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Economic Analysis of Integrated Rice-Duck Farming System (IRDFS) as Climate Change Adaptation Strategy in Vulnerable Areas: The Case of Cotabato Province, Philippines

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Abstract

The rice sub-sector in Cotabato province is grappling with the severe impacts of climate change, particularly heightened vulnerability to flooding. In response to these challenges, there is a pressing need to embrace adaptation and mitigation strategies that not only alleviate the current effects of climate change but also proactively address future scenarios. This study focuses on assessing the economic significance of the integrated rice-duck farming system (IRDFS) as a foundation step toward agricultural development in the region. Utilizing a combination of data from secondary sources, focus group discussions, and key informant interviews, the study explores the potential of IRDFS in adapting to the impacts of climate change on rice cultivation in Cotabato province. The findings reveal that the adoption of IRDFS yields positive economic indicators, including a positive NPV (NPV>0), a Benefit-Cost Ratio greater than 1 (BCR>1), and an Internal Rate of Return (IRR) of more than 10% discount rate. The positive financial metrics suggest that the IRDFS is not only economically viable but also environmentally sustainable. The integration of duck farming with rice cultivation demonstrates its potential to bring about a net welfare improvement in the rice sub-sector. This indicates that, beyond economic benefits, IRDFS aligns with environmentally conscious patterns, making it a promising strategy for the region. Therefore, it is recommended that various stakeholders, including government agencies, key players in the rice sub-sector, NGOs, and other relevant entities, collaborate to develop and implement policies promoting the widespread adoption of IRDFS in the province. By fostering the integration of ducks into rice farming practices, stakeholders can contribute to the resilience of the rice sub-sector against the adverse effects of climate change, thereby ensuring sustainable agricultural development in the province.

Introduction

Considered vulnerable to climate change, agriculture is both a victim and a contributor to greenhouse gas (GHG) emissions. In 2011, the agricultural sector was placed as the second largest GHG emitter, with claims of contributing 10% to 12% of total emissions (Cruz, 2016). Other recent estimates by Lenka et al. (2015) put this contribution as high as 24% and assess rice farming as one of the greatest contributors of methane emissions in the agriculture sector (van Groenigen et al., 2012). Any intervention to ensure sustainabil-

2

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan, 2025*

ity in rice production while concurrently addressing its environmental burdens has immense significance, as rice is the main source of food for approximately 70 million people and contributes 35% of total calorie intake (Quilloy, 2019; PCAARRD, 2002). In SOCCSKSARGEN region of the Philippines, the estimated per capita consumption of rice averaged 113.94 kilograms per year with high consumption (125.78 kilograms) in urban barangays annually as compared to the rural barangays (PSA, 2017).

Cotabato Province in SOCCSKSARGEN is vulnerable to climate change, yet the conventional rice farming systems continue to dominate production, depending heavily on synthetic inputs in the quest for maximum yields. Nevertheless, the continued excessive use of these inputs, in turn, contributes to GHG emissions, particularly methane (CH_4), with a global warming potential 25 times that of carbon dioxide (Fazli & Man, 2014). Conventional farming of rice, especially in flooded fields, creates an anaerobic condition that enhances methane production (Mitra et al., 2012). A number of studies have found that conventional farming is responsible for emitting higher amounts of methane (8.91 mg CH_4 m^{-2} d^{-1}) compared to modified cultivation systems (Fazli & Man, 2014). With the growing climate disasters in Cotabato Province, from droughts and floods causing countless millions of pesos in crop losses, there comes an urgent need for adaptive and sustainable agricultural practices.

The effect of climate change is severe as it creates damage to crops in the province. In 2019, the total damage of drought in all affected crops was approximately 40 million pesos. Rice or palay has been severely affected by climate hazards like drought with a damage value of 11.4 million pesos affecting 1,094 hectares of land and 188 farmers (Sarmiento, 2019). While there was various adaptation strategies developed in the rice sub-system, the Integrated Rice-Duck Farming System (IRDFS) was suggested as an option in climate change adaptation. Putting rice and ducks together would help in natural pest control; building soil fertility, and lessening methane emissions, which are caused mainly through continuous flooding (Vipriyanti et al., 2021; Elly et al., 2019; Suh, 2014). Unfortunately, studies on assessing whether IRDFS are economically viable and scalable in vulnerable areas such as Cotabato Province are few and far between.

Hence, this study seeks to determine the economic viability of IRDFS in the adaptation to climate change for rice farmers in Cotabato Province. It will assess the economic returns of IRDFS. By filling this gap, the study presents useful knowledge and recommendations for sustainable rice farming practices that can help build resilience for the environment and livelihoods of farmers.

Materials and Methods

Site Description

Cotabato province has been considered as the "rice granary" of the region producing 104,344 MT of rainfed rice and 419,615 MT of irrigated rice in 2018 (PSA, 2018). This production contributes 47.19% and 37.40%, respectively, to the total rice production of the region. From 2009-2018, the province has been leading the region in rice production. However, in 2016, the production of rice decreased by 6.33% for rainfed rice while 8.21% for irrigated rice due to the prolong drought experienced by the province. The province is also highly vulnerable to climate change. The study funded by DA-BAR and headed by the International Center for Tropical Agriculture (CIAT) mapped the level of vulnerability of the province (Figure 1). Also, the province is highly at risk of El Niño (Figure 2) and increase in temperature. The risk map of projected rainfall change (Figure 3) incorporates both rainfall

3

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan, 2025*

decreases and increases during the dry and wet season, respectively. These maps show the projected scenario of the province in 2080.

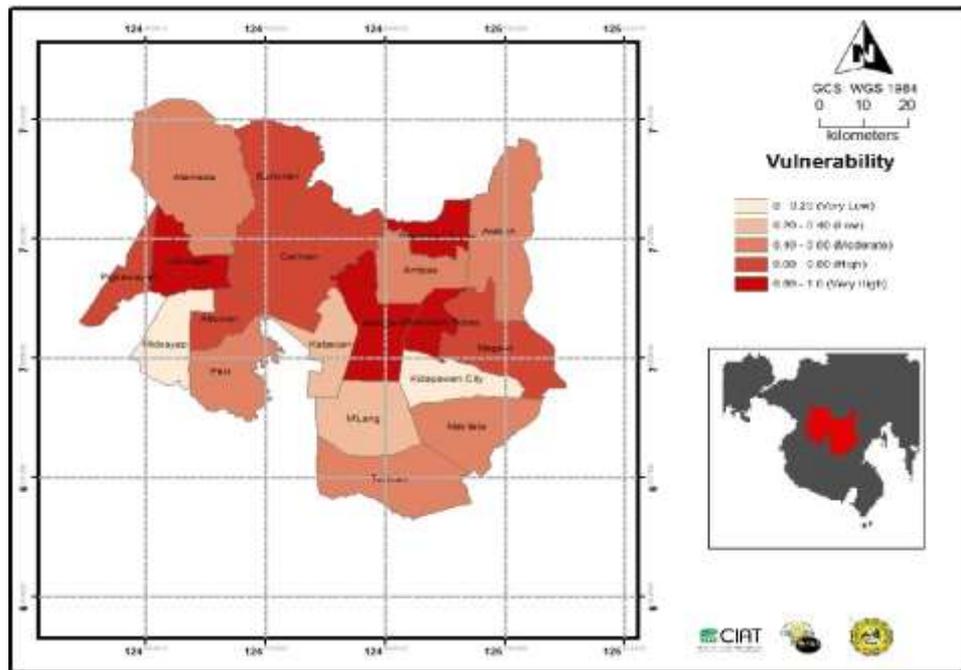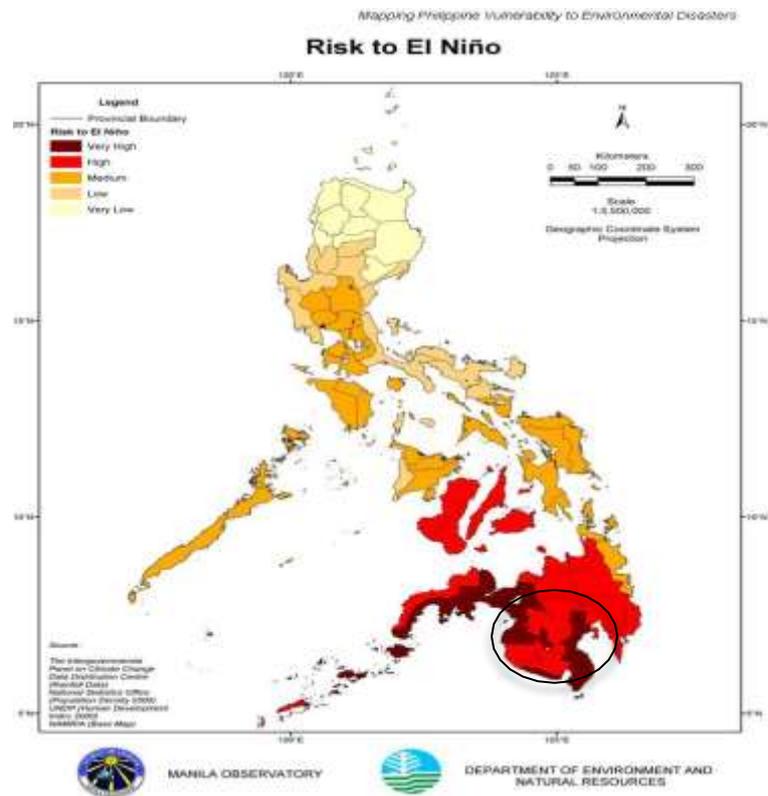**Figure 1.** Vulnerability map of Cotabato Province (Basan, 2016)

Figure 2. Risk map to El Niño (CEG, 2005)

4

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan,* 2025
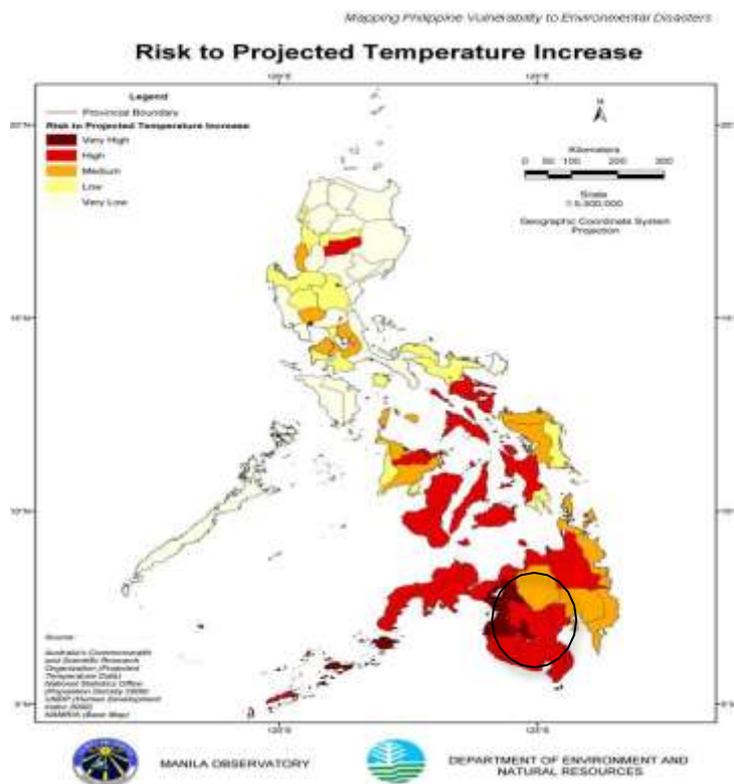
Figure 3. Risk map to Change in Temperature (CEG, 2005)

Data and Data Collection Procedure

Data on conventional rice from the results of the existing studies was used as secondary data reference. On the other hand, for data on integrated rice-duck farming, 70 farmers were purposively interviewed.These farmers were actively practicing IRDFS with a minimum farm size of 1.0 ha. Moreover, secondary data on discount rates and emissions were used to supplement the needed information for the Benefit-Cost Analysis. The data analyses were done using the CBA tool developed by the International Center for Tropical Agriculture (CIAT).

Data Analysis

Benefit-cost analysis was employed to generate the economic benefits of the IRDFS. The financial analysis utilized a discount rate of 12% 10%-15% in calculating the present value (PV) of benefits and costs spanning from year 1 to 10. The discount rate was derived from the approved social discount rate based on NEDA (2016). Mathematically, it computed as:

$$PV(Benefits) = \frac{B_1}{(1+r)^1} + \frac{B_2}{(1+r)^2} + \cdots + \frac{B_n}{(1+r)^n} \qquad (1)$$

$$PV(Costs) = C_o + \frac{C_1}{(1+r)^1} + \frac{C_2}{(1+r)^2} + \cdots + \frac{C_n}{(1+r)^n} \qquad (2)$$

5

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan, 2025*

Where $B_1 - B_n$ and $C_o - C_n$ are number of benefits and costs; r is the discount rate (10%); and t is the time of cash flow. The Net Present Value (NPV) was derived from the discounted present value (PVs). Additionally, benefit-cost (BCR) and internal rate of return (IRR) were computed. Specifically, the NPV was obtained by subtracting the sum of the PV of benefits from the sum of the PV costs (Sgroi et al., 2015). Mathematically, it expressed as:

$$NPV = \sum_{k=1}^{n} \frac{C_k}{(1+r)^k} \tag{3}$$

Where C_k mean the annual cash flow generated from the differences in revenues and annual costs; k represents the period of the cash flow; n is the duration of the project in years; r is the discount rate (10%). Accordingly, the project is good if the computed NPV is positive and the project is the most preferred. For BCR, this was obtained by dividing the sum of the discounted benefits (revenues) to the sum of the discounted cost (output) (Sgroi et al., 2015). It expressed as:

$$BCR = \frac{PV\ of\ benefits}{PV\ of\ costs} \tag{4}$$

The project is feasible or viable if the computed BCR is greater than one (1). Lastly, the IRR approach was performed to quantify the value created in terms of a percentage return, to be compared with the return on alternative investments (Bonazzi & Lotti, 2015) having NPV=0. This represented by the equation below:

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1+IRR)^t} - C_0 \tag{5}$$

Where Ct is the net cash inflow during period t; C_0 is the total investment cost; IRR is the internal rate of return; and t is the number of years. If the calculated IRR is greater than the predetermined discount factor (r), then a project is acceptable (Sgroi et al., 2015).

To examine the response of the financial parameters with market conditions, sensitivity analysis was conducted for IRDFS. Sensitivity analysis is primarily concerned with factor and combinations of factor that may lead to unfavorable consequences. It tries to estimate the effect of achieving project objectives if certain assumption does not, or only partly, occur (Iloiu & Csiminga, 2009). The analysis is carried through the formula:

$$SI = \frac{(NPV_b - NPV_1)}{(NPV_b - NPV_1)} x \frac{(V_b - V_1)}{V_b} \tag{6}$$

Where SI is the sensitivity index; NPV_b is the value of the NPV of the base case; NPV_1 is the value of the NPV in the sensitivity test; V_b is the value of the variable in the base case; V_1 is the value of the variable in the sensitivity test. Also, the switching values (SV) was conducted using the formula:

$$SV = \frac{(100\ x\ NPV_b)}{(NPV_b - NPV_1)} x \frac{(V_b - V_1)}{V_b} \tag{7}$$

6

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan,* 2025

Where SV is the switching values. In the sensitivity analysis, the following scenarios are used: a) 10% increase in total benefits; b) 10% increase in total cost; and c) simultaneous 10% increase in total benefits and 10% decrease in total cost.

Results and Discussion

Description of IRDFS as Adaptation Strategy

Animal-crop farming system is viewed to have a potential in increasing farmer's income and can improve farm-environment condition. In Bangladesh, feasibility studies about rice-duck farming system were done. The results of the study revealed that rice-duck production system is superior to the traditional rice farming system (solely rice) in the area in terms of economic and environmental effects. The yield of rice-duck production was 20% higher than the traditional, hence ensuring a net return of 50% and rice-provisioning ability (Hossain et al., 2005). According to Khan et al. (2005), rice-duck farming is a low-cost production system. The system increased the crop yield by 20% and increased the net income on a cash cost basis by 80%. Rice-duck production had significantly higher net return and was said to be more technically and economically efficient than rice monoculture. The net income of PHP 17,767 was obtained for rice-duck, which was higher in comparison to rice with PHP 7,625. The return-to-labor for rice-duck played out to be PHP 424.28 at a labor rate of PHP 150.00 per day (Barroga et al., 2007).

Many studies have shown the beneficial effects of rice-duck farming system in the environment. Findings revealed that organic rice-duck had significantly lower energy input of 79,307 MJ ha^{-1} than the conventional rice alone with an energy input of 94,377 MJ ha^{-1}. In terms of energy output however, rice-duck had higher results (117,325 MJ ha^{-1}) than conventional (111,914 MJ ha^{-1}). Hence, rice- duck farming has more energy efficiency than conventional rice farming (Pirdashti, et al., 2015). Huang et al., (2005) reported that rice-duck ecological planting and breeding can significantly reduce the methane emissions from the rice fields than the conventional rice farming system alone. FAO (2013) also emphasized that ducks as part of farming production system helps the rice seedlings grow vigorously as they eat both insects and weeds, thereby maintaining a good farm condition. An adult duck with an average weight of 1.0 kg can potentially eat more than 150 pests per day. The total number of insects in the rice paddy with released ducks reduced by 87.7% compared to non-duck rice field (Huang et al., 2013).

Economic Analysis of IRDFS as Adaptation Strategy

IRDFS has two main benefits: 1.) Increased income for the farmers and 2) reduces methane emission as well as increase environmental integrity. The increase in the net farm income of the farmer arises from the increase in yield of rice as well as the income from duck product sale like eggs and meat.

Net Present Value, Benefit-Cost Ratio and Internal Rate of Return are presented in Table 1. The results that integrated rice-duck farming system show higher viability highlighting an NPV of PHP 81,331.44 per hectare for 10 years. Moreover, the benefit-cost ratio showed an acceptable value given the decision criterion of greater than 1. The internal rate of return (IRR) for IRDFS has a value greater than 10%, the discount factor. This result also conformed with those studies of Khan et al. (2005.) and Barroga et al. (2007) revealing that IRDFS has positive and higher returns.

7

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan,* 2025

Table 1. Net present value (NPV), benefit-cost ratio (BCR), and internal rate of return (IRR) of integrated rice-duck farming system (IRDFS) farming in Cotabato province.

INDICATORS	VALUE
NET PRESENT VALUE, PHP	81,331.44
BENEFIT-COST RATIO	1.41
INTERNAL RATE OF RETURN (%)	65.00

Sensitivity Analysis

Table 2 shows the sensitivity analysis for integrated rice-duck farming system. In the first case where there is a 10% increase in total benefits, the NPV is higher relative to the base case. The BCR is also greater than 1. Based on these results, it can be said that the farming system is acceptable. With this scenario, the sensitivity indicator is 15.27. This means that the changes of 10% in the variable (total benefits) results in a change of 152.7% in the NPV implying that NPV is very sensitive to the change in the total benefit. The switching value of 6.55% means that a change in the total benefits will cause the NPV to become zero. In other words, it needs 6.55% for NPV to be zero. This further means that the lower the SV, the more sensitivity the NPV is to the change in the variable concerned and the higher the risk with the project.

Table 2. Sensitivity analysis of integrated rice-duck farming system (IRDFS) farming in Cotabato province.

SENSITIVITY SCENARIOS	NPV, PHP	BCR	SI	SV
10% INCREASE IN TOTAL BENEFITS	205,486.50	1.56	15.27	6.55
10% INCREASE IN TOTAL COST	61,712.90	1.29	2.41	41.46
SIMULTANEOUS 10% INCREASE IN TOTAL BENEFITS AND 10% DECREASE IN TOTAL COST	128,701.66	1.73	1.45	69.18

Note: NPV – net present value; BCR – benefit-cost ratio; SI – sensitivity index; SV – switching value

An increase of 10% in total cost resulted in a decrease in both NPV and BCR as compared to the base case. However, the decrease in both NPV and BCR did not mean a rejection of the systems since the values are positive and greater than 1, respectively. The sensitivity index of the 10% increase in the total cost is 2.41 which means that 24.1% is the change in the NPV if total cost will increase by 10%. Meanwhile, the switching value is 41.46%, which is relatively high. Thus, NPV is less sensitive to this change in total cost. In a simultaneous change of the benefit and cost as in the third case, the NPV is higher than the base case along with the BCR which is greater than 1. Still, given this change in benefit (increase by 10%) and costs (decrease by 10%), the NPV>0 and BCR>1, hence, the two strategies are acceptable. The sensitivity indicator is 1.45 and switching value is 69.18%. It can be inferred that a simultaneous change of 10% decrease in total cost and increase in total benefit, respectively, would result in 14.5% change in NPV and with a 69.18% switching value, there can be much lesser effect to the NPV.

8

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan,* 2025

Conclusions and Recommendations

The results of this study provide confirmation of the economically viable yet environmentally sustainable basis for integrated-rice duck farming system. The financial metrics – highlighted by the positive net present value (NPV>0), benefit-cost ratio (BCR>1), and internal rate of return (IRR) exceeding 10% discount rate - highlight the economic viability of IRDFS. Meanwhile, the ecological benefits lend a considerable credence to its case for a viable climate change adaptation strategy for rice subsector of Cotabato province.

With all the favorable returns from the IRDFS, maximize its adoption into the policy framework and promote it among farmers through technical training. The local government of Cotabato must enact and implement policies that complement IRDFS with financial incentives, grants for transport and procurement of ducks, and capacity-building programs to train farmers on the requisite skills for smooth integration. Strengthening extension services provides technical support, demonstration farms, and marketing strategies that illustrate the viability of the IRDFS as a climate change adaptation strategy. Better market development should also be made by improved value chain linkages between farmers, traders, and consumers ensuring a steady demand for IRDFS products such as rice, ducks, and eggs. Based on the benefits both the economy and environmental performance, IRDFS provides a viable solution aimed at at least maintaining sustainable agricultural development while assisting the farmers at the microeconomic level to adapt to climate change. Finally, continued research is warranted to optimize the implementation of the IRDFS, consider the long-term social, economic, and ecological effects, and assess possibilities for scaling this up into climate-vulnerable area. Through combined measures, IRDFS can offer a win-win opportunity in strengthening the resilience of the rice subsector in Cotabato Province while enhancing sustainable agriculture development.

Acknowledgment

Conflict of Interest

The author declares no conflict of interest.

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9

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan,* 2025

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10

Economic Analysis of Integrated Rice-Duck Farming System as Climate Change Adaptation Strategy in Vulnerable Areas | *Romiel John Basan,* 2025

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