

On System Dynamics: an Evaluation on the Environmental Impact of A Sustainable Agricultural Production System Innovation-- the Case in Cambanay, Danao City, Cebu

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Abstract: As the goals of “Promotion of Urban Farming in Remote Areas” and “Accelerating Agricultural innovation”, the agriculture development in Barangay Cambanay has not yet offered the opportunity. In this context, system dynamics will play a great role to simulate the environmental impacts of developing an agricultural innovation in the community so that proper policies backed up with some interventions can be identified. The model is simulated in a 10-year horizon. The status quo is relatively along the lower bound limit compared to the rest of the simulated values in, having its land productivity value of 0.0071%, environmental index of 20%, and harvest yield of 18,422.48 kg per square meter. If incentive policy switch is being implemented, the system will exponentially decrease having negative impact on its land productivity, environmental index, and harvest yield value. Meanwhile, if penalty policy switch is being implemented, the graph of the system will increase the values of the variables. Furthermore, if interventions are added on both of the policies, there will be a positive significant impact on the system ranging from to 23%-1289% increase on the land productivity, increase in environmental index and, increase in harvest yield. Finally, some suggestions are put forward, including government investment, protection of the agricultural ecological environment, and promotion of the agricultural market. It is anticipated that this system dynamic model and suggestions can contribute to the green development of agriculture in the Barangay Cambanay area and other remote small urban areas.

I. Introduction

The presence of issues regarding the disruption of the ecological environment has been evident globally. Agricultural innovation often creates long-term consequences in the environment which amplifies the socio-economic gaps in the community (Benabderrazik, 2021). There are some ecological and environmental problems that cannot be overlooked which grabs the attention of the general public (Wang, 2021). Regarding the environmental impact of agricultural innovation, it has to be put in topmost priority in order for the innovation further promote sustainability. The safeguarding of agricultural lands, particularly against the impacts of residential and commercial activities, is a matter of considerable importance. The persistent decline in agricultural land poses a genuine threat, primarily attributed to the processes of urbanization and development (Carating, 2011).

If ecological, and environmental factors are being considered upon the development of agricultural innovation, issues that are primarily caused by a lack of supply capacity, inefficiencies in resource utilization, and farmers' poor quality of life will be addressed (Liu, 2020). Furthermore, the development of the agricultural production system, depends on the carrying capacity of the community.

Barangay Cambanay, is a barangay in the city of Danao, in the province of Cebu. Its population as determined by the 2020 Census was 4,320. This represented 2.76% of the total population of Danao (PhilAtlas, 2023). The barangay has engaged in traditional crops production having 82 farmers, which is funded by the local government around 0.90% of the fixed asset investment from the 19% total allocation for fixed asset investment from the GDP of the community. Even if the community is capable of establishing an agricultural innovation, the budget allocation for establishing agricultural development for the barangay was not prioritized. As the goals of “Promotion of Urban Farming in Remote Areas” and

“Accelerating Agricultural innovation”, the agriculture development in Barangay Cambanay has not yet offered the opportunity. According to Li et al (2021), there are a lot of prominent difficulties to overcome. First, the natural environment is harsh, and the mountains and valleys spread are located in remote areas. Second, the infrastructure is generally backward, and no large-scale cities can be based on the radiation support of development. Third, the cultural environment is complex and is subject to many restrictions such as language, culture, religion, and other objective factors. Fourth, in the background of foreign capital, technology input and diversified value, the interaction mechanism between subjects tends to be complex, and participants’ motivation is not strong. These problems may restrict the factor for barangay Cambanay get a sustainable development of agriculture.

In this context, system dynamics will play a great role to simulate the environmental impacts of developing an agricultural innovation in the community so that proper policies backed up with some interventions can be identified. With the given allocation for agriculture in the community, system dynamic approach would simulate the impacts of some major sustainability variables in agricultural development. In addition, from the perspective of farmers' environmental regulation perception and social capital, there is still a lack of research on the farmers' Agricultural Green Production Technology (AGPT) adoption behavior (Guo, 2022). Hence, the paper is expected to suggest agricultural innovation features, specifically on the major contributors of environmental index, e.g., power consumption, and direct application of fertilizer to soil.

II. Literature Review

In this section, related literature concerning policies aimed at fostering the environmentally sustainable growth of agriculture are presented. Additionally, the application of system dynamics within the agricultural innovation is also presented.

1. Incentives for Environmentally Friendly Agriculture

Environmental regulation, as an important element of social regulation, refers to the fact that environmental pollution has negative externalities, and the government regulates individual economic activities by formulating corresponding policies and measures to achieve the goal of keeping the environment and economic development in harmony. In spite of the mosaic of drivers that are recognized to affect adoption, economic incentives to guide 'sustainable agricultural behaviour' (hereafter sustainable behaviour) are still the preferred tool among policy makers, though they exhibit variable degrees of success (Dayer et al., 2018, Rode et al., 2014). In addition, it has been observed that the use of payments can change intrinsic motivations of behaviour, usually negatively, by making actions financially-conditioned (Deci, 1971, Frey and Jegen, 2001, Ryan and Deci, 2000b). Hence, economic and motivational factors not only have a relevant influence on behaviour, but also might be conditioning each other, so we expect an interplay between both variables affecting SA adoption (Bopp, 2019).

Farmers appear responsive to the financial incentives offered by the government through the programs implemented relating to agricultural development program that could support replanting and rehabilitation of forest. One positive approach to complement the rehabilitation program is to enhance public awareness on the social benefits and costs of indiscriminate deforestation vis-à-vis sustainable production and agro forestry systems. Furthermore, the great variability in the biophysical characteristics of the areas, socio-economic settings of farmers, and market conditions in major island groups of the country: Luzon, Visayas and Mindanao. These differences will affect the choice, acceptability and adaptability of possible agricultural development that may be considered to address both economic and environmental concerns in remote communities. (Bullecer, 2006, Baracol, 2006).

Successfully putting regulatory policies into action and providing sufficient backing for replanting and intercropping have the potential to boost land productivity. Collaborative efforts among farmers' groups, the private sector, local government units (LGUs), and government regulatory agencies are crucial institutional factors that could contribute to the overall success of initiatives aimed at improving farm productivity and income. Additionally, such collaborative measures may help mitigate the indiscriminate deforestation (Pabuayon, et. al (2008).

2. Penalties for Violation of Green Agriculture Development

Based on analysis of the results from the study by Yue, et.al., (2022), penalty mechanisms had relatively lower interaction values, the government should extend regulatory and direct penalties and work closely with local

authorities to implement penalty mechanisms in the most effective manner. The government should ensure targeted implementation of penalty mechanisms, based on quantitative assessment.

The government should optimize the use of agricultural land through well-articulated economic integration strategy fashioned to pave way for cleaner and low-carbon technologies sources like solar, geothermal, biomass, biogas, tidal power, photovoltaic, and wind energy in the agricultural production to avoid further deterioration of the environment. Hence, Muoneke (2022), recommends increasing carbon taxes, and implementing penalty for violators, and strict environmental regulations, should be prioritized. Despite the absence of a legislated Land Use Act that defines protection policies for agricultural lands, there are more than enough laws and uncoordinated and sometimes

conflicting policies. For one, it is not that easy to reclassify an agricultural land to non-agricultural considering the rigorous requirements. But land owners are more than willing to sacrifice agricultural productivity for decades just to prove to authorities that their landholding is no longer productive for agriculture. Furthermore, strict enforcement of local zoning or land use ordinances; maintain buffer between residential development and farms. Provide stricter penalties for non-compliance; although in essence, many communities are now suffering for their environmental mismanagement (such as forest denudation) as formerly non-flood prone communities are now suffering from flood. As the case of forest denudation, it would sometimes be too late to realize the importance of farms not only in terms of food security but also in other amenities like loss of biodiversity resulting in incidence of pests and diseases (Carating, 2011).

3. System dynamics modeling in agricultural innovation

A study by Rubin, et. al., (2022), utilized system dynamics modeling to make scenarios on the rice food system and simulate the realistic values of rice production in the Philippines. The importance of the system dynamics is to see the system's holistic view. It can be used to identify possible study areas that significantly impact the system, in this case, rice production and consumption in the Philippines. Furthermore, the study concluded that, it is necessary to appropriately invest and plan for better use of the available arable land for rice farming and instruct the agricultural community to improve the usage of agricultural land to increase their rice production. Another system dynamics study by Ibragimov et. al., (2019), offers a systemic understanding of the oil palm production system and environmental issues associated with low land productivity. This study demonstrates that yield is primarily affected by R&D, automation and mechanization, and ecological factors. To some extent, yield is also affected by local input production, accelerated replanting, and labor. In particular, R&D intervention plays a prominent role in increasing the harvest yield.

Simulation using system dynamics model explores the systematic interaction of agricultural innovation on indices pertaining to economic, environmental, and social sustainability. A study by Walters, et. al., (2016), use system dynamics model to evaluate the role of each driver in determining the differences in sustainability between three distinct production systems: crops only, livestock only, and an integrated crops and livestock system. The result from these modelling efforts found that the greatest potential for sustainability existed with the crops only production system. While this study presents a stand-alone contribution to sector knowledge and practice, it encourages future research in this sector that employs similar systems-based methods to enable more sustainable practices and policies within agricultural production.

A system dynamics approach of simulation results show that these three policies can promote agriculture's economic and ecological benefits in the Sichuan Tibetan area. Among them, population policy and investment policy have the most obvious effect on promoting economic benefits, while green policy has the most obvious impact on improving the ecological benefits. The simulation results help to provide some suggestions that the local government can reference to promote sustainable development of agriculture. (Wenke, et. al., 2022). In the context of green agriculture, Egerer et al. (2021) constructed a system dynamics model and conducted a leverage point analysis on key factors in the model. Policy implications for local agriculture from this study include: policymakers should provide financial incentives to increase water reservation in the region; farmers should improve irrigation efficiency and crop production techniques; society should raise awareness of water shortages linked to climate change and evolve sustainable patterns of water use and consumption.

From the implication of the literature presented, the promise of this paper to create significant policies that promotes environmentally friendly agricultural innovation is already expected.

The model

1. *Model structure*

a. *Reason to use system dynamics modeling*

System dynamics is an effective way to deal with linear and nonlinear interactions, large-scale, complex, and dynamic systems (Kunc, 2017, Winke, 2022). From the perspective of causality and structure influencing behavior, the system dynamics method constructs a model based on the internal microstructure of a system. It examines the internal relationships between the system's structure, its functions, and the evolution of local agriculture.

Using the data obtained, the causal-loop diagram and the stock and flow diagram which plays an important role towards the progress of the study. Shown in Fig.1 is the IPO diagram used in creating the system dynamics model in the agriculture system of Barangay Cambanay, Danao City.

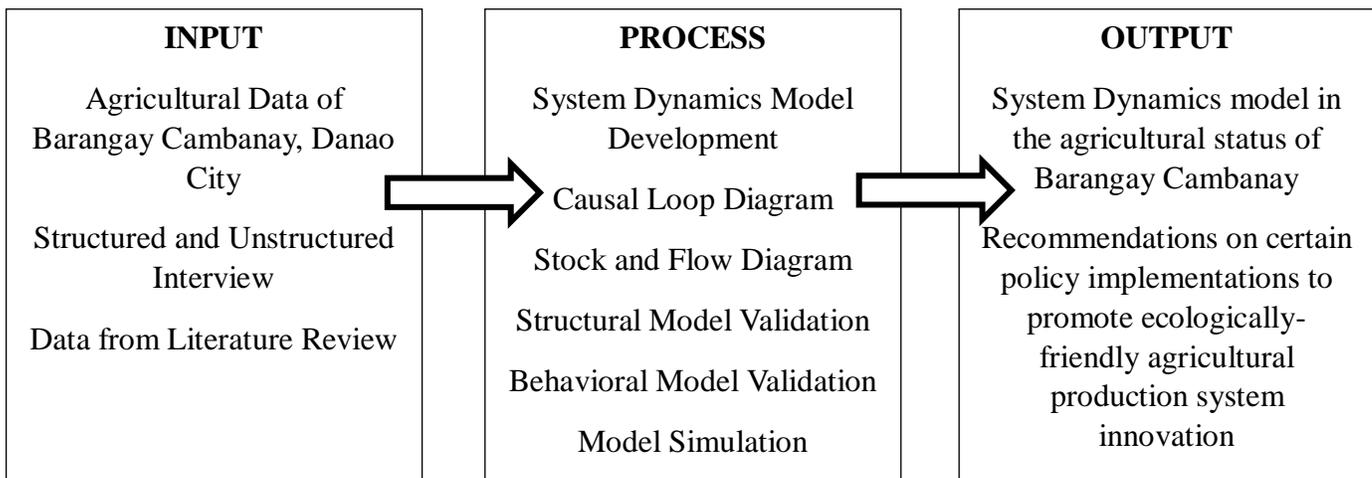
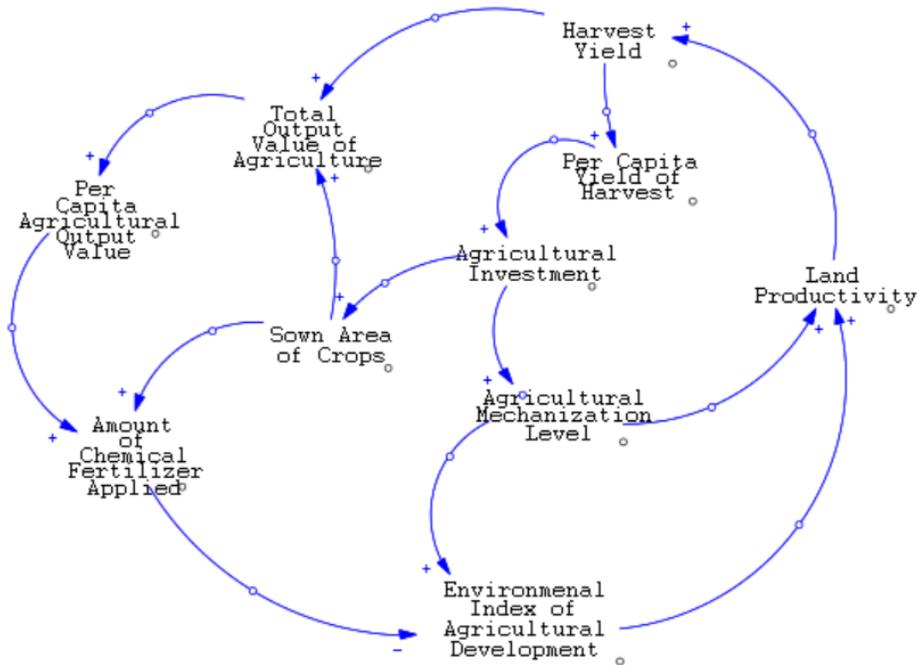


Fig. 1. IPO Diagram of the flow of the study.

b. Causal Loop Diagram (CLD)

A causal loop diagram is an important tool to show the feedback structure of the system (Yao et al., 2018). Fig. 2 shows the causal loop diagram which will serve as the basis of the stock and flow diagram.

Fig 2. Causal Loop Diagram of the Agricultural Production System in Cambanay, Danao City



The basic idea of the model is that, growth of the agricultural output value will promote a negative impact on the environmental development index of agriculture. Since, direct usage of chemical fertilizer on soil harms agriculture’s environmental development index. Improvement of the environmental development index of agriculture, will promote the growth of the harvest output and the sustainable development of agriculture in general. Furthermore, the agricultural mechanization level is expected to increase the environmental index, as long as it is invested in such a way that it does not increase the consumption of chemical fertilizer within the system. Moreover, it will increase the land productivity of the system.

The per capita agricultural output value is identified as having a negative impact on the consumption of chemical fertilizers. Consequently, an elevation in agricultural output value contributes positively to the agricultural innovation environmental index. Beyond these aspects, the interactions among other factors consistently exhibit positive relationships. For instance, enhancing the environmental index of agriculture proves advantageous in stimulating land productivity, thereby fostering growth in harvest output.

The data sources in this paper are obtained from the Agriculture Office of Danao City from 2020-2022, which is eventually forecasted through trend which models the agricultural production system in the community in a 10-year horizon until 2033.

c. Stock and Flow Diagram (SFD)

Stock and flow diagram is used to analyze data which will give a better representation of the CLD. The complexity of the SFD requires the proponents to input equations, constants, and necessary computations in the model. The stock and flow diagram in Fig. 3 is composed of elements which are described to different specifications for better visualization of the model as shown in Table 1.

Table 1. Variables and Equations of the system dynamics model.

Description	Code	Equation	Unit
Agricultural Fixed Asset Depreciation	AFAD	TAFABC*DRAFA	/
Total Agricultural Fixed Asset in Barangay Cambanay	TAFABC	TAFABC(t) = TAFABC(t - dt) + (IIA - AFAD) * dt INIT TAFABC = 20000 AFAIR = GRAPH(PCHY) (0.00, 0.009), (10.0, 0.009), (20.0, 0.009), (30.0, 0.009), (40.0, 0.009), (50.0, 0.009), (60.0, 0.009), (70.0, 0.009), (80.0, 0.009), (90.0, 0.009), (100, 0.009)	pesos per year
Agricultural Fixed Asset Investment Ratio	AFAIR		/
Agricultural Fixed asset per square meter	AFAPSM	VPSM*(TAFABC/SAC)*Inflation_Rate	pesos per year
Amount of Fertilizer used per square meter	AFUSM	TAFU/SAC AGRPDC = GRAPH(TIME) (2022, 0.029), (2023, 0.029), (2024, 0.029), (2025, 0.029), (2026, 0.029), (2027, 0.029), (2028, 0.029), (2029, 0.029), (2030, 0.03), (2031, 0.03), (2032, 0.0301), (2033, 0.0302)	kg per square meter per year
Annual Growth Rate of Population in Danao City	AGRPDC	CRFU = GRAPH(TIME) (2022, -0.0126), (2023, -0.0128), (2024, -0.0129), (2025, -0.0131), (2026, -0.0133), (2027, -0.0135), (2028, -0.0136), (2029, -0.0138), (2030, -0.014), (2031, -0.0142), (2032, -0.0144), (2033, -0.0146)	/
Change Rate of Fertilizer Used	CRFU	CRSAC = GRAPH(TIME) (2022, -0.0125), (2023, -0.0126), (2024, -0.0128), (2025, -0.0129), (2026, -0.0131), (2027, -0.0133), (2028, -0.0135), (2029, -0.0136), (2030, -0.0138), (2031, -0.014), (2032, -0.0142), (2033, -0.0144)	/
Change Rate of Sown Area of Crops	CRSAC		/
Consumption per Peso	CPP	constant = 0	KW per peso per year
Depreciation Rate of the Agricultural Fixed Asset	DRAFA	constant= 0.1	/
Environmental Index of Agricultural Production System Innovation	EIAPSI	(0.30*PAUF)+(0.078*PPAC)-(0.48*(AFUSM)+(0.12*TPAPI))/(AFUSM+PPAC+TPAPI+PAUF)	/

Factors Affecting Fertilizer Usage	FAFU	FAFU = GRAPH(PCAOV) (0.00, 0.00), (1.00, 0.1), (2.00, 0.2), (3.00, 0.3), (4.00, 0.4), (5.00, 0.5), (6.00, 0.6), (7.00, 0.7), (8.00, 0.8), (9.00, 0.9), (10.0, 1.00) /	
Fixed Asset Investment Ratio	FAIR	FAIR = GRAPH(TIME) (2022, 0.19), (2023, 0.208), (2024, 0.224), (2025, 0.237), (2026, 0.249), (2027, 0.258), (2028, 0.267), (2029, 0.275), (2030, 0.281), (2031, 0.287), (2032, 0.293), (2033, 0.298) /	
Gross Domestics Product of Danao City	GDPDC	GDPDC(t) = GDPDC(t - dt) + (GGDPDC) * dtINIT GDPDC = 157554239.80	pesos per year
Growth In Existing Industry	GEI	TOVA*(GROVA+CRSAC)+(AO VPPE*NAEBC) /	
Growth in Gross Domestic Product in Danao City	GGDPDC	GDPDC*GRGDPDC GRAEBC = GRAPH(TIME) (2022, -0.0125), (2023, -0.013), (2024, -0.0128), (2025, -0.0129), (2026, -0.0131), (2027, -0.0133), (2028, -0.0135), (2029, -0.0136), (2030, -0.0138), (2031, -0.014), (2032, -0.0142), (2033, -0.0144) /	pesos per year
Growth Rate of Agricultural Employee in Barangay Cambanay	GRAEBC	GRGDPDC = GRAPH(TIME) (2022, 0.1), (2023, 0.0921), (2024, 0.0843), (2025, 0.0778), (2026, 0.0722), (2027, 0.0673), (2028, 0.063), (2029, 0.0593), (2030, 0.056), (2031, 0.053), (2032, 0.0504), (2033, 0.0479) /	
Growth Rate of Gross Domestics Product of Danao City	GRGDPDC	GROVA = GRAPH(TIME) (2022, 0.00), (2023, -0.0034), (2024, -0.0036), (2025, -0.0039), (2026, -0.0041), (2027, -0.0044), (2028, -0.0046), (2029, -0.0049), (2030, -0.0051), (2031, -0.0054), (2032, -0.0056), (2033, -0.0059) /	
Growth Rate of Output Value of Agriculture	GROVA		kg per square meter per year
Harvest Yield	HY	(760*SAC)*LP	
Incentive Policy for Less Fertilizer Usage Activate	IPLFUA	if(ISLFU=0)and(time>YII)then(0)else(1) /	
Incentive Switch for Less Fertilizer Usage	ISLFU		0 /
Investment in Agriculture	IIA LP	AFAIR*TIFA 0.1*AFAPSM*EIAPSI /	pesos per year

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Land Productivity			
Number of Agriculture Employees in Barangay Cambanay	NAEBC	$PBC * PAEBC * (1 + GRAEBC)$	people per year
Output Value of Agriculture Produced Per Employee	AOVPPE	constant = 904.25	pesos per year per person
Penalty Policy for High Power Consumption activate	PPHPCA	if(PSHPC=0)and(time>YPI)then (0)else(1)	/
Penalty Switch for High Power Consumption	PSHPC		0 /
Per Capita Agricultural Output Value	PCAOV	$TOVA / TPDC$	pesos per person per year
Per Capity Harvest Yield Population in Barangay Cambanay	PCHY	$HY / (TPDC * PPBC)$	kg per person per year
	PBC	$TPDC * PPBC$	people per year
Proportion of sown area usage per employee	PSAUPE	constant=0.01205 PAEBC = GRAPH(TIME) (2022, 0.0188), (2023, 0.0184), (2024, 0.018), (2025, 0.0175), (2026, 0.017), (2027, 0.0165), (2028, 0.016), (2029, 0.0155), (2030, 0.0148), (2031, 0.0144), (2032, 0.014), (2033, 0.0136)	/
Proportion of Agricultural Employees in Barangay Cambanay	PAEBC	PPBC = GRAPH(TIME) (2022, 0.0278), (2023, 0.0279), (2024, 0.028), (2025, 0.0282), (2026, 0.0283), (2027, 0.0285), (2028, 0.0286), (2029, 0.0288), (2030, 0.0291), (2031, 0.0293), (2032, 0.0294), (2033, 0.0296)	/
Proportion of population in Barangay Cambanay	PPBC		/
Proportion of Preserved area coverage	PPAC	constant=0.0023	/
Propration of area used for farming	PAUF	constant=0.8507	/
Sown Area of Crops	SAC	$SAC(t) = SAC(t - dt) + (VSAC) * dt$ INIT SAC = 341568.64	square meter per year
Total Amount of Chemical Fertilizer Used	TAFU	$TAFU(t) = TAFU(t - dt) + (VFU) * dt$ INIT TAFU = 19138.51	kg per year
Total Investment in Fixed Asset	TIFA	$GDPDC * FAIR$	pesos per year

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Total Output Value of Agriculture	TOVA	$TOVA(t) = TOVA(t - dt) + (GEI) * dt$ INIT TOVA = 75071.67	pesos per year
Total Population in Danao City	TPDC	$156412 * (1 + AGRPDC)$	people per year
Total Power of Agricultural Production Innovation	TPAPI	$(CPP - PPHPCA) * AFAPSM$	kw per year pesos per square meter
Value per square meter Variations of Fertilizer Used	VPSM VFU	constant=0.06 $TAFU * ((IPLFUA + CRFU) - FAFU)$	/
Variations of Sown Area of Crops	VSAC	$SAC * CRSAC * NAEBC * PSAUPE$	square meter per year
Year of Incentive Implementation	YII		2022 /
Year of Penalty Implementation	YPI		2022 /

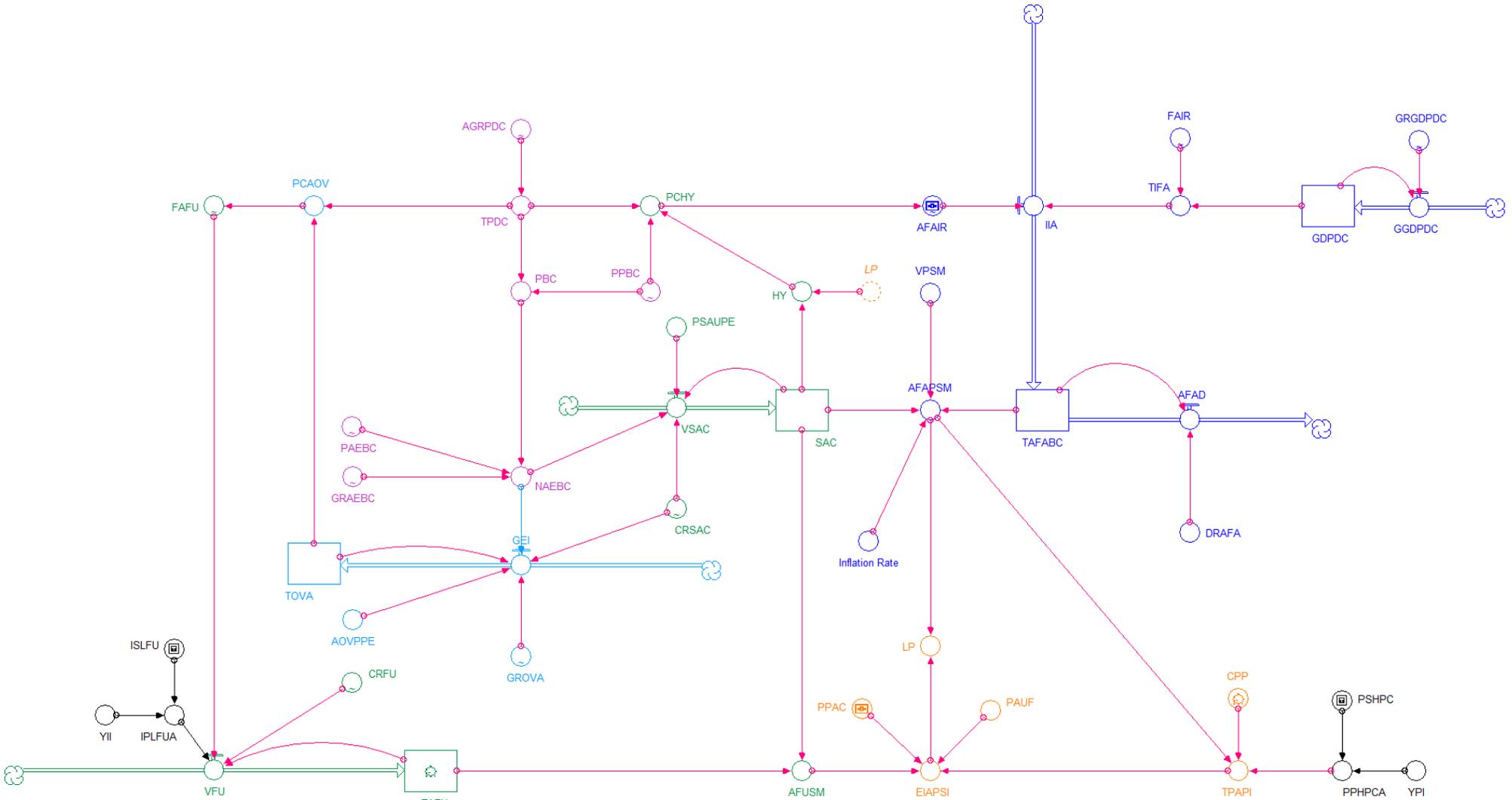


Fig 3. Stock and flow diagram of the agricultural status of Barangay Cambanay, Danao City

d. Model Validation

After building the system dynamics model, its validation needs to be verified (Peterson and Eberlein, 1994). The historical test of the model refers to the comparison between the simulation value obtained after the model is run and the real value. If the error between the two values is acceptable within a certain range (0%-15%), it indicates that the model has high credibility and can be used in the next step. Table 2 shows that the relative errors of each simulation value are within an acceptable range, so the model can be used to predict and analyze the future situation.

e. Model Simulation with Policy Scenario

i. Measures of Policy

Based on the existing studies about agricultural policy incentives, penalty, and system dynamics, two main policies are proposed considering the specific circumstances of Barangay Cambanay area: fertilizer application policy, and power consumption policy. Moreover, the policies are combined with some interventions to further enhance the result of the policies – reforestation, and increase in agricultural investment ration. Specific measures of these policies are shown in Table 3. These policies will be used to assess the impact on the harvest yield, land productivity, and the environmental index on the community, through the total fertilizer used annually, kW consumption per peso, agricultural fixed asset investment ratio, and the proportion of preserved area.

Table 2. Comparison of the simulation and historical value

Year	Population in Barangay Cambanay (people)			Number of Agricultural Employee in Barangay Cambanay (people)			Total Investment in Fixed Asset (pesos)		
	Historical Value	Simulation Value	Relative Error	Historical Value	Simulation Value	Relative Error	Historical Value	Simulation Value	Relative Error
2022	4405	4,476	0.02	83	83	0.00	2,233,876.82	2,423,530.52	0.08
2023	4447	4,490	0.01	82	82	0.00	2,704,995.94	2,918,440.97	0.07
2024	4491	4,505	0.00	81	80	0.01	3,176,115.06	3,432,400.87	0.07
2025	4579	4,532	0.01	80	78	0.02	3,647,234.18	3,937,746.81	0.07
2026	4654	4,558	0.02	79	76	0.03	4,118,353.30	4,458,994.83	0.08
2027	4730	4,584	0.03	78	74	0.05	4,589,472.42	4,953,739.11	0.07
2028	4807	4,610	0.04	77	73	0.06	5,060,591.54	5,471,560.37	0.08
2029	4886	4,635	0.05	76	71	0.07	5,531,710.66	5,990,538.90	0.08
2030	5047	4,691	0.08	75	69	0.09	6,002,829.78	6,484,231.19	0.07
2031	5123	4,717	0.09	74	67	0.10	6,473,948.90	6,993,554.86	0.07
2032	5199	4,744	0.10	73	65	0.11	6,945,068.02	7,518,168.95	0.08
2033	5276	4,770	0.11	72	64	0.12	7,416,187.14	8,031,847.20	0.08

Table 3. Specific measures of the policy.

Policy	Specific Measures
Fertilizer Application Policy	Incentives will be given for those crop production system having no or less direct application of chemical fertilizer to soil.
Power Consumption Policy	Penalty will be given for those crop production who consumes relatively higher than the expected power consumption of the innovation.

Simulation Results and Scenario Analysis

A. Scenario Analysis

Since the model is designed in a 10-year horizon, the 2033 simulated data is being compared to the 2022 status quo. The simulation shows the effect of the specific measures of policy and the interventions, to the major data needed to establish an agricultural production system innovation: land productivity, environmental index, and harvest yield.

The values of the status quo and the policy scenarios are shown in Table 4. All the values are based on the historical data for 2022. There will be an added value on the status quo if certain policies are being implemented.

The status quo is simulated in the system dynamics model as shown in Fig. 4(a-c), which shows that the behavior of the graph for both the land productivity and harvest yield is relatively increasing, however, the environmental index of the community will decrease to zero along the 10-year horizon.

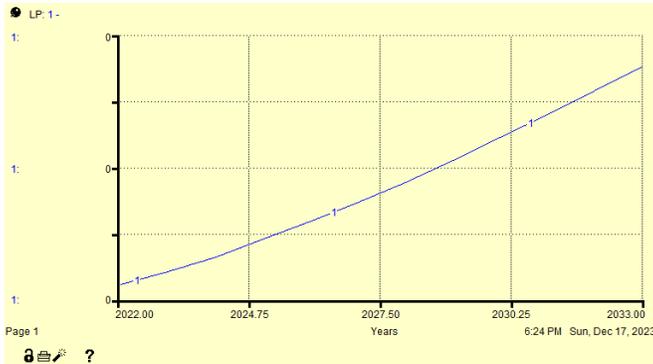


Fig. 4 (a). Status quo of the land productivity.

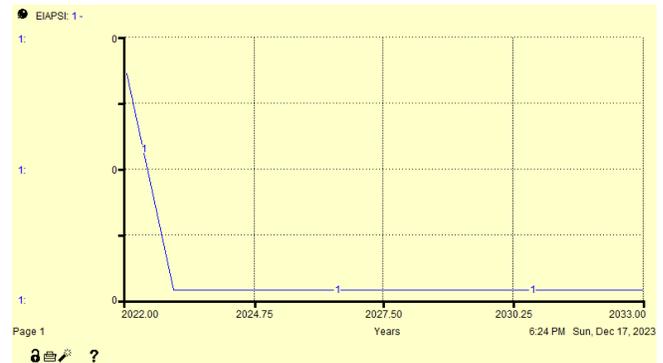


Fig. 4 (b). Status quo of the environmental index

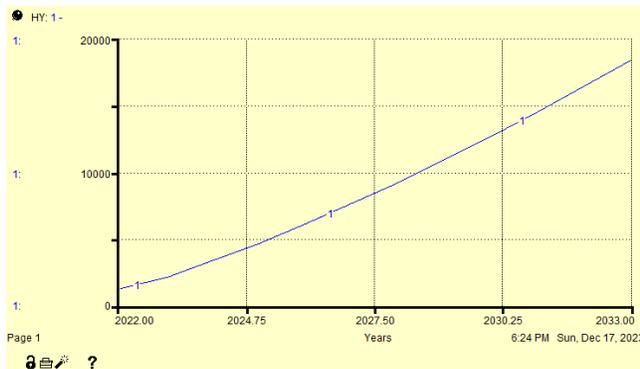


Fig. 4 (c). Status quo of the harvest yield.

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Variables	Scenario 1 (Incentives Switch for Less Fertilizer Usage Activated)		Scenario 2 (Penalty Switch Activated for High Power Consumption)		Scenario 3 (Incentive Switch for Less Fertilizer Usage Activated + Zero Applied to Soil Fertilizer Intervention)		Scenario 4 (Incentive Switch for Less Fertilizer Usage Activated+Zero Applied to Soil Fertilizer Intervention+ Increase Agricultural Fixed Asset Investment Ratio)		Scenario 5 (Incentive Switch for Less Fertilizer Usage Activated+ Zero Applied to Soil Fertilizer Intervention+ Increase Agricultural Fixed Asset Investment Ratio+ Increasing Preserved Area)		Scenario 6 (Policy Switch for High Power Consumption + Increase Power Consumption)		Scenario 7 (Policy Switch for High Power Consumption+Increase Power Consumption+Increase Agricultural Fixed Asset)		Scenario 8 (Policy Switch for High Power Consumption + Increase Power Consumption+Increase Agricultural Fixed Asset+Increasing Preserved Area)		
	Status Quo	Value	Change Rate (%)	Value	Change Rate (%)	Value	Change Rate (%)	Value	Change Rate (%)	Value	Change Rate (%)	Value	Change Rate (%)	Value	Change Rate (%)	Value	Change Rate (%)
Incentives Switch for Less Fertilizer Usage Activated	0	1	1.0000	0	0.0000	1	1.0000	1	1	1	0	0	0.0000	0	0.0000	0	0.0000
Penalty Switch Activated for High Power Consumption	0	0	0.0000	1	1.0000	0	0.0000	0	0	0	0	1	1.0000	1	1.0000	1	1.0000
Total Annual Fertilizer Usage (kg per year)	19138.5	19138.	5	0.0000	19138.	5	0.0000	12	-0.9994	12	-0.9994	12	-0.9994	5	0.0000	19138.5	0.0000
Consumption	0	0	0.0000	0	0.0000	0	0.0000	0	0	0	0	50	50.0000	50	50.0000	50	50.0000

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per peso (kW
per peso)

0

Agricultural
Fixed Asset
Investment
Ratio (%)

0.009	0.009	0.0000	0.009	0.0000	0.009	0.0000	0.100	0.100	10.1111	0.1000	0.0000	0.0090	0.0000	10.111	0.1000	10.1111	0.1000
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Proportion of
Preserved
Area (%)

0.0023	0.0023	0.0000	0.0023	0.0000	0.0023	0.0000	0.002	0.002	0.0000	0.1	0.9770	0.0023	0.0000	0.0023	0.0000	0.1	0.9770
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Table 4. Values Status Quo and Policy Scenarios

From status quo, certain policy scenarios are applied to distinguish the change rate on the values of main variables in realizing the agricultural development in the barangay. The line for each graph represents certain policy scenario as shown in Table 5.

Table 5. Color code of the status quo and the policy scenario

Policy Scenario	Color Code
Status Quo	Dark Blue
Scenario 1 (Incentives Switch for Less Fertilizer Usage Activated)	Orange
Scenario 2 (Penalty Switch Activated for High Power Consumption	Pink
Scenario 3 (Incentive Switch for Less Fertilizer Usage Activated + Zero Applied to Soil Fertilizer Intervention)	Dark Green
Scenario 4 (Incentive Switch for Less Fertilizer Usage Activated + Zero Applied to Soil Fertilizer Intervention+ Increase Agricultural Fixed Asset Investment Ratio)	Yellow
Scenario 5 (Incentive Switch for Less Fertilizer Usage Activated+ Zero Applied to Soil Fertilizer Intervention+ Increase Agricultural Fixed Asset Investment Ratio + Increasing Preserved Area)	Purple
Scenario 6 (Policy Switch for High Power Consumption + Increase Power Consumption)	Light Blue
Scenario 7 (Policy Switch for High Power Consumption + Increase Power Consumption + Increase Agricultural Fixed Asset)	Light Green
Scenario 8 (Policy Switch for High Power Consumption + Increase Power Consumption +Increase Agricultural Fixed Asset + Increasing Preserved Area)	Magenta

As seen in Fig. 5 (a-c), the status quo is relatively along the lower bound limit compared to the rest of the simulated values, having its land productivity value of 0.0071%, environmental index of 20%, and harvest yield of 18,422.48 kg per square meter. On scenario 1, where incentive policy switch is being implemented, the graph of the system will exponentially decrease having its land productivity value of - 0.071% , environmental index of -21%, and harvest yield of -19,034.79 kg per square meter. This proves the reason why incentives should not be imposed without any intervention, since it will lead to people not doing efforts. Meanwhile, on scenario 2, where penalty policy switch is being implemented, the graph of the system will increase having its land productivity value of 0.074% , environmental index of 20%, and harvest yield of 18,444.65 kg per square meter.

Furthermore, if interventions are added on both of the policies, there will be a positive impact on the system compared ranging from 23% to 1245% increase on the land productivity, 25%-30% increase in environmental index, 23%-1289% increase in harvest yield. Shown in Table 6, are the results of the different policies and intervention policy on the status quo on the 10-year horizon.

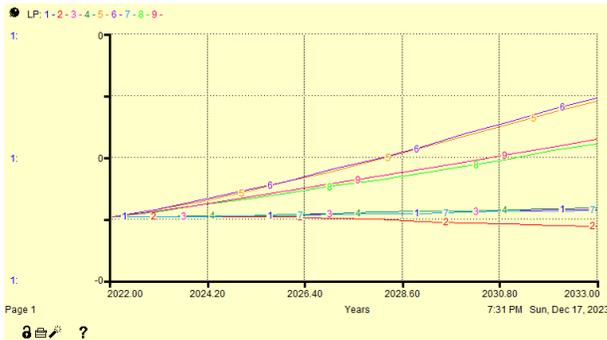


Fig. 5 (a). Policy applied on land productivity.



Fig. 5 (b). Policy applied on environmental index



Fig. 5 (c). Policy applied on harvest yield.

Table 6. Result of the 10-year horizon (2033) simulation.

	Land Productivity	Environmental Index (%)	Harvest Yield (kg per square meter)
Status Quo	0.000071	0.2000	18422.48
Scenario 1 (Incentives Switch for Less Fertilizer Usage Activated)	-0.000710	-0.2100	-19034.79
Scenario 2 (Penalty Switch Activated for High Power Consumption)	0.000740	0.2000	18444.65
Scenario 3 (Incentive Switch for Less Fertilizer Usage Activated + Zero Applied to Soil Fertilizer Intervention)	0.000087	0.2500	22647.18
Scenario 4 (Incentive Switch for Less Fertilizer Usage Activated+Zero Applied to Soil Fertilizer Intervention+ Increase Agricultural Fixed Asset Investment Ratio)	0.000953	0.2500	247471.00
Scenario 5 (Incentive Switch for Less Fertilizer Usage Activated+Zero Applied to Soil Fertilizer Intervention+ Increase Agricultural Fixed Asset Investment Ratio+ Increasing Preserved Area)	0.000985	0.2600	255925.05
Scenario 6 (Policy Switch for High Power Consumption + Increase Power Consumption)	0.000674	0.1900	17505.01
Scenario 7 (Policy Switch for High Power Consumption + Increase Power Consumption+Increase Agricultural Fixed Asset)	0.000613	0.1600	159279.77
Scenario 8 (Policy Switch for High Power Consumption +	0.000649	0.1700	168582.10

Increase Power
Consumption+Increase
Agricultural Fixed
Asset+Increasing Preserved
Area)

III. Discussions

a. Policy Implications and Suggestions

As seen in Table 6, if there will be no interventions needed for the policy maker to implement, imposing penalty policy without intervention is better than incentive policy, since penalty policy would not entail a negative impact on the current system, and it may impact also the land productivity for at most 944% compared to the status quo. Meanwhile, the incentive policy will decrease the effectivity of the status quo for about 1101%.

If the policy maker would impose a policy with intervention, it can be observed that incentive-driven policies are relatively better compared to the penalty-driven policies. Aside from having 1289% to 851% comparison on the maximum contribution of the policy with multiple intervention, the penalty-driven policies entail negative impacts also on the variables. Furthermore, it can also be observed that the more the interventions added on the policy, the higher the increase on the values of the variables in the system.

Therefore, the sustainable agricultural innovation should have less electricity consumption, or at least maximize the usability of the innovation with less direct application of fertilizer to soil. Some possible innovation would be an improvised aeroponics system, and a box-type hydroponics system. It is also best to conduct reforestation activity, such as tree growing, and mangroves planting activity especially when establishing an agricultural innovation. There should be an imposed incentives when establishing agricultural production innovation, such as opening an employment to the community, in order for the system to be ecologically sustainable.

b. Research Limitations

The system of ecologically sustainable development of agriculture is quite complex and comprehensive, involving various aspects. There were some inadequacies in the research. For example, it is assumed that the agriculture system is affected by the above factors, which is not comprehensive. In addition, the study simplified some factors such as the proportion of agricultural employees and the depreciation rate of agricultural fixed assets and set them as constants. These limitations are expected to be gradually resolved in future research.

IV. Conclusions

In this paper, a model of the environmental impact of the development in the agricultural sector specifically in agricultural innovation in the Barangay Cambanay area is constructed using the system dynamics method, and two policy simulation scenarios are proposed, namely, Fertilizer Application Policy, and, Power Consumption Policy. The simulation results show that these two policies can promote agriculture's economic and ecological benefits in the Barangay Cambanay area. Among them, fertilizer application policy with interventions have the most obvious effect on promoting economic benefits. The simulation results help to provide some suggestions that the local government can reference to promote sustainable development of agriculture. Since a single policy has limited effect, only by adding multiple interventions on the policy from the perspectives of population, society, investment, and ecological protection can the sustainable development of agriculture in the Barangay Cambanay area be effectively promoted. There is scope for improvement in this paper. Some model factors are derived from previous studies, and the adaptability of the policies needs to be verified. In addition, interactions between enterprises and farmers and the enterprises and governments have been omitted. Future studies will focus on the dynamic interrelationships among stakeholders in promoting regional agricultural development.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT 4.0 in order to guide the structure and coherence of the research review, and was used as a support upon completing the paper. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

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