Synergistic Paradigms: Developing R&D and Extension Framework for Sustainable Agrifood Systems

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Abstract: *The increasing complexity of agrifood systems and their environmental impacts necessitates innovative research frameworks that integrate diverse methodologies and technologies. This paper presents a novel approach to formulating a community-based research and development (R&D) and extension framework that combines Futures Thinking, Geographic Information Systems (GIS), and Remote Sensing. By converging these paradigms, the proposed framework aims to address the multifaceted challenges of agrifood systems and waste generation. The integration of Futures Thinking facilitates long-term strategic planning and scenario development, while GIS and Remote Sensing provide spatial analysis and real-time data collection capabilities. This synergistic approach not only enhances the understanding of current agrifood systems but also anticipates future trends and challenges, enabling more sustainable and resilient community-based interventions. The paper discusses the trade-offs involved in this integration, such as data complexity and resource requirements, and proposes strategies to optimize the framework's effectiveness.*

Keywords: Futures Thinking; SDG, community-based, sustainability

1. INTRODUCTION

Agrifood systems are vital for daily life, ensuring food security, economic stability, and environmental sustainability [1]. However, these systems face numerous challenges, including resource depletion, climate change, and waste generation [2]. Addressing these challenges requires innovative research frameworks to tackle these issues effectively through integration of various methodologies and technologies. This paper explores the convergence of Futures Thinking, GIS, and Remote Sensing to formulate a community-based R&D framework focused on sustainable agrifood systems and waste management, eventually impacting everyday problems and improving quality of life.

As a strategic planning approach, Futures Thinking (FT) seeks to anticipate future trends, uncertainties, and potential scenarios, and incorporate them into present-day planning. It enables stakeholders to envision long-term goals and develop adaptive strategies. FT helps identify emerging issues, technological advancements, and socio-economic shifts that could impact food production and sustainability.

In the paradigm of Geoinformatics, the application of Geographic Information Systems (GIS) and Remote Sensing (RS) technologies are widely documented [3]. The integration of GIS, a powerful spatial analysis and visualization tool, provides a spatial dimension to data analysis, enabling more precise and targeted interventions. This spatial awareness is crucial for understanding the complex interactions between agricultural practices, environmental conditions, and community dynamics [4]. While RS technologies such as satellite imagery and drone surveillance, offer real-time data collection and monitoring capabilities. These technologies are invaluable for tracking environmental changes, assessing crop conditions, and detecting waste generation patterns.

Thus, this study is motivated to combine both paradigms in formulating a community-based R&D Framework as a response to issues and challenges faced in the study area relating to the agrifood systems and waste management.

2. THE CHALLENGES IN AGRIFOOD SYSTEMS AND WASTE MANAGEMENT

Ramaprasad and Kasyap [5] noted that the global food system has three recognized challenges: (a)increasing the availability of food consumption, (b) reducing food loss, and (c) reducing food waste.

For the past five years, the Agriculture, Forestry, and Fishery (AFF) sector in the Caraga Region has contributed to the economy's continued deceleration. The said scenario has been characterized by low productivity of the sector. Other factors that brought effects include the high poverty among farmers, fisherfolks, and rural communities. However, among the factors, the poverty incidence among farmers, fisherfolks, and individuals is a major reason the region is still poor [6].

Focusing on the agricultural food systems (Agrifood systems), the government has prioritized revitalizing the AFF sector to be included in the priority development agenda. As the sector remains the second major source of employment in the region, several challenges are faced for the industry: aging farmers and increased off-farm employment as influenced by higher wages in other sectors. On the other hand, the poverty incidence among the marginalized farmers and fisherfolks in the region remains high at 40.7 percent (110, 247 farmers) and 28.6 percent (12, 436 fisherfolks) in 2018 [6].

While the Philippines is still in its nascent stage towards circular economy, the country has incorporated circular economy principles in laws and mechanisms. According to the baseline data captured by the United Nations Development Programme in the Philippines [7], the country has achieved several milestones in improving waste management and reducing its environmental impact by closing the 945 illegal dumpsites as of 2021. The report also revealed that only 26 to 58 percent of the households are engaged in waste management. Moreover, the study revealed the existence of some research conducted but there is still a need to account for the initiatives towards the support of Agrifood systems. With the report provided, another challenge sprouted: it has been known that more data are still to be gathered.

Every farmer desire to increase their income as they engage in the production of various agricultural commodities. In addition, it has been noted that in all aspects of farming, the occurrence of food loss is present. Food loss is a major issue affecting the supply chain. It occurs when the quantity or quality of food diminishes before reaching retailers, food service providers, or consumers, due to decisions made earlier in the chain [8]. In contrast, food waste occurs when retailers, food service providers, and consumers make decisions or take actions that lead to a reduction in the quantity or quality of edible food [9]. Less food loss and waste would lead to more efficient land use and better management of water resources, which would positively impact climate change and livelihoods [10]. This problem occurs in all parts of the value chain. Thus, the call to resolve this issue requires a bold initiative from all sectors of the government, especially on policy development and strict implementation. In this aspect, collaboration must be strengthened among scientists, researchers, and other stakeholders.

3. METHODS

Table 1. Summary of Tools and Methods employed.

Phase	Tools Used	Approaches /Resources
Problem Identification and Sensing	1.Environmental Scanning 2.Futures Triangle 3.Baseline Data Gathering	Workshop/ Group Brainstorming FGD/Field Interview
SDG Mainstreaming	1.Gaps Analysis, 2.Vision and Mission Alignment and Recalibration	Workshop
Technology Integration and Method Conceptualization	Literature Review	Literature Survey Marix / Narrative
Framework Formulation	Matrix Analysis Framework/ Model	Brainstorming

This study employed both FT and scientific literature survey to formulate a community-based research and development (R&D) and extension framework for Agrifood System as shown in Table 1. The study is divided into four phases, namely: 1) Problem Identification and Sensing; 2. SDG Mainstreaming; 3. Technology Integration and Method Conceptualization, and 4. Framework Formulation. Table 1 provides the different approaches and tools employed in each phase.

4. RESULTS AND DISCUSSION

4.1 Formulating the Agrifood Systems Research Framework : The Case of Caraga State University

The implementation of a synergistic approach successfully established a FT-based program where research and development, extension, innovation, and commercialization are carried out according to its technical purview. Aside from that, the method employed ensures that the community is engaged at the forefront all throughout its conduct while significantly addressing the components of the sustainable development goals desired to be addressed.

This approach combines modern technologies, data-driven insights, and community participation to enhance agricultural productivity, promote sustainable and ethical practices, and improve food security.

4.2 FT-based Problem Identification and Sensing

Table 2. Signals, Drivers, and Trends (SDT) Matrix

Signals	Drivers	Trends
Drip irrigation, mulching, water recycling	climate change, low income of	Climate-Smart systems
Urban Farming	urbanization, limited agricultural land area	Vertical and Rooftop Vegetation
product-specific agri-product stores	Health/Diet Consciousness	Organic farming
integration of drones	high supply and market competition	Precision Farming
Aging workforce	Farming perceptions on farming income and success, urban lifestyle preference of new graduates	Agricultural Economics, Technology Integration, short-term trainings and/or vocational programs, overseas farming jobs
Low R&D and Innovation index for Agriculture	Market vulnerability, Knowledge transfer gaps, fragmented programs and governances	Start-ups (for value adding and product innovation), social-media marketing,
Conversion of Native Plants into High Value Crops	Market demand, consumer acceptance, supply chain infrastructure	Large scale mechanized farming

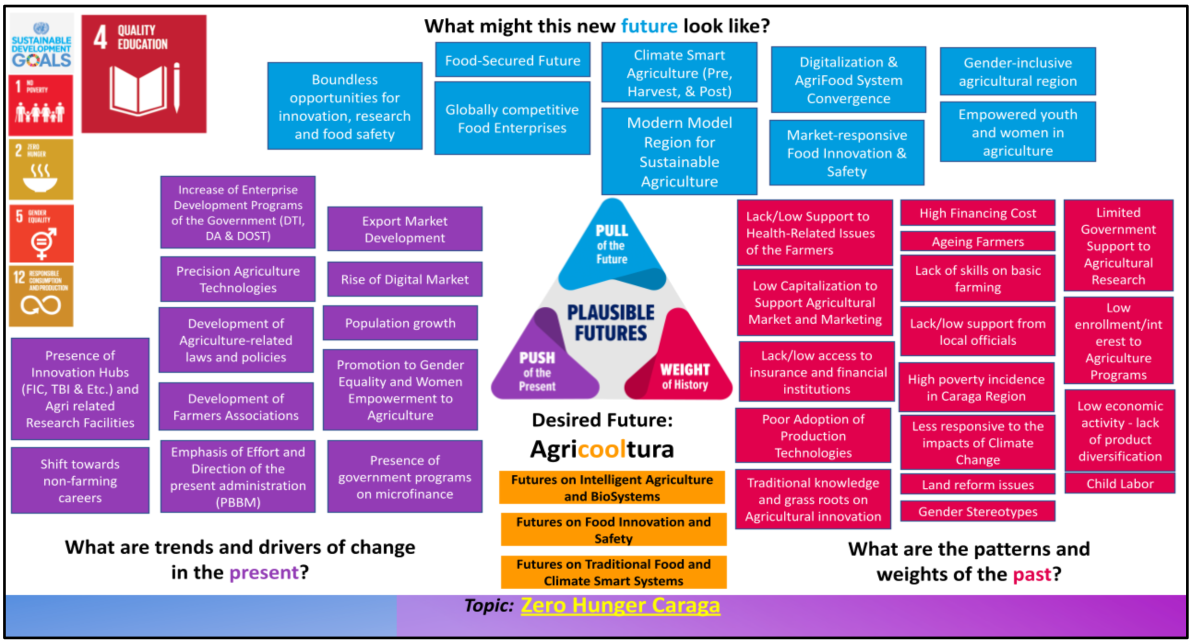

Fig. 1. The Futures Thinking Triangle.

The first Futures Thinking tools employed in this study is the Signals, Drivers, and Trends (SDT) matrix. The authors identified the signals, the driving forces to summarize current and emerging drivers of change that highly impact the Agrifood Systems. The SDT matrix was determined through a brainstorming activity during a workshop and helped the authors identify current or potential activities, trends, and developments in order to identify the problem. Table 2 shows the SDT forces of change of the AgriFood Systems used for scanning developments in the external (contextual) macro environment.

The next step is to reflect how these SDTs can influence the AgriFood sector with a longer future perspective using the Futures Thinking Triangle (FTT). Then, these drivers of change were categorized in Push of the Present, Weights of the Past, and Pull of the Future domains. In other words, the SDTs were expanded to determine which of these trends drives the change of the present, what are the patterns and weights of the past that is holding back the change, and what trends might shape the future of AgriFood Systems. Fig. 1 shows the FTT of AgriFood Systems focused on SDG 2 (Zero Hunger) with attributions and intersections on SDGs 1 (No Poverty), 4 (Quality Education), 5 (Gender Equality), and 12 (Responsible Consumption and Production).

A community-driven development of smart agrifood systems involves empowering local communities to play an active role in the design, implementation, and management of technologically advanced agricultural and food production systems. Through a Focus Group Discussion, baseline data gathered from 20 rice farmers as a pilot study. The rice farmers interviewed about their current farming practices, their observations and perceptions about farming methods and modern machineries, agricultural wastes, and sustainable farming. Among the key discussion points and findings during the FGD are as follows:

1. **Current Practices:** The Rice Farmers shared that they practice both traditional (synthetic) and organic farming methods. The traditional rice farming method highlights the reliance on manual labor and limited use of modern technology while the organic farming demonstrates various use of agrifood waste products as fertilizers.
2. **Challenges:** The main challenges identified were pest management, water scarcity, soil fertility, and access to high-quality seeds. Farmers also expressed concerns about market prices and the impact of climate change on crop yield.
3. **Technology Adoption:** The farmers already employ the use of machineries during the harvesting period. There was also a keen interest among the farmers in adopting smart agriculture technologies such as automated irrigation systems, drone-based crop monitoring, and regular soil health monitoring.
4. **Community Involvement:** The discussion underscored the importance of involving the local community in the research and extension projects to ensure sustainable and inclusive development. Farmers were supportive of the idea of a community-driven waste bank to manage agricultural waste effectively.

4.3 Vision-Mission Alignment and RDE Framework Recalibration

It has been a prevalent observation that State Universities and Colleges' (SUCs) civic engagements are minimal and that their research and development endeavors are not significantly responding to the needs of the community. This challenges the people in the academe to capitalize on its extension function in addressing this concern since extension serves as the conduit between the technical aspects of the things that the experts do in the Universities to make them more comprehensible by the community, which among else should be the core beneficiary of all the developmental endeavors of the academe. Ideally, extension programs must involve designing activities that affect behavior change through constituent-driven programs focused on outcome-based objectives using a variety of educational processes and techniques over a continuum of time. But the conventional way of designing and implementing this among SUCs is that extension programs only come after the research and development project has been completed and there is new knowledge developed.

In the VUCA (Volatile, Uncertain, Complex, and Ambiguous) world, CSU's new Vision and Mission are tailored to address the demands of the digital age. The Vision of CSU is to be "a socially engaged digital, innovation, and entrepreneurial university excelling globally in science, engineering, and the arts by 2028." This Vision emphasizes the importance of digital innovation and entrepreneurship, areas where an innovative and integrative RDE framework and education system can make a significant impact.

The Mission of CSU is "to be a responsible steward of problem-solvers and value creators who are driven to create a sustainable future for the region, the nation, and beyond." This Mission aligns with the transformative potential of a FT-based and an RS and GIS-based RDE framework by preparing students to become innovative leaders and solution-oriented professionals.

With these Vision and Mission statements, CSU commits to solve the current and future problems of job mismatch, poverty, and hunger. As such, the recalibrated goals for the RDE framework formulation are as follows:

- Improve academic programs and education systems to align with the future’s needs.
- Focus and synergize research, development, innovation, and extension programs to explore new technologies and new business models.
- Promote and disseminate new technologies and new business models to expand the productive capacities of the society.
- Foster partnerships with global and glocal networks of universities/industries to collectively co-design effective and innovative solutions.

4.3 Technology Integration

Community-driven development of smart agrifood systems not only enhances agricultural productivity and food security but also contributes to the social and economic well-being of local communities. By combining technological innovation with local knowledge and active participation, this approach can lead to more resilient, sustainable, and inclusive food systems. Using all the data gathered through FT workshops and FGDs, the authors then employed a scientific approach on how geoinformatics technologies like remote sensing and GIS can further solidify the CSU RDE Framework. Table 3 shows the literature survey matrix of the concepts and established methods applicable to AgriFood Systems studies.

As shown in Table 3, RS and GIS techniques were used to prepare maps and to get information and data. Advanced high-resolution satellite imagery has enhanced the accuracy of predicting crop yields, distinguishing between crop types, estimating crop planting areas, and modeling crop growth [34-36]. It has been a crucial method for assessing crop yield [26-28].

Table 3. Literature Survey Matrix

RDE Program Components of AgriFood Systems	Concepts/Methods	Reference/s
Suitability Mapping		
• urban waste disposal	site selection using GIS	[11]
• waste collection bin allocation	site selection using GIS	
Precision Farming		
• soil monitoring	IOT-driven, Computer Vision, AI	[12-15]
• crop monitoring	Computer Vision, AI	[12], [15]
• farm machinery	Nanotechnology, ICT integration, UAVs	[13], [15]
Crop Monitoring		
• production/ yield estimation	linear regression modeling, remote sensing, and GIS	[16-22]
• agricultural area mapping, change detection, damage estimation	deep learning, machine learning, UAV-based time series mapping	[4, 17] [18] [21-22]
• nutrient status monitoring	hyperspectral remote sensing	[20]
Crop Pest Infestation Modeling	GIS, remote sensing, agent-based modeling	[23]
Agricultural Waste Monitoring		
• biowaste	GIS, remote sensing	[24]
• plastic waste	GIS, remote sensing	[25-26]
• chemical waste	GIS, remote sensing	[27]
Business Model Development		
• supply chain analysis	big data analysis, GIS analytics	[28]
• data aggregation, and ICT integration	data protection, web automation, android systems	[28-29]
• product value-adding	alternative material, bio-based biodegradable film, green village concept	[30-38]
• waste valorization	value-added metabolites	[32]
	alternative fuel	[34]
	hydrodesulfurization of heavy oil	[35]
	silica-nanoparticles from rice husks	[37]

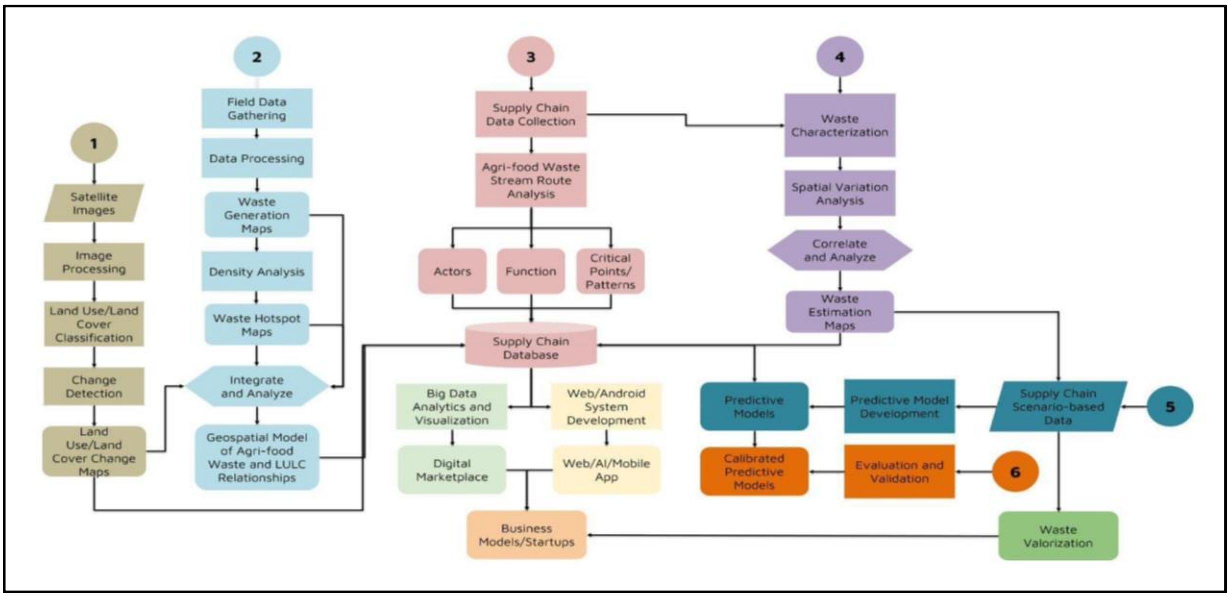

Fig. 2.The Agrifood System framework for Rice Crops.

The technological advancements of geospatial technologies, especially in imaging sensors and classification, machine learning [4] [17], [19], spatial analysis techniques [23], [25] and the use of unmanned aerial vehicles (UAVs) [22] have refined the processes and procedures involved in crop yield estimations, enabling more precise and reliable predictions.

The waste generated by the rice industry, for example, poses significant challenges regarding its volume, quality, and potential. Reusing and valorizing these wastes effectively involves identifying, assessing, measuring, and classifying residues [31-34]. This is followed by their application in relevant industries through traditional or innovative new technologies [32], [34-38].

5. CONCLUSIONS

In conclusion, this paper proposes a novel research and development framework that integrates Futures Thinking, Geographic Information Systems (GIS), and Remote Sensing. This study demonstrated that the crafting of a community-driven, future-proof, data-driven RDE framework for Agrifood Systems is plausible. As an example, this study focused on rice plantations as shown in Fig. 2. This synergistic approach significantly strengthens the Caraga State University RDE Framework for addressing the complex challenges on smart agrifood systems and waste generation. By combining long-term vision, spatial analysis, and real-time data, the framework allows for a more comprehensive understanding of current systems and the ability to anticipate future trends.

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