing. Monocropped rice dominates the low elevation while patches of fruit trees, vegetables, and monocropped rice are common in mid- elevation community. The upstream community, which is prone to soil erosion is dominated by vegetables and some fruit trees. Agricultural intensification is observed in high and mid-elevation communities while land use change is prevalent in the low-elevation community. Unstable market prices of produce, and declining farm income are among the socioeconomic issues. These findings highlight the need for technology and social interventions that address these interconnected challenges and promote sustainable development within SEPL communities to increase their resiliency against vulnerabilities.

Keywords: Livelihood and governance, Socio-ecological production landscape communities, Sub-watershed

1. Introduction

FAO Global Forest Resource Assessment highlights that more than 30 million hectares of forests are lost in Southeast Asia between the period of 1990 and 2015. Forest loss significantly affects the socio-ecological conditions, particularly food and livelihoods of the local communities, as well as the ecosystem services that forest landscape provides. Furthermore, degraded forests are more vulnerable to natural disasters and extreme events, which significantly create impact on humans. Thus, effective forest landscape governance remains a challenge.

An important component of a forest landscape is the socio-ecological production landscapes (SEPL). SEPL refers to the dynamic cultural mosaics of habitats and land uses where the interaction between people and the landscape maintains or enhances biodiversity while providing humans with goods and services needed for their well-being (UNU-IAS, Biodiversity International, IGES and UNDP 2014). However, industrialization, urbanization, and diverse production areas have been transformed towards a system that requires intensive use of external inputs; land use change brought about by the growing demand for food and income by the increasing global population threatened the ecological integrity, and ultimately the human well-being.

Several literatures point out the vulnerability of the agriculture and forestry sectors, particularly the smallholder farmers and forest-dependent communities to climate change impacts in Southeast Asia (Evangelista et al., 2015; Landicho et al., 2016; Lasco et al., 2011; Morton, 2007; Peras, Pulhin & Inoue, 2016), and many parts of the world (Roshani, 2022). Among these impacts include increased use of farm inputs, decline in crop yield, decline in farm income (Landicho et al., 2015; Tolentino & Landicho, 2013), and food insecurity after extreme weather events (Harvey et al., 2018). In particularly, vulnerability of forest-dependent communities to climate change and natural hazards is determined by their socioeconomic status (Chechina et al., 2018) as well as their marginalized environment and the lack of basic services (Tapia, Peras & Pulhin, 2014*)*.

With the crucial role of agriculture in the economy and its vulnerability to climate change impacts and other stressors, there is a need to invest in measures that would build and enhance the adaptive capacity and resilience of rural farming communities (Lasco et al., 2011; Landicho et al., 2019;Silici et al., 2021). Akinyi et al. (2021) also highlighted that achievable innovations or combinations of strategies can help significantly reduce poverty among vulnerable groups.

Nature-based solutions to the vulnerabilities and challenges being faced by the smallholder farmers include technology interventions including agroforestry. Over 100 countries ratifying the UN Framework Convention on Climate Change (UNFCCC) highlighted the importance of the land sector, that covers agriculture and forestry, in their Intended Nationally Determined Contributions (INDC). The UNFCCC and the UNCBD has emphasized the role of agroforestry in promoting climate change adaptation and reducing deforestation and forest degradation. A 2018 assessment indicated that 60 out of 147 countries proposed agroforestry as a strategy in their NDCs, which efforts of each country to reduce national emissions and adapt to the impacts of climate change as exemplified in the Paris Agreement. Meanwhile, 50% of the 73 developing countries with REDD+ strategies, identified agroforestry to combat deforestation and forest degradation. As mentioned above, the ASEAN-Member States also identified agroforestry as a strategy to achieve resilience in the ASEAN region, and endorsed the ASEAN Guidelines on Agroforestry Development in October 2018.

This paper highlights the vulnerabilities and challenges faced by farmers across the Sta. Cruz Sub-Watershed, and emphasizes the opportunities that can be tapped to address these challenges.

2. Methodology

2.1 Study Sites

Sta. Cruz Sub-Watershed is located in the northern part of the Laguna de bay basin and occupies a total land area of 14,611 hectares. The sub-watershed covers 10 municipalities, whose land cover is dominated by coconut plantations (42%), followed by forested areas (18.5%), brushland (16.13%) and urban areas (11.44%). The study sites represent the downstream, mid-stream and upstream communities. These include Barangay Patimbao in Sta. Cruz, Laguna; Barangay Baanan in Magdalena,Laguna; and, Barangay Luquin, in Liliw, Laguna, respectively.

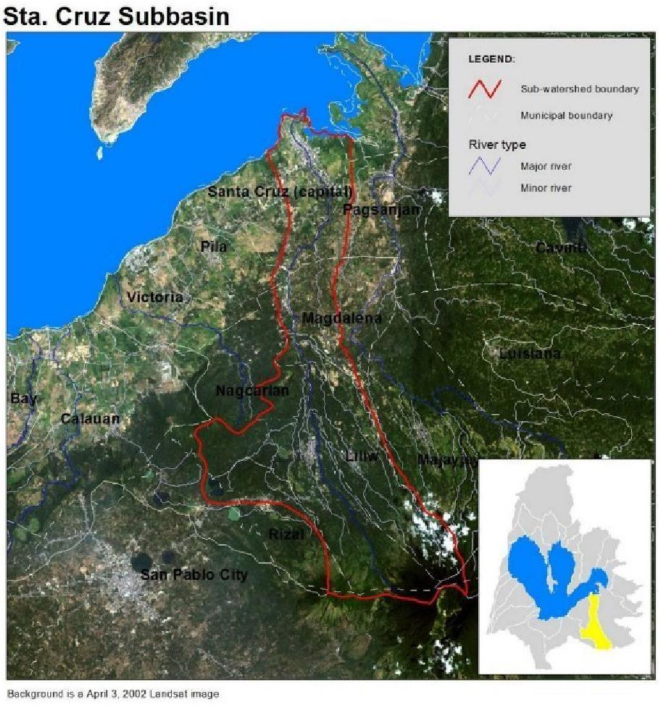


Figure 1. Sta.Cruz Sub-watershed Laguna, Philippines

2.2 Socio-Economic Characterization

2.2.1 Household Survey

Simple random sampling was used to select survey respondents. Sampling intensity was computed using Slovin’s formula, $n=N/(1+N*e^2)$. Where n=sample size, N=total population and e=error margin of 5 %.

2.2.2 Focus Group Discussion

Focus Group Discussion (FGD) was employed to gather data about the socioeconomic conditions of the local communities, using the following tools: a) *Resource mapping*, which enabled the community members to draw a map of their communities, highlighting the different natural and physical resources, and important landmarks. b) *Participatory assessment of community vulnerabilities*, which allowed the participants to recall the major shocks and stresses and the degree of effect of these stresses on the health of the household members, agricultural production, and livelihoods. c) *Livelihood analysis*, helped the local stakeholders trace and identify the different income sources of the community members. Through their discussions, the local stakeholders have identified the level of importance of the different capitals (human, social, financial, natural and physical) on the different livelihoods. d) *Ranking of issues and problems* provided the local stakeholders an opportunity to articulate the problems within their communities in terms of economic, ecological and social dimensions.

2.2.3 Key Informant Interviews *(*KII*)*

KII was used to validate results from the survey. It was participated by farmer leader, agricultural technicians, environment officers, village officials, youth leader and women leader.

2.2.4 Rapid Biophysical Assessment

Transect and village walks were used to assess the biophysical conditions of the communities across SEPLs. These tools enabled the team to observe the farming systems, farm components, soil conditions, natural resources, as well as other important landmarks across the transect line. A transect map was generated, which provides an overview of the biophysical conditions of the study sites.

2.2.5 Data Analysis

The data was analyzed using descriptive statistics (i.e. frequency counts and percentages), and general categorization was used to analyze the FGD results, which are mostly qualitative in nature. KII summarized the data and information gathered. Meanwhile, the transect map was used to analyze biophysical characterization. GIS was also used to determine the geographical location, altitude and coordinates.

3. Results and Discussion

3.1 Socio-economic Analysis

Results of the household survey indicate that most of the farmer-respondents from the three study sites are male and their mean age ranges from 49 to 63 years old. The average household size in all three sites is four and their source of income is farming and non-farming. Based on the results, Magdalena, Laguna had the highest farm income of Php 157,279.00 followed by Liliw, Laguna with Php 132,548.35 while Sta.Cruz Laguna had an average annual income pf Php 90,839.00. The average farm size ranges from .49 ha to 2.65 ha. The average farm size cultivated is from .43 ha up to 2.63 hectares. When it comes to land ownership, most farmer respondents from Liliw, Laguna rent or lease their farms, whereas those from

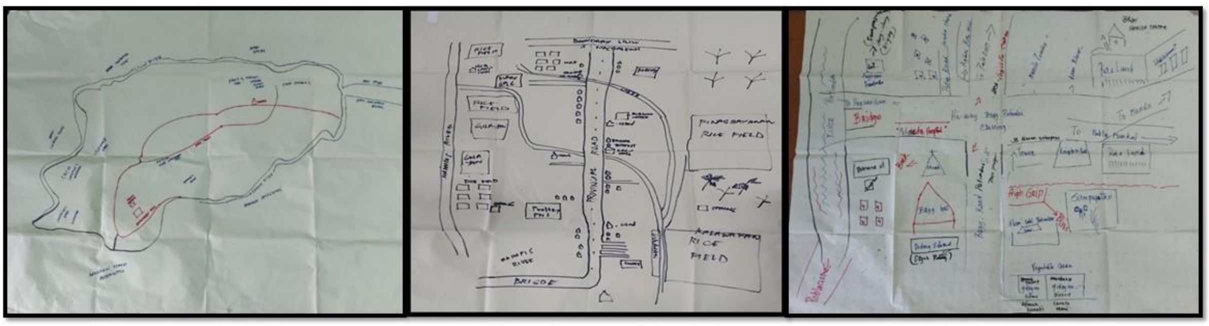
Magdalena, Laguna, and Sta. Cruz Laguna is either a tenant or an owner/title holder of the land (Table 1).

Table 1. Socio-economic of the three study sites

Category	Study sites		
	Liliw	**Magdalena**	**STA. Cruz**
Sex			
a) female	22%	21%	42%
b) male	78%	79%	58%
Mean Age	49	60	63
Mean HH size	4	4	4
Mean Annual HH income (farming+non farm)	Php 132,548.35	Php 157,279.00	Php 90,839.00
Mean Farm size	.49 has	2.65 has	1.21 has
Mean Farm size (cultivated)	.43 has	2.63 has	1.18 has
Mean HH members engaged in farming	1	1	1
Main sources of income			
a) farming	72%	66%	67%
b) non-farm	18%	34%	33%
Status of land ownership	Lease/rent	Owned/titled	Tenant

3.2 Description of the study sites

The river system from high- (Brgy. Luquin, Liliw), mid- (Brgy. Banaan, Magdalena) to low-elevation (Brgy. Patimbao, Sta.Cruz) communities is one of the common natural resources in the Socio-Ecological Production Landscape (SEPL) in Laguna, Philippines (Figure 2). Institutions to include school, church, barangay health centers, barangay hall are commonly found in all communities. On the contrary, post-harvest facilities such as rice mill and dryer are only available in the low-elevation community. The low elevation community is dominated with rice monoculture. On the other hand, the mid-elevation community is still into rice monocropping with patches of farms planted with fruit trees and vegetables while the high-elevation community is dominated by vegetable crops and some fruit trees. Majority of the population in these communities depend on farming as their main source of livelihood.



a) Brgy. Luquin, Liliw　　b) Brgy. Baanan, Magdalena　　c) Brgy. Patimbao, Sta.Cruz

Figure 2. Community Resource Map

3.3 Livelihood Analysis

The livelihood activities of the local communities across SEPLs were farming (vegetable, rice production, sampaguitahan, fruit trees), livestock raising (large and small ruminant poultry), sari sari store, driver/operator (jeepney and tricycle), microfinance, tablea maker, farm labor, buy and sell, fishing, furniture making and balut vendor. The level of importance of the capital ranges from 1-5 with 1 as the least important and 5 as the most important.

For high-elevation community, the most important asset for their livelihood activities was human capital followed by financial capital while natural asset was the least important. Livelihood activities such as vegetable farming, driver/operator and laborer were moderately vulnerable while buy and sell was highly vulnerable to climate change, natural calamities, pandemic, and market uncertainties. Fruit farming was highly vulnerable to climate change.

For mid-elevation community, financial capital was the most important asset for their livelihood activities while social asset was the least important. The livelihood activities were moderately vulnerable to climate change and natural calamities as well as pandemic and market uncertainties.

For low-elevation community, the most important asset was financial capital while physical asset was the least important. On the other hand, physical asset was the most important asset for fishing activities while financial asset was the least. Livelihood activities were low to moderately vulnerable to climate change and natural calamities. Meanwhile, their livelihood activities were moderately and highly vulnerable to pandemic. High income from plant selling was realized during the pandemic while online selling, service providers and selling of balut were considered not vulnerable to any uncertainties and natural calamities by the communities.

Major Shocks and Stresses Across the Landscape

The major shocks that were encountered by the communities in the last five (5) years (2017-2021) as well as the degree of effects of each shock were determined. These major shocks include natural disasters, health-related, crop and livestock production failure, peace and order and COVID-19. Typhoons and drought are the natural hazards experienced by all communities across the SEPL. Meanwhile, the Mt. Taal eruption was identified by the mid-elevation community in 2020, affecting a few residents and their agricultural crops. In terms of health-related shocks, flu, and fever are common illnesses encountered by the communities. Specifically, dengue was identified by low and mid-elevation communities, while measles and chikungunya were identified by the low-elevation communities. For shocks and uncertainties affecting crop and livestock production of the communities across SEPL, fluctuating price of produce (rice, corn, vegetables and sampaguita), pests and diseases (cocolisap, tungro, tungaw, dapo, snail, rat, African Swine Flu) and too much rain due to climate change were highlighted. With regards to peace and order, theft and boundary conflicts were identified by the communities as their present concerns. The residents across SEPL identified the COVID-19 pandemic as the major shock they experienced in 2020-2021. The marketing of their farm produce was severely affected due to travel restrictions and protocols. Limited access to seeds and the availability of farm labor during the pandemic significantly affected the livelihood of farming communities. The people’s livelihood was critically impacted as some identified they experienced loss of income and employment during the pandemic. Social activities of the youth were severely affected during the pandemic. The low elevation community had access to free internet connection for online learning during the pandemic.

Issues and Problems being faced by the SEPLs

1. ***The three study sites are confronted with numerous challenges and problems.***

- For the upstream community, which is Barangay Luquin in Liliw, among the problems include the occurrence of pests and diseases; low price of farm produce; high price of farm inputs, including labor; market price dictated by buyers and traders; low farm productivity due to continuous price increases of inputs; non-adoption of organic pest controls; declining soil fertility; stolen farm produce; oversupply of vegetables; aging farmers; and, soil erosion in some steep areas. Other problems include land disputes, climate change, farm-to-market roads, lack of postharvest facilities, and farmers are unaware of the potentials of agroforestry over monocropping
- Barangay Baanan, a mid-stream community, is faced with challenges such as the occurrence of natural calamities that damage the crops and the physical infrastructure affecting the marketing of agricultural produce. Most of the farmers also lack capital as profit from farming is used to settle their debts; crop and livestock pests and diseases; middlemen dictating the prices of farm produce; some farmers do not own their farms; conversion of agricultural area to resorts; and lack of irrigation
- The downstream community, Barangay Patimbao in Sta. Cruz, Laguna are confronted with problems such as lack of capital for farm establishment; climate change which results to the unavailability of lack of irrigation water; market price fluctuations of farm produce; high cost of labor; and land conversion
- The youth sector across the mid-stream and downstream communities are facing mental health issues. Many of them are also classified as out-of-school youth

2. ***Farmers employ practices and strategies to address the issues and problems confronting their agricultural production***

- In the upstream community, farmers use soil conditioners to maintain and enhance soil fertility. Some farmers, however, have partnered with a chemical company to avail of the sample and free pesticides to control and manage crop pests and diseases. This strategy was thought of to minimize their expenses in farm inputs. To help improve the prices of produce such as vegetable crops, the farmers have formulated a joint resolution with the neighboring barangays to implement a uniform and fixed price for farm produce such as tomatoes, eggplant, pechay, and cabbage. Prices are posted on bulletin boards to give farmers an idea of the current market price before trading with the local traders.
- To address their problem with marketing their produce, the leaders of the farmers' associations consolidate the farm produce and look for buyers outside the community. Farmers also participate in the LGU-organized markets and festivals for diverse market channels

- In the downstream community, farmers oftentimes seek assistance from the Department of Agriculture for planting materials and fertilizers. To maintain soil fertility, soil testing is also regularly being conducted to determine the type and amount of fertilizers for application. Some farmers likewise practice organic farming to lessen their reliance to pricey commercial fertilizers. Crop diversification is also being practiced to ensure multiple harvests, which can serve as their safety nets for market risks (i.e. low and fluctuating prices of farm produce)

3. Local government units provide technical and logistics support to help farmers address or mitigate their problems in agricultural production

- In the upstream community, the LGU developed a right/just pricing of commodities. The KADIWA Program facilitates the transport of farm produce from the steep farms to the market. Regarding crop pests and diseases, the Office of the Municipal Agriculturist has already coordinated with the Regional Crop Protection Center for trials of biological pest control agents, such as neem. This will discourage farmers from relying heavily on synthetic pesticides. The LGU also facilitates farmers' registration with the crop insurance system.
- To address the farmers' problem of negotiation with the middlemen, the LGU in the mid-stream community, directly buys the farm produce from the farmers and sells it to other markets outside the community. Specifically, the Office of the Municipal Agriculturist trains farmers to maximize digital platforms in their agriculture production and marketing. On the other hand, the Office of the Municipal Environment and Natural Resources Office ensures environmental stability through programs on farm waste utilization, including composting, tree planting activities, and regulation on backyard livestock farming. The municipality also plans to establish nurseries for easier access to plant materials during tree planting activities and collect fruit seeds thrown away for consumption as a source of planting materials.
- The LGU in the downstream community implements programs that help promote solid waste management and environmental protection. These include the "Gawad Pinaka-Kalikasan " which is an annual monitoring of school projects and activities on environmental protection and beautification; "Tetra Pack Project ", a program that promotes recycling; "Kalinga sa Kalikasan", a partnership with a private company that also promotes reuse and recycling of plastic wastes. Moreover, the Office of the Municipal Agriculturist, provides farm inputs (i.e. seeds, fertilizers) to the farmers; provides assistance to farmers for crop losses through the crop insurance system; and provides access to the rice processing system to help local farmers reduce losses from postharvest, and to improve the quality of milled rice for better farm income. The Office continuously promotes the use of organic fertilizers.

4. ***The forestry sector implements governance mechanisms to ensure the stability and integrity of the socioecological production landscape within the Sta. Cruz Sub-Watershed***

- Deployment of River Rangers who are tasked to collect the wastes and water hyacinth in the river system; and conduct water quality assessment of the 14 major rivers in Laguna
- To ensure that communities do their part in managing and conserving natural resources and ensure the sustainable management and governance of the whole socio-ecological landscape, CENRO executes continuous information dissemination and monitoring. These include different lectures on the importance of planting along the contour lines in upland areas and monitoring and updating the certificate with partner POs within CBFM areas. The office also continuously introduces its programs and encourages private and other government institutions/individuals to adopt those programs, monitoring illegal activities through the Lawin Patrol Application and close coordination and communication with LGUs and Watershed Management Council.

Biophysical characteristics of the three communities

The SEPLs' elevation ranges from 17 to 849 masl. Monocropped rice dominates the lower part, while patches of fruit trees, vegetables, and monocropped rice are common in mid-altitudes. The upper part, which is prone to soil erosion are dominated by vegetables and some fruit trees. Agricultural intensification is observed in forested areas, while land use change is prevalent in the lower part of the SEPL. Most of the farms are rainfed. The farm in mid-stream and upstream communities have rolling to steep slopes, while farms in the downstream community is relatively flat (Table 2).

Table 2. Summary of transect map of the study sites.

Categories	High elevation	Mid-elevation	Low elevation
Land use	Agricultural lands plus some residential in the lower part	Perennial trees with some agricultural crops	Open field areas, rice fields, residential, built-up areas, home gardens, vacant lots with fruit crops and other perennial trees incorporated with cash crops
Elevation	647-849 masl	123-155 masl	17-84 masl
Perennial Trees	kakawate (*Gliricidia sepium*), duhat (*Syzygium cuminii*), pili (*Canarium ovatum*), lipote *(Syzygium polycephaloides)*, binayuyu *(Antidesma ghaesembilla*), Narra (*Pterocarpus indicus*), mahogany (*Swietenia macrophylla*), durian (*Durio zibethinus*), lanzones (*Lansium*	lanzones (*Lansium domesticum*), coconut (*Cocos nucifera*), rambutan (*Nephelium lappaceum*), banana (*Musa sp.*), cacao (*Theobroma cacao*), kakawate (*Gliricidia sepium*), mangoes (Mangifera indica), calamansi (*Citrofortunella macrocarpa*) and some	lanzones (*Lansium domesticum*), mango (*Mangifera indica*), santol (*Sandoricum koetjape*), rambutan (*Nephelium lappaceum*), cacao (*Theobroma cacao*), tamarind (*Tamarindus indica*) and coconut (*Cocos nucifera*), banana (*Musa paradisiaca*), papaya

Categories	High elevation	Mid-elevation	Low elevation
	domesticum), coconut (*Cocos nucifera*),	bamboo species and forest tree such as mahogany (*Swietenia macrophylla*)	(*Carica papaya*), ilang-ilang (*Cananga odorata*), pomelo (*Citrus maxima*), balimbing (*Averrhoa carambola*), kakawate (*Gliricidia sepium*), guava (*Psidium guajava*), talisay (*Terminalia catappa*), guyabano (*Annona muricata*), jackfruit (*Artocarpus heterophyllus*),avocado (*Persea americana*), bamboo
Cash crops	sweet potato (*Ipomoea batatas*), red pepper (*Capsicum annum*), cassava (*Manihot esculenta*), raddish (*Raphanus sativus*), cabbage (*Brassica oleracea* var. *capitata*), tomatoes (*Solanum lycopersicum*), beans (*Phaseolus vulgaris*) and chayote (*Sechium edule*)	eggplant (*Solanum melongena*), beans (*Phaseolus vulgaris*), lady's finger (*Abelmoschus escuentus*), mustard greens (Brassica juncea), squash (*Cucurbita maxima*), and dragon fruits (*Selenicereus undatus*)	sampaguita (*Jasminum sambac*), lady's finger (*Abelmoschus esculentus*), pechay (*Brassica rapa*), mustard green (*Brassica juncea*), rice (*Oryza sativa*), sweet potato (*Ipomoea batatas*), eggplant (*Solanum melongena*), ginger (*Zingiber officinale*), patola (*Luffa acutangular*) and gabi (*Colocasia esculenia*) and pineapple (*Ananas comosus*)
Source of water	rainfed	rainfed, creek and water pump	rainfed, deepwell and water pump
Opportunity	Agroforestry model farm, presence of pathways, existence of cable tramline, access to road, integration of high value fruits trees	Presence of fruit trees and raising livestock can be a source of income	Road accessibility, integration of hogh value fruits trees, potential area ofr planting agricultural crops

Opportunities for enhancing resilience

1. ***Nature-based strategies for addressing vulnerabilities to climate-related stressors include agroforestry and crop diversification.*** These technologies do not only address the socioeconomic concerns of the farmers, particularly in ensuring multiple harvests, diverse source of income, and ensuring food security. These technologies and management practices also contribute to ecological stability and climate change mitigation.

   Agroforestry, the combination of trees, crops, livestock and/or fishery activities provides multiple benefits and enhances farm and ecological resilience, and thus, improve peoples' livelihoods. Agroforestry can improve the resiliency of agricultural systems (Brown et al., 2018) and livelihoods (Dinesh et al., 2017); mitigate climate change impacts (Quandt et al., 2017; Brown et al., 2018; Gnolonfoun et al., 2019); and enhance food security of smallholder farmers (Macandog et al., 2010; Landicho et al., 2017).

2. ***Existing people's organizations and farmers' associations within the three communities,*** which could serve as the conduits of issues and challenges being faced by the communities, as well as channels of development support and programs of national government agencies and local government units These people's organizations also offer opportunities to enhance both the bonding and bridging social capitals of the three communities. The accumulation of social capital provides safety nets to the farmers and communities, in general, in times of emergency and uncertainties

3. ***Technical assistance and support from development organizations.*** The local government units, particularly the agriculture and environment sectors, including the field offices of the Department of Environment and Natural Resources provide technical assistance, and implement training programs to these communities being part of the Sta. Cruz Watershed. These areas have also become the study sites of research and development projects of state universities and research institutions, including the University of the Philippines Los Baños. Hence, understanding their local conditions could pave the way for developing projects that would help address their problems and challenges, including resilience-building

Conclusion

The findings of this research confirm results of previous researches that the agriculture sector, particularly the smallholder farmers, are vulnerable to both climate and non-climate stressors. They are exposed to numerous challenges which hamper the optimization of benefits from their existing farming systems. However, there are technology and social interventions which can help address these challenges and enhance their resilience.

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Effect of Drying Condition on Quality of Robusta Coffee Blossom Tea

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Abstract

The objective of this research was to study the effect of drying conditions on the quality of Robusta coffee blossom tea. The commercial tea produced by a local small enterprise at Ban Natong, Phrae province (control) was compared to a laboratory prototype. Both conditions were prepared using pan roasting then sun drying. The commercial tea produced by a local small enterprise at Ban Natong, Phrae province (control) was compared to a laboratory prototype. Both conditions were prepared using pan roasting then sun drying. The commercial tea was prepared under condition without control of temperature and time. The prototype was prepared using pan roasting at 75-80 °C for 20 minutes then sun drying for 3 days (average temperature of daytime was 40°C and night time was 24 °C). The chemical properties of Robusta coffee blossom were analyzed and found that the blossom contained moisture content and total phenolic contents of 83 % and 30.07 mg GAE/g, respectively. The DPPH inhibition of the blossom presented at 71.19 %. The color vales (L*, a* and b*) and moisture content of tea from both conditions were compared. The results found that there were no significant differences in color values and moisture content. The L*, a* and b* values of control were 8.06, 8.51 and -2.69, respectively, and the L*, a* and b* values of the prototype were 7.81, 9.72 and -2.33, respectively. Moisture contents of control and prototype were 2.14 and 2.24%, respectively. The moisture contents of tea from both conditions were lower than the Thai Community Product Standard (120/2546). The drinking tea was prepared by soaking 1.6 g dried tea in 110 mL. hot water at 85°C for 4 minutes. The results presented that the drinking tea from control and prototype showed phenolic contents of 504.41 mg GAE/L and 644.60 mgGAE/L, respectively and DPPH inhibition of 45.69 and 54.26 respectively. The results revealed that drying process control was a critical aspect of production systems, playing a pivotal role in maintaining and providing high quality products.

Keywords: Bioactive compound, Coffee blossom, Drying, Roasting, Robusta

1. Introduction

Robusta coffee, *Coffee robusta* Pierre ex A Frochner, belongs to the family of Rubiacea. The Robusta coffee is originally grown in central and western sub-Sahara Africa (Chairgulprasert & Kongsuwankeeree, 2017). However, it is now cultivated widely in several parts of the world and becomes the most valuable traded commodity worldwide, with global retail sales estimated to be US$ 90 billion. Brazil is the largest world's coffee producer, followed by Vietnam and Colombia (Damatta et al., 2007). Thailand is one of the exporters of coffee. It is not only an important product in the market, but also one of the vital channels for promotion employment (Chuqian, 2018). Southern Thailand mostly produces Robusta coffee beans. In contrast, Arabica coffee is commonly produced in northern Thailand such as Phrae Province. Nowadays, coffee by-products such as coffee pulp, coffee husk and coffee flower have been converted into value-added products due to their bioactive compounds.

A flower that has recently been attracting increasing attention in research is the coffee flower (Chairgulprasert & Kongsuwankeeree, 2017). It is also worth mentioning that harvesting the flowers does not result in low productivity of the beans, since they are only harvested after pollination (Damatta, et al., 2007). The white flower has a highly recognizable scent, and could be a potential source of food and beverage ingredients as it is a rich source of bioactive compounds (Nguyen et al., 2019). The biochemical and phytochemical composition of Arabica and Robusta coffee beans have been extensively investigated due to rich in compounds with antioxidant capacity, such as caffeic acid, chlorogenic acid, p-coumaric acid, ferulic acid, caffeine, and trigonelline (Çelik & Gökmen, 2018, Wirz et al., 2022).) that can play a crucial role in human health as antioxidants and help prevent cardiovascular diseases, cancers, and diabetes (Mak et al., 2013). However, few studies have evaluated other parts of the plant (Chairgulprasert & Kongsuwankeeree, 2017; Nguyen et al., 2019). It is worth emphasizing the importance of studying factors that can affect the antioxidant potential of food matrices. Alkaltham, Salamatullah, & Hayat (2020) and Cheng et al. (2019) found that the drying method was able to influence the antioxidant capacity of coffees. Chairgulprasert & Kongsuwankeeree (2017) and Nguyen et al. (2019) studied the antioxidant potential of coffee flowers; however, they did not evaluate the influence of processing variables (dehydration method for conservation and mode of extraction of bioactive compounds). Therefore, the objectives of this research were to 1) compare the commercial tea produced by a local small enterprise at Ban Natong, Phrae province (control) and the laboratory prototype and 2) evaluate potential bioactive compounds and the antioxidant capacity of coffee flowers of Robusta coffee to promote the local product.

2. Methodology

2.1 Material

The Robusta coffee (*Coffea canephora*) blossoms were collected during the period of February 2024 from Ban Natong, Phrae province, Northern part of Thailand with an average elevation above sea level of 600 meters. Fresh blossoms were packed in an airtight container and kept at -18 °C until the moment of analysis. The blossoms were measured chemical properties including moisture content, total phenolic content and antioxidant capacity.

2.2 Preparation of Robusta coffee blossom tea

The blossoms were harvested by hand and foreign matters were then removed manually. Pan roasting was used and subsequently sun drying for 3 days in the sanitary plant. Two conditions of drying consisted of a commercial process and prototype process were compared.

The commercial process (control) was the process of local small enterprise at Ban Natong, Phrae province. The blossoms were roasted without control of temperature and time and the drying step did not collect data of precise temperature.

The prototype process was developed in this study. The blossoms were roasted at 75-80 °C for 20 minutes then sun dried for 3 days (average temperature of daytime was 40°C and night time was 24 °C).

After the drying process, the resultant blossoms were then packed in an airtight container and kept at -18 °C until the moment of analysis of physicochemical properties consisted of color values (L* = lightness (0=black, 100= white), a* (-a* = greenness, +a* = redness) and b* (-b* = blueness, +b* = yellowness)) and moisture content.

2.3 Preparation of drinking Arabica coffee blossom tea

The drinking tea was then prepared following Choosut (2019) by soaking 1.6 g dried tea in 110 mL. hot water at 85°C for 4 minutes. The physicochemical properties consisted of color values (L*, a*, b*), total soluble solid, pH, total phenolic content and antioxidant capacity were analyzed.

2.4 Method of Analysis

2.4.1 Physical properties analysis

The color of samples was measured using a colorimeter (Colorimeter, NH300, China). Results were expressed in CIE color values; L* = lightness (0=black, 100= white), a* (-a* = greenness, +a* = redness) and b* (-b* = blueness, +b* = yellowness). All the analyses were performed in triplicates.

2.4.2 Chemical properties analysis

Total soluble solid was measured using Pocket refractometer 0-85 °Brix (ATAGO, Japan), pH value was conducted by pH meter (pHTestr30, Singapore) and moisture content was determined by moisture balance (Sartorius Model MA35M, Germany).

Total phenolic content was determined using the Folin-Ciocalteu method (adapted slightly from Singleton et al., 1999) with slightly modifications. One mL of extract was added with 1 mL of Folin-Ciocalteu 10% (w/v). The solution was stirred and 5 mL of 0.40 M Na_2CO_3 solution was then mixed and wrapped with parafilm. The solution was left in dark condition at ambient temperature for 30 min. The absorbance was recorded at 765 nm using a spectrophotometer (Helios UUA-161514, Thermo Scientific, USA). The content of phenolic compounds was determined from the standard curve of gallic acid concentration of 20.00-100.00 ppm (y = 0.0107x+0.0499, R2 = 0.9985). The results were expressed in mg of gallic acid equivalents per liter of sample (mg GAE/L).

The evaluation of the antioxidant capacity by DPPH inhibition. The radical scavenging activity of extract was measured using the stable radical 2, 2 –diphenyl-1-picrylhydrazyl (DPPH) in accordance with Chairgulprasert & Kongsuwankeeree (2017). Briefly, 2 mL of extract was mixed with 2 mL of methanolic solution of 0.2 mM DPPH. The control was obtained without extract. The mixture was vortexed vigorously and left for 30 min at room temperature in the dark. The bleaching rate of a stable DPPH was monitored at a characteristic wavelength in the presence of the sample using a spectrophotometer (Helios UUA-161514, Thermo Scientific, USA). In its radical form, DPPH absorbs at 517 nm but, upon reduction by an antioxidant or a radical compound, its absorption decreases. The percentage inhibition values (I) were calculated as given in Equation (1) López-de-Dicastillo et al. (2012).

$$I\ (\%) = [(\text{abs control} - \text{abs sample})/\text{abs control}] \times 100 \quad (1)$$

2.5 Statistical analysis

Completely randomized design (CRD) was used for the experiment. All the analyses were performed in triplicates. Pair sample T-test at 5 % level of significance ($P \leq 0.05$) was employed for data analysis using SPSS for Window version 29 (Trial version).

3. Results and Discussion

3.1 Chemical properties of fresh Robusta coffee blossom

The Robusta coffee blossoms were collected from Ban Natong, Phrae province Northern part of Thailand with an elevation of 600 meters above mean sea level. The results for the chemical properties of the fresh Robusta coffee blossom are presented in Table 1.

Table 1. Chemical properties of Robusta coffee blossom

Parameters	Content
Moisture content (%, wet basis)	83.65±0.15
Total phenolic content (mgGAE/g of fresh coffee blossom)	30.07±0.03
DPPH inhibition (%)	71.19±2.07

From table 1, the results presented that the moisture content, total phenolic content and DPPH inhibition of fresh Robusta coffee blossom were 83.65±0.15 (%, wet basis), 30.07±0.03 mgGAE/g of fresh coffee blossom, and 71.19±2.07%, respectively. The total phenolic content in study found a similar result with previous study of Chairgulprasert & Kongsuwankeeree (2017). The Robusta coffee blossom was collected from a coffee plant in Surat Thani province Southern part of Thailand during periods of January to March and found that the total phenolic content of blossom collected in January was 28.32 mgGAE/g of fresh coffee blossom, while, the blossoms were collected during February and March provided 4 and 5 folds of total phenolic contents compared to January.

The fresh Robusta coffee blossom was then processed for making tea using two processes of commercial tea produced by a local small enterprise at Ban Natong, Phrae province (control) was compared to a laboratory prototype.

3.2 Quality of Robusta Coffee Blossom Tea

The commercial tea produced by a local small enterprise at Ban Natong, Phrae province (control) was compared to a laboratory prototype. Both conditions were prepared using pan roasting then sun drying. The commercial tea was prepared under condition without control of temperature and time. The prototype was prepared using pan roasting at 75-80 °C for 20 minutes then sun drying for 3 days (average temperature of daytime was 40°C and night time was 24 °C). The fresh blossom and tea are shown in Figure 1. The qualities of Robusta coffee blossom tea were measured. The results are presented in Table 2 and Table 3.

(a) (b) (c)

Figure 1. Photographs of (a) Robusta coffee blossom, (b) Tea from original process and (c) Tea from prototype process

Table 2. Physicochemical properties of Robusta coffee blossom tea

Parameters	Original process	Prototype process
L* ns	8.06±0.42	7.81±1.26
a* ns	8.51±2.20	9.72±1.08
a* ns	-2.69±2.25	-2.33±1.73
Moisture content (%, wet basis) ns	2.24±0.08	2.14±0.11

Note: ns means not significant ($p>0.05$) different within the same row by Pair Sample T-test

The results show that there was no significant difference ($p>0.05$) of L*, a* and b* values influenced by drying conditions. The L*, a* and b* values of Robusta coffee blossom tea prepared by commercial process were 8.06, 8.51 and -2.69, respectively, while tea prepared by prototype process were 7.81, 9.72 and -2.33, respectively. The results indicating the color shade of tea were dark. This is related to the browning reaction during roasting and drying of coffee blossoms. Basically, melanoidins are the polymeric and colored products of the Maillard reaction. This reaction takes place during processes which involve heating (cooking, baking, and roasting) of foods containing reducing sugars and compounds possessing free amino groups (Nguyen et al., 2019). Therefore, the color of Robusta coffee blossom was darker after the process. The moisture content of tea prepared by commercial and prototype processes were 2.24 and 2.14 % (wet basis), respectively. The results were similar with Srisuk et al. (2022). They developed healthy sachet drinks from organic herbs in Chachoengsao Province and presented moisture content ranging from 2.59-2.91%. The moisture contents of coffee blossom tea from both conditions were lower than the Thai Community Product Standard (120/2546). The drinking tea was then prepared by soaking 1.6 g dried tea in 110 mL. hot water at 85°C for 4 minutes. The visual appearances of drinking tea are presented in Figure 2.

Figure 2. Appearance of drinking Arabica coffee blossom tea

The drinking tea was then analyzed. The results demonstrated as shown in Table 3 and Table 4.

Table 3. Physical properties of drinking Robusta coffee blossom tea

Parameters	Control	Prototype
L* ns	24.74±0.11	25.10±0.51
a* ns	-1.54±0.42	-1.26±1.38
a* ns	-4.61±0.19	-5.02±0.74

Note: ns means not significant ($p>0.05$) different within the same row by Pair Sample T-test

Table 4. Chemical properties of Drinking Robusta coffee blossom tea

Parameters	Control	Prototype
Total soluble solid (°Brix)	0.90±0.00	1.10±0.00
pH	5.51±0.05 a	6.24±0.02 b
Total phenolic content (mgGAE/L)	504.41±39.24 a	644.60±13.90 b
DPPH inhibition (%)	45.69±0.33 a	54.26±0.58 b

Note: Mean ± standard deviation values followed by a different letter within the same row are significantly different ($p\leq0.05$) by Pair Sample T-test

The results presented that there were no significant differences on color values of drinking tea. The drinking tea provided the similar color as shown in Figure 2. Although different conditions offered the similar physical properties, the chemical properties were difference as demonstrated in Table 4. The drinking tea from control and prototype showed total soluble solid at 0.90 and 1.10 °Brix, respectively, and pH at 5.51 and 6.24, respectively. Total soluble solid found in tea is a result of sugar and organic acid containing in coffee blossom. From the previous study of De Abreu Pinheir et al. (2021) who found that Conilon coffee blossom which planted in Brazil had total titratable acidity 0.23 g 100 g−1 (as citric acid) and pH at 6.34. Conilon is another species with very similar properties to Robusta but with some genetic differences (Muner et al., 2019). The pH of tea prepared by prototype process close to study of De Abreu Pinheir et al. (2021). The pH of tea prepared by prototype process differed from prototype process. Its pH also similar with the tea prepared from *Caesalpinia sappan* L, *Pogonatherum paniceum* (Lamk) Hack and *Cinnamomum iners* Reinw.

ex Blume. The tea presented pH ranging 6.32-6.89 (Srisuk et al., 2022). The lower pH indicating higher acidity of tea then provide sour taste which may affect consumer preference.

The results also presented significant difference ($p \leq 0.05$) in total phenolic content and DPPH inhibition. The tea from commercial and prototype process had total phenolic content of 504.41 mg GAE/L and 644.60 mgGAE/L, respectively and DPPH inhibition of 45.69 and 54.26 respectively. The results demonstrated that the prototype process showed superior in bioactive compound and antioxidant activity. Alkaltham, Salamatullah, & Hayat (2020) and Cheng et al. (2019) found that the drying method was able to influence the antioxidant capacity of coffees. Büyükbalci & El (2007) determined total phenolic contents of some herbal teas included black tea, green tea peppermint relax tea, thyme, olive leaves, sage, absinthium, roselle and shrubby blackberry and found total phenolic contents at 1,430, 4,070, 3,750, 860, 1,510, 70, 330, 570, 170 and 340 mg GAE /L, respectively. This indicated that total phenolic contents of Robusta coffee blossom were similarly with relax tea. Büyükbalci & El (2007) informed that relax tea was commercial tea containing *Hypericum perforatum* and lavender. In addition, DPPH inhibition of drinking tea showed the similar result with Srisuk et al. (2022) who found that tea produced from mixing of 73% *Caesalpinia sappan* L, 20% *Pogonatherum paniceum* (Lamk) Hack and and 7% *Cinnamomum iners* Reinw. ex Blume. Presented 69.42 % DPPH inhibition. This study can be concluded that Robusta coffee blossom had efficiency for tea production as relax tea.

4. Conclusion

Based on this study, it can be concluded that the fresh Robusta coffee blossoms had moisture content, total phenolic content and DPPH inhibition at 83.65 % (wet basis), 30.07 mg GAE/g and 71.19%, respectively. The resultant blossoms tea after processed using commercial and prototype processes had moisture content at 2.14and 2.24%, respectively. The moisture contents of tea from both conditions were lower than the Thai Community Product Standard (120/2546). The prototype process which controls temperature and time during pan roasting can enhance bioactive compounds and antioxidant activity. The drinking tea is prepared from a prototype process by soaking 1.6 g dried tea in 110 mL. hot water at 85°C for 4 minutes had total phenolic content and DPPH inhibition at 644.60 mg GAE/L and 54.26% which were higher than commercial processes. Comparison of the results found in this study with previous study of herbal tea, the resultant from this research can be produced as relax tea. Therefore, Robusta coffee blossoms can be applied as raw material for production of value-added products.

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Evaluation of Total Phenolic Content, Antioxidant Activity and Chlorophyll Content of *Murraya siamensis* Leaf Extract

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Abstract

The objective of this research was to evaluate total phenolic content, antioxidant activity and chlorophyll content of ethanolic extract of *Murraya siamensis* leaves. Young and mature leaves were collected from the Crop Production Technology farm, Maejo University-Phrae campus. The leaves were then oven dried at 50°C for 20 hours. Four treatments consisted of fresh young (FY), fresh mature (FM), dried young (DY) and dried mature (DM) leaves were then extracted for analysis. The estimation of total phenolic content was done by using the Folin-Ciocalteu method. The antioxidant efficacy of extract was evaluated using (DPPH) 2,2-Diphenyl-1-picrylhydrazylradical scavenging activity. Chlorophyll contents were measured using spectrophotometer at 645 and 663 nm. Total chlorophyll, chlorophyll a, and b were calculated. The results presented that total phenolic content of FY, FM, DY and DM leaves were 7.53, 6.22, 16.64 and 12.73 mg GAE/g, respectively, while, DPPH inhibition were 74.63, 72.83, 90.32 and 91.00%, respectively. Chlorophyll a of FY, FM, DY and DM leaves were 0.475, 0.447, 1.214 and 1.147 mg/g, respectively, while, chlorophyll b were 0.051, 0.078, 0.366 and 0.478, respectively. Therefore, total chlorophyll of FY, FM, DY and DM leaves were 0.526, 0.525, 1.580 and 1.634 mg/g, respectively. The results can be concluded that the oven dried young leaves had maximum total phenolic content, while oven dried mature leaves had maximum total chlorophyll. The results of these bioactive compounds will be important for decision of application of the extract from *Murraya siamensis* leaves in agricultural products.

Keywords: Chlorophyll, DPPH inhibition, *Murraya siamensis*, Total phenolic content

1. Introduction

The species *Murraya siamensis* Craib, namely "Prong Fah" in Thai. This plant is a small shrub found in tropical and subtropical areas of Thailand and other countries in Southeast Asia (Suphrom et al., 2024). Fresh leaves of *M. siamensis* are normally used in traditional Thai cuisine due to their sweet and spicy tastes (Suphrom et al., 2024).

Bioactive compounds such as alkaloids (Yohanes et al., 2023), coumarin (Ito et al., 2005), and flavonoids (Suphrom et al., 2024) were found in *M. siamensis* leaves. This spicy has been study on potential biological activity including antidiarrheal (Mandal et al., 2010), anti-inflammatory (Chen et al., 2020), cytotoxic (Ma et al., 2021), antioxidant (Suphrom et al.,

2024) activities Therefore, the leaves of *M. siamensis* have been used to treat various ailments such as cough, sore throat, flatulence, and asthma (Ito et al., 2005).

The extraction of plant leaves has been study by Kingne et al. (2018), Habermann et al. (2016), Murugan et al. (2016) and Tomaino et al. (2005) and found that there were many factors impact on bioactive activities of plant extracts such as maturation, extraction method, drying condition. During leaf maturation, changes in the oxidative metabolism of plant tissues occur MLinarić et al. (2016). Jokili, Shaari & Razak (2019) reported that the bioactive compounds of *C. alata* leaves collected at different stages of maturity (young, medium and old) were measured and increased with age. Drying process is very important to extend the shelf life of a herbal product. Drying of herbs inhibits microbial growth and forestalls certain biochemical changes. However, at the same time it can also give rise to other alterations that affect herb quality, such as changes in appearance and the chemical properties of the products (Jokili, Shaari & Razak, 2019). Thus, the objective of this research was to evaluate total phenolic content, antioxidant activity and chlorophyll content of ethanolic extract of *Murraya siamensis* leaves.

2. Methodology

2.1 Material

Murraya siamensis leaves were harvested from the Crop Production Technology farm, Maejo University-Phrae campus in the morning. The leaves separated into two groups of young and mature leaves. The young leaves were the leave age less than 21 days, while mature leaves were above 21 days. The wilting leaves were removed and fresh leaves were then packed in an airtight container and kept at -18 °C until the moment of analysis.

2.2 Drying of *Murraya siamensis* leaves

The leaves were rinsed with tap water to remove dust and were subsequently oven dried at 50°C for 20 hours. Fours treatment consisted of fresh young (FY), fresh mature (FM), oven dried young (DY) and oven dried mature (DM) leaves were then extracted for analysis.

2.3 Extraction of *Murraya siamensis* leaves

Four treatments consisting of fresh young (FY), fresh mature (FM), oven dried young (DY) and oven dried mature (DM) leaves were then extracted. The samples were chopped into small pieces and ground into a fine powder and extracted using 95% ethanol (ratio 1:20 w/v). The mixtures were shaken 120 rpm at room temperature for 24 hours and then filtered through filter paper no. 1. The filtrates were removed using a rotary evaporator at 45 °C. The viscous crude ethanolic extracts were kept at 4 °C until the moment of analysis.

2.4 Method of Analysis

2.4.1 Physical properties analysis

The color of samples was measured using a colorimeter (Colorimeter, NH300, China). Results were expressed in CIE color values; L* = lightness (0=black, 100= white), a* (-a* =

greenness, +a* = redness) and b* (-b* = blueness, +b* = yellowness). All the analyses were performed in triplicates.

2.4.2 Determination of Total Phenolic Content

Total phenolic content was determined using the Folin-Ciocalteu method (adapted slightly from Singleton et al., 1999) with slightly modifications. One mL of extract was added with 1 mL of Folin-Ciocalteu 10% (w/v). The solution was stirred and 5 mL of 0.40 M Na_2CO_3 solution was then mixed and wrapped with parafilm. The solution was left in dark condition at ambient temperature for 30 minutes. The absorbance was recorded at 765 nm using a spectrophotometer (Helios UUA-161514, Thermo Scientific, USA). The content of phenolic compounds was determined from the standard curve of gallic acid concentration of 20.00-100.00 ppm ($y = 0.0107x+0.0499$, $R^2 = 0.9985$). The results were expressed in mg of gallic acid equivalents per liter of sample (mg GAE/L).

2.4.3 Evaluation of Antioxidant activity

The evaluation of the antioxidant capacity by DPPH inhibition. The radical scavenging activity of extract was measured using the stable radical 2, 2 –diphenyl-1-picrylhydrazyl (DPPH) in accordance with Chairgulprasert & Kongsuwankeeree (2017). Briefly, 2 mL of extract was mixed with 2 mL of methanolic solution of 0.2 mM DPPH. The control was obtained without extract. The mixture was vortexed vigorously and left for 30 min at room temperature in the dark. The bleaching rate of a stable DPPH was monitored at a characteristic wavelength in the presence of the sample using a spectrophotometer (Helios UUA-161514, Thermo Scientific, USA). In its radical form, DPPH absorbs at 517 nm but, upon reduction by an antioxidant or a radical compound, its absorption decreases. The percentage inhibition values (I) were calculated as given in Equation (1) López-de-Dicastillo et al. (2012).

$$I\ (\%) = [(\text{Abs control} - \text{Abs sample})/\text{abs control}] \times 100 \quad (1)$$

2.4.4 Determination of Chlorophyll content

Chlorophyll was extracted in 80% acetone. The 663nm and 645nm wavelength spectrophotometer was used for different readings of chlorophyll a and chlorophyll b. Weight 1 g of finely cut leaves and mixed well into a clean mortar. Grind the sample to a fine pulp by adding 20 mL of 80% acetone. The extract was centrifuge at 5,000 rpm for 5 minutes and transferred the supernatant to a 100 mL volumetric flask. Grind the residue with 20 mL of 80% acetone and again centrifuge and transfer the supernatant to the same volumetric flask. This procedure was repeated to change the residue green color to colorless. Washed the mortar and pestle thoroughly with 80% acetone and collected in the volumetric flask. To make the final volume of extract up to 100 mL with 80% acetone. The absorbance of the samples was recorded at the 645 and 663nm against the solvent 80% acetone as a blank. The amounts of chlorophyll a, b and total chlorophyll were calculated as given in Equation (2), (3) and (4), respectively (More & Borkar, 2016).

mg Chlorophyll a/g sample = $[(12.7 \times A_{663})-(2.69 \times A_{645})] \times V/[1,000 \times W]$ (2)
mg Chlorophyll b/g sample = $[(22.9 \times A_{645})-(4.68 \times A_{663})] \times V/[1,000 \times W]$ (3)
mg Total chlorophyll a/g sample = $[(20.2 \times A_{645})-(8.02 \times A_{663})] \times V/[1,000 \times W]$ (4)

Where A = absorbance at specific wavelengths
V = final volume of chlorophyll extract in 80% acetone
W = fresh weight of tissue extracted.

2.5 Statistical analysis

Completely randomized design (CRD) was used for the experiment. All experiments were performed in triplicate, all data are expressed as the mean ± standard deviation. Data were subjected to Analysis of Variance (ANOVA) using SPSS for Window version 29 (Trial version). In case of any differences in mean, multiple comparisons were performed using Duncan's Multiple Range Test (DMRT) at 5 % level of significance ($P \leq 0.05$).

3. Results and Discussion

The extracts of four treatments consisted of fresh young (FY), fresh mature (FM), dried young (DY) and dried mature (DM) leaves were analyzed the physical and chemical properties as following data.

3.1 Color values of *Murraya siamensis* leaves

The color values of *Murraya siamensis* leaves consisted of fresh young (FY), fresh mature (FM), dried young (DY) and dried mature (DM) leaves as shown in Table 1.

Table 1. Color values of *Murraya siamensis* leaves

Sample	L*	a*	b*
Fresh young leaves (FY)	54.46±1.33 ^{b}	-5.50±1.17 ^{c}	35.91±2.05 ^{b}
Fresh mature leaves (FM)	34.01±1.21 ^{a}	-12.13±1.17 ^{a}	21.06±1.60 ^{a}
Dried young leaves (DY)	49.05±1.63 ^{b}	-9.40±0.69 ^{b}	44.76±0.88 ^{c}
Dried mature leaves (DM)	37.31±1.58 ^{a}	-10.40±1.18 ^{a}	36.40±5.84 ^{a}

Mean ± standard deviation values followed by a different letter within the same column are significantly different ($p \leq 0.05$) by Duncan's multiple range test

From table 1, ANOVA showed a significant difference ($p \leq 0.05$) on color values consisting of L*, a* and b*. The results showed that FY, FM, DY and DM had L* and b* values of 54.46, 34.01, 49.05 and 37.31, respectively and 35.91, 21.06, 44.76 and 36.40, respectively. These results demonstrated the young leaves presented a higher lightness and yellowness compared to mature leaves; meanwhile, there was no difference in L* value influenced by the drying process. The a* values of FY, FM, DY and DM leaves were -5.50, -12.13, -9.40 and -10.40, respectively. The lower in a* values (negative value) indicate higher in greenness. The visual appearance of *Murraya siamensis* leaves were presented in Figure 1 and 2.

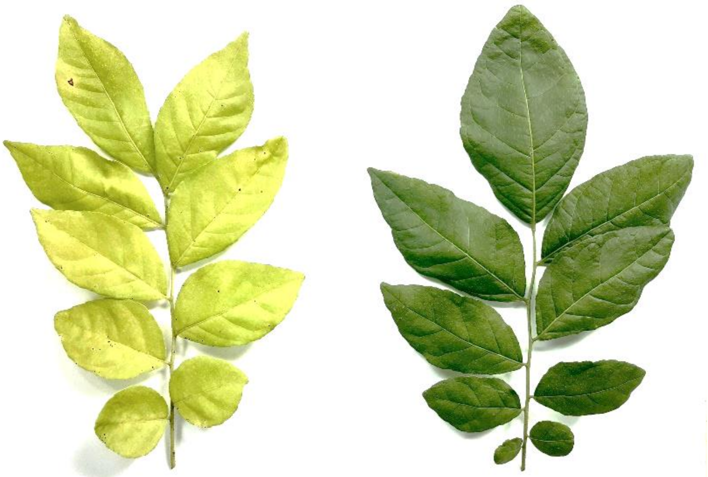

Figure 1. *Murraya siamensis* leaves: young leaves (left) and mature leaves (right)

Figure 2. Dried *Murraya siamensis* leaves: young leaves (left) and mature leaves (right)

The results demonstrated that mature leaves had lower in a* value (-a) indicating higher in green color. Green color of plants is generally influenced by chlorophyll content. This may result from mature leaves being higher in chlorophyll as in Table 3. Generally, this pigment occupies a unique role in the physiology, productivity and economy of green plants. Quantity of chlorophyll per unit area is an indicator of photosynthetic capacity of a plant (Barua, Das & Gogoi, 2016).

3.2 Total phenolic content and antioxidant activity of *Murraya siamensis* leaves

Phenolic compounds are the major secondary metabolites found in plants which are used for their defence. In many studies the antioxidant activity of plant extracts has been attributed to these molecules (Kingne et al., 2018). The extract of *Murraya siamensis* leaves were analyzed for total phenolic content by the Folin-Ciocalteu method and antioxidant activity by DPPH inhibition. The results are presented in Table 2.

Table 2. Total phenolic content and antioxidant activity of *Murraya siamensis* leaves

Sample	Total phenolic content (mg GAE/g fw)	DPPH Inhibition (%)
Fresh young leaves (FY)	7.53±0.21 [b]	74.63±0.71 [b]
Fresh mature leaves (FM)	6.22±0.29 [a]	72.83±1.32 [a]
Dried young leaves (DY)	16.64±0.63 [d]	90.32±0.29 [c]
Dried mature leaves (DM)	12.73±0.44 [c]	91.00±0.30 [c]

Mean ± standard deviation values followed by a different letter within the same column are significantly different (p≤0.05) by Duncan's multiple range test

From table 2, ANOVA showed significant difference (p≤0.05) on total phenolic content and DPPH inhibition. The results presented that FY, FM, DY and DM had total phenolic content of 7.53, 6.22, 16.64 and12.73 mg GAE/g fw, respectively, while DPPH inhibition were 74.63, 72.83, 90.32 and 91.00%, respectively. The results indicated that dried leaves had higher total phenolic content and antioxidant activity than fresh leaves. Basically, fresh leaves have high moisture content compared to dried samples therefore lead to lower bioactive compounds. Moreover, in comparison between young and mature leaves, the results found that young leaves presented higher total phenolic content and DPPH inhibition than mature leaves. This study found a similar result with previous study of Murugan & Velayudhan (2016) with the leaves of *Tectona grandis*. They found that the young leaves had higher phenolic content than the mature stage. Similar results also reported by Habermann et al. (2016), the phenolic content and antioxidant activity of young leaves of *Blepharocalyx salicifolius* extract were higher than those of mature leaves. Moreover, Kingne et al. (2018) also found that young leaves extracted from mango (*Mangifera indica*) and avocado (*Persea americana*) were richer in phenolic content than mature ones. Therefore, the state of maturity of plants had an impact on their phenolic content and antioxidant activity. Generally, plants are always kept in dried matter to prolong shelf-life. However, there was also a study found that drying generally causes the depletion of naturally occurring antioxidants due to the instability of these compounds induced by the heat of drying (Tomaino et al., 2005). Thus, this study would like to observed the impact of drying at 50 °C for 20 hours on properties of leaves and found that drying at this condition did not decrease total phenolic content and antioxidant activity but increase due to removal of water then lead to higher concentration of total phenolic content and chlorophyll which presented in next step.

3.3 Chlorophyll content of *Murraya siamensis* leaves

Chlorophyll contents including chlorophyll a, b and total chlorophyll of *Murraya siamensis* leaves extract were measured and demonstrated in Table 3.

Table 3. Chlorophyll content of *Murraya siamensis* leaves

Sample	Chlorophyll a (mg/g)	Chlorophyll b (mg/g)	Total chlorophyll (mg/g)
Fresh young leaves (FY)	0.475±0.003 [a]	0.051±0.003 [a]	0.526±0.003 [a]
Fresh mature leaves (FM)	0.447±0.001 [a]	0.078±0.002 [b]	0.525±0.003 [a]
Dried young leaves (DY)	1.214±0.006 [b]	0.366±0.002 [c]	1.580±0.006 [b]
Dried mature leaves (DM)	1.147±0.005 [b]	0.478±0.003 [d]	1.634±0.005 [c]

Mean ± standard deviation values followed by a different letter within the same column are significantly different ($p \leq 0.05$) by Duncan's multiple range test

From table 3, ANOVA showed significant different ($p \leq 0.05$) on chlorophyll a, b and total chlorophyll. The results presented that chlorophyll a content of FY, FM, DY and DM leaves were 0.475, 0.447, 1.214 and 1.147 mg/g, respectively, while, chlorophyll b contents were 0.051, 0.078, 0.366 and 0.478, respectively. Therefore, total chlorophyll of FY, FM, DY and DM leaves were 0.526, 0.525, 1.580 and 1.634 mg/g, respectively. This could be related to an increase in the photosynthetic performance at steady-state levels is observed when the plant gets older (Bielczynski et al., 2017). The results found in this study was similarly with previous study of Kamble et al. (2015). A total of ten plant species were selected namely Mango (*Magnifera indica*), Hibiscus (*Hibiscus rosasinensis*), Gavua (*Psidium guajava*), Almond (*Prunus dulcis*), Bryophyllum (*Bryophyllum pinnatum*), Sapodilla (*Manikara zapota*), Neem (*Azadiracta indica*), Ashoka (*Polyalthia longifolia*), Ficus (*Ficus benjamina*) and Datura (*Datura metal*) and were used for analysis of chlorophyll content. In all the cases the adult leaves showed higher chlorophyll content in comparison to young leaves. This has been proved that the age of leaves was an important factor for chlorophyll content. Generally, the chlorophyll also plays important role in plant physiology and it can be act as nutrition in decline blood sugar conditions, detoxification, digestion, excretion and decreasing allergens (Singh et al., 2011, Srichaikul et al., 2011). The similar trend also observed by Jolkili, Shaari & Razak (2019). The extract of *Cassia alata* leaves from mature stage had higher chlorophyll than the young one. This study can be assumed that mature leaves have higher potential to decline blood sugar.

4. Conclusion

Based on this study, the results can be concluded that the oven dry process did not influence the lightness of *Murraya siamensis* leaves but it was affected by the maturity stage. The dried young leaves had maximum total phenolic content, while oven dried mature leaves had maximum total chlorophyll. The results of these bioactive compounds will be important for the decision of application of the extract from *Murraya siamensis* leaves in agricultural products. This project is supposed to apply *Murraya siamensis* leaves extract in gummy jelly products to act as antioxidants.

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Development of Sauce from Reject Gros Michel Banana (*Musa sapientum*) Cultivated for Exporting

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Abstract

The purpose of this project was to optimize the amount of Gros Michel banana for production of sauce. The poor quality bananas cultivated in Chumphon Province which did not pass for export were used. The effects of banana amounts at 40, 45 and 50 % (w/w) on the quality of sauces were conducted. The chemical properties including total soluble solid (TSS), pH, titratable acidity (TTA), total sugar and reducing sugar, and physical properties including viscosity, flow rate and color values (L*, a*, b*) were measured. The results showed that the amount of banana influenced significantly ($p \leq 0.05$) on TSS and all physical properties. An increase in the amount of banana provided a significant ($p \leq 0.05$) increase in TSS and viscosity but decreased flow rate. For color values, an increase in the amount of banana decreases L* value indicating lower lightness but increases a* (redness) and b* (yellowness) values. The sauces prepared using 40, 45, 50% (w/w) had TSS at 39.00, 39.90 and 40.30 °Brix, respectively, and viscosity at 1,904, 2,000 and 2,800 cPs, respectively, while flow rate at 0.13, 0.11 and 0.08 cm/s, respectively. The sauces contained banana at 40, 45, 50% (w/w) had L* value at 30.70, 31.05 and 29.81, respectively, while, b* value at 4.07, 4.30 and 4.98, respectively and b* value at 6.44, 6.39 and 7.04, respectively. There was no significant ($p>0.05$) difference on pH, TTA, total sugar and reducing sugar. The sauces presented pH, TTA, total sugar and reducing sugar in a range of 3.59-3.61, 0.87-0.89 % (as acetic acid), 33.58-35.24% and 7.25-8.02 %, respectively. Basically, viscosity is an important rheological property of sauce. Therefore, based on a commercial product which has a viscosity of approximately 2,000 cPs, the formula containing 40% and 45% (w/w) of banana could be used for the development of the product in the next sensory evaluation.

Keywords: Banana, Sauce, Viscosity

1. Introduction

Banana is one of the most widely consumed fruits and ranks fourth after rice, wheat and corn among the world's most economically important food crops (Zaidan et al., 2021) because it is rich in nutrients, starch, sugar, and vitamins A and C, potassium, calcium, sodium, and magnesium (Phukasmas, 2017). It has been demonstrated that banana can accelerate the production of serotonin in human brains. Serotonin is able to stimulate the human nervous system and make people feel happy and peaceful. Therefore, banana is also known as the "happy fruit" (Wang et al., 2015). It is one of Thailand's most important economic crops. Due to the widespread utilization of different parts of bananas, 15,051,333 kg of fresh bananas and processed bananas were exported from Thailand in 2020 (Pakeechai et al., 2022). Basically, grading involves the inspection, assessment and sorting of various foods regarding quality, freshness, legal conformity and market value. However, some bananas which were rejected for export are still rich in nutrients. Processing the reject fruits can reduce losses due to rejection. Both raw and ripe bananas can be processed into numerous food products. The fruit can be consumed as fried banana, banana chips, and sweet banana in coconut cream (Nimsung et al., 2007). Ditchfield et al. (2004) that banana puree has a longer shelf life than the fruit and can be used as an ingredient for many food products such as baby food, gelatin, cake, bread, pie, yogurt, juice, ice cream, pudding, among others. Martinez et al. (2025) reported that oxidized ripe banana is a good ingredient in salad dressing as it contains antioxidants, vitamins, dietary fibers, and starch. As a condiment that is served with the main dish, banana sauce compliments the main food and enriches its flavor. Thailand Sauces Market is expected to grow during 2024-2030 (6Wresearch, 2023). Thus, production of sauce using reject Gros Michel banana can be an alternative income source for banana farmers and processors. One of the important properties that must be controlled in fluid products is viscosity. The increase of banana content in the product may have affected the fluid properties like viscosity and flow behavior. Eamratanawong (2003) reported that the suitable level of banana content was 40%. The 60% banana content was too thick while 20% banana content was too thin. Although the texture of 30-50% banana content was not different, the panelist preferred at 40% banana content more than 30% and 50% banana content. Therefore, this study aimed to optimize the level of banana for production of sauce.

2. Methodology

2.1 Material

The bananas cultivated in Chumphon Province which were rejected for export were used. Garlic and chili peppers were purchased from a local market in Phrae Province. White sugar (Thai Roongrueng Co., Ltd.), Salt (Thai Refined Salt Co., Ltd.) and Distilled vinegar (PFC Food, Co., Ltd.) were used in this study. The formulation of sauce as presented in Table 1.

Table 1. The formulation of sauce.

Ingredients	Amount of Gros Michel Bananas (%)		
	Treatment 1	Treatment 2	Treatment 3
Gros Michel Bananas	40	45	50
Garlic	2.5	2.5	2.5
Chili pepper	2.5	2.5	2.5
White sugar	17	17	17
Distilled vinegar (5% acetic acid)	18	18	18
Salt	1	1	1
Water	19	14	9
Total	100	100	100

2.2 Preparation of banana sauce

Preparation of banana sauce was adopted from papaya sauce produced by Penjumras et al. (2018). Gros Michel banana fruits were cleaned, peeled and trimmed. These were pureed using a blender at a speed 5 (700 watts) for 1 minute. Chili pepper was cleaned and the seeds removed. Garlic was cleaned and peeled. The chili pepper and garlic were then steamed for 30 minutes. The steamed chili pepper and garlic were then blended with distilled vinegar and water using a blender at speed 5 (700 watts) for 30 seconds. All blended ingredients were then mixed and filtered through 50 mesh sieves. The filtrate was then mixed with white sugar and salt. The mixture was then heated at 80-85°C for 15 minutes and hot filled in a glass bottle. The sample sauce was kept at 4°C until prior to analysis.

2.3 Method of Analysis

2.3.1 Physical properties analysis

The color of samples was measured using a colorimeter (Colorimeter, NH300, China). Results were expressed in CIE color values; L* = lightness (0=black, 100= white), a* (-a* = greenness, +a* = redness) and b* (-b* = blueness, +b* = yellowness). Viscosity using Brookfield viscometer (RVT, Brookfield viscometer, USA). The viscosity of banana sauce was measured with a viscometer (RVT, Brookfield viscometer, USA). The 400 mL of sauce was poured into a 500 mL beaker and its viscosity was measured. Flow rate using Bostwick consistometer. A measured sample, usually 75 ml, is placed in the reservoir behind the gate. The gate is released, by pressing the lock release lever - the spring action ensures it opens instantaneously. As the sauce flows down the instrument for 30 seconds then its progress can be accurately measured using the graduated scale. All the analyses were performed in triplicates.

2.3.2 Chemical properties analysis

Total soluble solid was determined using Pocket refractometer range of 0-85 °Brix (ATAGO, Japan). pH value was measure using pH meter (pHTestr30, Singapore). Titratable acidity and total sugar and reducing sugar using Lane and Eynon method (AOAC, 2000). All the analyses were performed in triplicates.

2.4 Statistical analysis

Completely randomized design (CRD) was used for the experiment. Data were subjected to Analysis of Variance (ANOVA) using SPSS for Window version 29 (Trial version). In case of any differences in mean, multiple comparisons were performed using Duncan's Multiple Range Test (DMRT) at 5 % level of significance ($P \leq 0.05$).

3. Results and Discussion

The physical properties including viscosity, flow rate and color values and chemical properties including Total soluble solid, pH, titratable acidity (% as acetic acid), total sugar and reducing sugar were present in Table 2 and Table 3, respectively.

Table 2. Physical properties of Sauce from Rejected Gros Michel Bananas

Physical Properties	Gros Michel Bananas (%)		
	40	**45**	**50**
Viscosity (cPs)	1,904.00±6.93[a]	2,000.00±0.00[b]	2,800.00±0.00[c]
Flow rate (cm/s)	0.13±0.01[c]	0.11±0.01[b]	0.08±0.00[a]
Color values			
L*	30.70±0.17[b]	31.05±0.07[b]	29.81±0.73[a]
a*	4.07±0.09[a]	4.30±0.22[b]	4.98±0.13[c]
b*	6.44±0.23[a]	6.39±0.09[a]	7.04±0.12[b]

Mean ± standard deviation values followed by a different letter within the same row are significantly different (p≤0.05) by Duncan's multiple range test

From table 2, ANOVA showed significant difference (p≤0.05) on viscosity, flow rate and color values of L*, a* and b*. The results presented that the sauce containing 40, 45 and 50% of Gros Michel banana pulp had viscosity of 1,904, 2,000 and 2,800 cPs, respectively, while flow rate were 0.13, 0.11 and 0.08 cm/s, respectively. These demonstrated that the increase of banana pulp tended to increase viscosity then led lower in flow rate. The higher of Gros Michel banana pulp influenced higher in total soluble solid as shown in Table 3 then resulting in the higher its viscosity. In addition, bananas rich in dietary fiber which can absorb water molecules then lead viscosity of fluid increase (Zaidan et al., 2021). The viscosity of a product is dictated by the intermolecular forces that exist among a molecule and water solutes such as sugars and acids. This interaction is caused by hydrogen bond strength and intermolecular spacing, which are highly reliant on concentration and temperature (Kaur, Aggarwal & Kumar, 2021). The similar result was found by Azami, Ahmad & Abd. Wahab (2023). The higher viscosity makes the sauce more difficult for them to flow, therefore, increased banana pulp decreased the flow rate of sauce. Comparison of viscosity to commercial product and found that its viscosity is approximately at 2,000 cPs which provide the suitable texture for consumer. Thus the proper banana content for preparation of sauce could be 40-45%. The similar result was found by Eamratanawong (2003) which concluded that the Gros Michel banana pulp for production of sauce was 40%.

The color values of the sauce demonstrated that L*, a* and b* were affected by the addition of banana pulp. An increase in banana pulp at 50% decreases in L*(lightness), increases a* (redness) and b* (yellowness) which indicates higher in dark and intensity of color. These may be due to the browning reaction of both Maillard and enzymatic browning reaction. Banana contains high contents of glucose, fructose and proteins which increase the Maillard reaction meaning that enzymes such as polyphenol oxidase might be present in pulp contributing to enzymatic browning (Alkarkhi et al.,2011; Escalante-Minakata et al., 2018; Martinez et al., 2025). The similar trend was found by Martinez et al. (2025) who study the usage of ripe banana pulp for the development of a salad dressing. Basically, the redness value is caused by the combination of carotenoid pigments such as capsanthin and capsorubin from chilli (Arimboor & Natarajan, 2015).

Table 3. Chemical properties of Sauce from Rejected Gros Michel Bananas

Physical Properties	**Gros Michel Bananas (%)**		
	40	**45**	**50**
Total soluble solid (°Brix)	39.00±0.17 [a]	39.97±0.15 [b]	40.30±0.10 [c]
pH	3.60±0.01	3.59±0.02	3.61±0.01
Titratable acidity (% as acetic acid)	0.87±0.03	0.88±0.02	0.89±0.02
Total sugar	33.58±1.14	34.65±1.28	35.24±0.92
Reducing sugar	7.25±0.24	7.39±0.62	8.02±0.17

Mean ± standard deviation values followed by a different letter within the same row are significantly different ($p \leq 0.05$) by Duncan's multiple range test

From table 3, ANOVA showed significant difference ($p \leq 0.05$) on total soluble solid. The results presented that the sauce containing 40, 45 and 50% of Gros Michel banana pulp had a total soluble solid of 39.00, 39.97 and 40.30 °Brix, respectively. The increase in banana pulp resulted in an increase of total soluble solid. This may be related to bananas containing high contents of glucose and fructose (Martinez et al., 2025). This study found that there were no differences ($p > 0.05$) on pH, titratable acidity, total sugar and reducing sugar influenced by the content of banana pulp. The pH values were in the range of 3.59-3.61 which were lower than the Thai Community Product Standard (1223/2549) which specify that the pH value of banana sauce must be lower than 4.5. However, the result presented that total sugar and reducing sugar tended to increase with increased banana pulp. Phillips et al. (2021) report that bananas contain 12.67% of sugar, so increasing banana pulp affected increasing total soluble solid, total sugar and reducing sugar. Generally, the higher the sugar content of food products, the sweeter it will taste, therefore, too high of sugar content may affect the sensory characteristics of sauce.

4. Conclusion

Based on this study, the formula containing 40 and 45 % (w/w) presented viscosity of 1,904 and 2,000 cPs, respectively and flow rate at 0.13 and 0.11 cm/s, respectively. There were no significantly different of pH, TTA, Total sugar and reducing sugar, L* and b* values between 40 and 45 % (w/w) formula. Based on a commercial product which has viscosity approximately 2,000 cPs, therefore the formula containing 40 and 45 % (w/w) of banana could be the selected level for development of the product in the next step of sensory evaluation.

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