# THE POTENTIAL OF INTEGRATED RICE-DUCK FARMING IN COMMUNITIES ALONG THE BICOL RIVER BASIN, PHILIPPINES

Diomerl Edward B. Baldo[1*] and Ricky P. Laureta[2]

[1]Partido State University, Caramoan Campus
Cadong, Caramoan Camarines Sur, 4429, Philippines

[2]College of Arts and Sciences, Partido State University
San Juan Bautista, Goa, Camarines Sur, 4422, Philippines

*Corresponding author: debbaldo@parsu.edu.ph

***Abstract*** — Bicol is one of the most vulnerable regions in the Philippines due to its geographic location. Climate risks that lead to low rice productivity are intensified by large bodies of water such as the Bicol River Basin, covering three provinces and 43 municipalities in the region. The present study aims to assess the effects of integrated rice-duck farming (IRDF) in six farm sites from three municipalities (Baao, Canaman and Minalabac) in Camarines Sur situated along the BRB. Using Student's t-test, IRDF demonstrated significant results in Taban, Minalabac in terms of number of grains, number of tillers, number of panicles and the weight of grains in grams ($p<0.05$) compared to conventional farming. In contrast, no yield was recovered in San Fransisco, Baao where persistent flooding was observed during the cropping season. Post-harvest soil analysis demonstrated notable variation in phosphorus concentrations (highest in DCDR at 24.72 ppm and lowest in Mangayawan at 6.94 ppm) among other parameters. Water quality analysis revealed strong distinction in the amounts of $PO_4$, at 36.34 ppm in Taban against 1.21 ppm in Sta. Eulalia, Baao. IRDF is an effective faming methodology when optimum conditions are present in farm communities. Nonetheless, IRDF is a promising strategy that can be instigated in policy frameworks to ameliorate rice productivity in climate-risk exposed farmlands.

***Keywords* — Bicol River Basin, climate risk, conventional farming, integrated rice-duck farming, physico-chemical analysis**

## INTRODUCTION

Rice is one of the most important grain crops in the Philippines. It is a major food component of every Filipino (Macalad et al., 2019). According to the works of Barroga et al. (2007), 90% of the country's population consider rice as the major staple food. This information is supported by the country's vast land area of cultivate potential, making rice industry accountable for 0.7% of the country's gross domestic product (GDP) in 2018 (Lacambra et al., 2020). According to the report of Sebastian et al. (2000) in the Food and Agricultural Organization (FAO), 11.5 million Filipinos are dependent on rice farming as their primary source of income. However, in the third quarter of 2021, agriculture, forestry and fishery (AFF) has been reported to contract a -1.7 growth rate in the gross national income and gross domestic product (GDP) (Philippine Statistics Authority, 2021). With this, the farming industry in the Philippines is challenged to promote efficient production and stable source of income to rice farmers.

To address the goal for viable, productive and profitable farming and avert gaps in rice yield, researchers and farmers, together with concerned government agencies have established good practice options (GPO). However, the choice of the best individual farming technique varies in every farmland. The integration of the best component technologies should (i) guarantee timely cropping that shall result to productive yield, (ii) maximize the use of resources and farming inputs, (iii) provide immediate profit investment as evidenced by economic benefits, and (iv) minimize the effects as environmental hazard (Alam and Starr, 2013).

One of these farming practices that has been developed over the years is the integrated rice-duck farming (IRDF), an innovative farming process where ducks feed on the farm insects and weeds in paddies and fertilize rice plants. The methodology has reached many Southeast Asian countries such as Malaysia, Vietnam, Indonesia and the Philippines. A number of studies have reported the beneficial effects of the rice-duck system when associated to farming. In the Philippines, particularly in Bukidnon, Barroga and associates (2007) highlighted that IRDF effectuated to 36.58% rise in technical efficiency in crop yield. In Bicol Region, FAO (2013) reported preliminary data on the effects of IRDF in Buhi, Guinobatan and Gubat and mentioned that farmers' income escalated as much as 30% compared with the earnings from the conventional farming.

Bicol Region with its geographic location is considered as highly vulnerable to natural disasters such as typhoons, floods, and volcanic eruptions. These natural phenomena usually lead to discernible devastations with major effects on agriculture industry. The risks in the region are intensified by major land and water bodies such as volcanoes (Mayon, Isarog, Malinao, etc.) and the large river, Bicol River Basin (BRB), respectively. This amass river has a total land area if 317, 103 ha and range into the provinces of Albay, Camarines Sur and Camarines Norte and 43 local government units (LGU) which are situated within the BRB (DENR, 2015). Because of the presence of the BRB, flooding has become the most pervasive hydrologic hazards that threatens the entire Bicol plain. The projected flooded area in BRB is 42, 124 ha and is expected to increase to 50, 402 ha or 16% of the BRB. This results to significant loss in agricultural productivity, specially to irrigated rice lands. In the last quarter of 2020 amidst the COVID-19 pandemic, the regional agriculture was ravaged by a series of strong typhoons that hit the provinces and subsequently affected the impoverished locals of the region. Department of Agriculture (DA) has estimated a total loss of 968 million pesos that has affected 40, 519 farmers in the area. (Philippine News Agency, 2020). This phenomenon is believed to be a contributor to the decline in the GDP share of agriculture for that year. With this, the present study generally aims to determine the influence of IRDF to representative farmlands in Baao, Canaman and Minalabac along the vulnerable communities in Camarines Sur. Specifically, it aims to compare traditional farming techniques against IRDF in terms of its effect on productivity using number of grains; number of tillers; number of panicles and weight of grains in grams. Further, it aims to assess the post-harvest physicochemical characteristics of the farm's irrigation and determine the nutrient status of the soil using standardized protocols.

## MATERIALS AND METHODS

### Study Site

The experimentation was conducted in six study sites from three vulnerable municipalities in the province of Camarines Sur (Laureta and de la Vega, 2020). These sites are located along the Bicol River, exposing the populace's agricultural operations to natural disasters. These sites are: Sta. Eulalia, Baao (13.4329°, 123.3152°), San Francisco, Baao (13.4505°, 123.3350°), San Francisco, Canaman (13.6448°, 123.1141°), Mangayawan, Canaman (13.6225°, 123.1220°), Del Carmen-Del Rosario, Minalabac (13.5655°, 123.1907°) and Taban, Minalabac (13.5544°, 123.1996°). Figure 1, annual average rainfall in Camarines Sur is 2,565 mm with an estimated mean temperature of 27.0 °C, and lastly with relative humidity of 25.8% (Philippine Statistics Authority, 2019). The research was carried out in July to December 2019. The rice variety used in the experiment was Green Super Rice 11 (GSR11).

The trials were conducted solely in the fields of farmer cooperators from each study sites. Each farmer cooperator allotted approximately 0.50 ha, which was then equally divided into two parts: the rice duck system which served as experimental setup, and the farmers' conventional or traditional method of rice planting which was treated as the control. Farmlands set up were divided by a demarcated area and were protected with fences. In the traditional portion of the land, conventional farming techniques were practiced such as usual application of insecticides, pesticides and herbicides. As opposed with this set-up, no application was added in the experimental plots to directly observe the effectiveness of the ducks in the production system. Additionally, the rice-duck plots did not receive fertilizer in any form. In the traditional rice plots, complete (PNK;14-14-14) fertilizers and urea were applied, as usual practice of the local farmers.

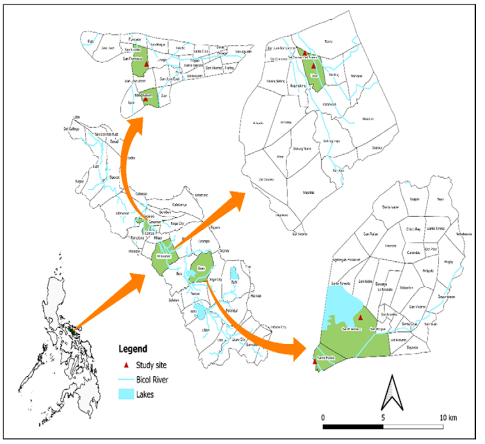


**Fig. 1.** Bicol River Territorial Map.

### Rice-duck farming set-up

For the IRDF set-up, the methods described by Hossain et al. (2005) were adapted with modifications. Ten days after transplantation, 20-day-old ducklings were allowed to freely navigate in the farm (150/ plot). At the initial stage, the animals were kept in the plots for 2-4 hours a day. When the ducks become familiar to the environment, they were released in the plots in extended hours. Possible predators were prevented by establishing mesh nets within respective designated plots. As ducks reached four months old, they were detached from the rice fields to prevent matured ducks from overgrazing the plots at the flowering stage. Each of the demonstration trial was treated as a replication. At the harvest period, data on growth, yield-contributing characteristics such as number of grains, number of tillers, number of panicles and the weight of grains in grams and yields of the crops were recorded.

**Post-harvest Water and Soil Analysis**

A representative water sample of 500 ml from irrigation systems was collected and stored in a properly rinsed polyethylene bottle. Floating debris and any other contaminants were avoided while collecting the sample. Also, 500g of soils were randomly sampled from 10 different spots of the plot at 1 m depth. Soils were allowed to air-dry for approximately one week. After appropriate labelling of site and date of collection, analyses were performed at the Department of Agriculture 5 Regional Soils Laboratory.

**Determination of Nitrogen (N)**

Soil organic is oxidized with potassium dichromate in concentrated sulfuric acid. The green color of dichromate is measured. The calculation of amount of organic carbon is based on the oxidation, under the same conditions of organic standards like sucrose, dextrose and the disodium salts of ethylinediaminetetracetic acid. Soil sample at 0.5 g was placed into a 250 ml of erlenmeyer flask. Potassium dichromate in 2 ml was added to the solutions. After, 5 ml of $H_2SO_4$ were added and cooled down. 20 ml of $DH_2O$ was further added. The mixture was allowed to stand over night to allow soil particles to settle completely. Absorbance was measured at 627 nm.

**Determination of Phosphorus (P)**
**Standard Preparation**

Sodium bicarbonate ($NaHCO_3$) was used as extracting solution and was prepared by dissociating 42g of sodium bicarbonate in distilled water ($DH_2O$) to a volume of 1000 ml. The pH was adjusted to 8.5 with 50% sodium hydroxide (NaOH). Fifty percent (50%) sodium hydroxide was prepared by dissolving 50g of NaOH in a 100 ml $DH_2O$. Acid molybdate stock solution was also prepared by mixing dissolved 6 g of ammonium molybdate in 25 ml of $DH_2O$ and 0.1455g of potassium anyimonyl tartrate in 5 ml $DH_2O$. Reagent B was prepared by dissolving 2.639g of ascorbic acid to 500 ml of Acid molybdate stock solution. The stock standard phosphorus solution was set by adding 0.2197g of potassium dihydrogen phosphate ($KH_2PO_4$) in about 25 ml of DH2O. This was diluted to a final volume of 1000 ml with extracting solution. Concentration of working standard ranged from 0.2-5.0 mg/l P. Calibration standard was prepared by pipetting a 5 ml aliquot of each of the working standards. Standards were allowed to develop color and the absorbance was read at 882 nm. $R^2$= 0.9990.

**Sample preparation**

Soil sample weighing 2g was placed in a 100 ml polyethylene bottle and duplicated. Briefly, 40 ml of extracting solution was added. The bottle was safely covered and shaken at 200 rpm or more for 30 minutes. Blank sample was also prepared. The extract was filtered into a 125 ml of erlenmeyer flask. This was added with 15 ml $DH_2O$ and 5 ml of Reagent B. The flask was agitated for thorough mixing. The reaction was incubated for 10 minutes and the absorbance was read spectrophotometrically at 882 nm.

**Determination of Potassium (K)**

The exchangeable base is extracted by leaching the soil with ammonium acetate buffered at pH 7.0. The exchangeable bases are directly determined in the ammonium acetate ($NH_4OAc$) extract by atomic absorption spectrophotometry. Briefly, $NH_4OAc$ solution was prepared by dissolving 7708 g of $NH_4OAc$ in 1000 ml distilled water. pH was adjusted to 7.0 with acetic acid. Leaching tubes were prepared. Two grams of soil was placed into the tube and leached by adding 10 ml aliquots of ammonium acetate at 20-minutes interval. Leachate was collected in the 50 ml flask and made up to the mark with ammonium acetate leaching solution. Potassium (K) was computed using the formula:

Exch K (cmol/kg soil) = (a-b) (0.0639) x DF x MCF

Where; DF- dilution factor; MCF- moisture content factor

**Data Analysis**

Statistical analysis was performed using Microsoft Excel and verified using SPSS v20.0. Student's T-Test was used to analyze the significance between the two treatments in each parameter ($p<0.05$).

## RESULTS AND DISCUSSION

The comparison of the rice yield characteristics between the two experimental set- ups is presented in Fig. 2. Indistinct relationship among the parameters with varying significance is noted in every location site. Using the data in the number of grains, significant effect was noted in the traditional farming practice in Sta. Eulalia, Baao, and DCDR, Minalabac (Fig. 2A). However, increased number of grains was observed in the IRDF set-up in Taban, Minalabac. The rice's tiller number was also measured. Higher results were noted in conventional farming set-ups in Mangayawan, Canaman and DCDR, Minalabac, but tiller number has significantly risen in the IRDF arrangement in Taban (Fig. 2B). The result in the number of panicles further supports in beneficial effects of IRDF in Taban which recorded the highest number of panicles (Fig. 2C). Congruently, positive response in the weight of IRDF rice grains were observed from samples in Taban. Samples from other experimental sites showed denser grains from the traditional farming (Fig. 2D).

Soils from the different experimental sites were collected after integrated rice-duck farming. The status of the soil nutrient (Table 1) demonstrated that among the six

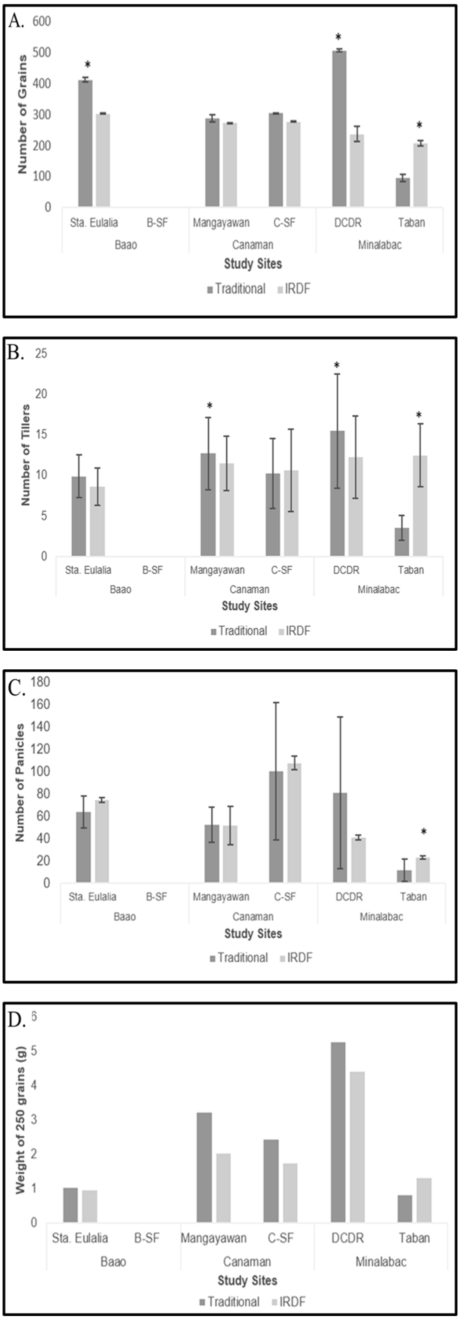


**Fig. 2.** Comparison of rice yield characteristics of traditional and integrated rice duck farming (IRDF). number of grains (A), number of tillers (B), number of panicles (C) and weight of 250 grains (D). SF- San Francisco, DCDR-Del Carmen Del Rosario. Values are expressed as Mean ± SD. n=12. *Significant at $p<0.05$ Level using Student's t-test.

sampling sites (excluding San Francisco, Baao where no data were generated), sampling site in Mangayawan, Canaman showed the most varying difference in two important parameters, least amounts of phosphorus (6.94 ppm) and incongruently the highest electrical conductivity (EC at 2.540 mS/cm) which basically measures the soluble salts in the soil samples essential to the proliferation status of a cell population.

Overall, soil samples from various study sites recorded a homogenous result of medium nitrogen (N) % with ranges from 3.84-4.13 organic matter (OM). Variations in the phosphorus (P) level were noted. Magayawan has low P level at 6.94. Medium levels of P were noted in Sta Eulalia, Baao, SF, Canaman and DCDR, Minalabac at ranges 14.06-15.86 while high levels of P were illustrated by soils samples collected from Taban, Minalabac. For potassium (K) quantification, all soil samples fall under the “deficient” category with less than 0.2 meq/100g soil.

For post-harvest soil analysis, the electrical conductivity was measured. This is reflective of salt concentrations, defined as dissolved organic solutes and are commonly calcium, magnesium, sodium, chloride, sulfate and bicarbonate (Center for Agriculture, Food and the Environment, 2016). It was established that soluble salts above which fall above the normal range may cause to a number of crop issues root injury, leaf chlorosis, marginal burn and sometimes wilting. This is attributable to low yield productivity in areas with high EC levels such as Mangayawan. In this site, the most acidic soil at 5.36 mS/cm was observed, followed by soils sampled from DCDR. The rest of soil samples illustrated slightly acidic status of pH ranging from 5.61 to 5.97 mS/cm.

The presence of N, P and K in fertilizers are important for an optimum productive crop (Stellacci et al., 2013; Montavani et al., 2017). When these nutrients are at excessive doses, NPK balance effects to soil-related harms such as acidification, loss of organic matter, deterioration of the structure, and reductions in biological activity and fertility (Moe et al., 2019). The modern rice varieties engineered today demand standard nutrients that allow an optimal production. However, this brings threat as the same varieties drain the soil with important nutrients at faster phase

**Table 1.** Nutrient profile of the soils from IRDF plot.

| | | Nutrient element | | | | |
|---|---|---|---|---|---|---|
| Location | Site | N (%OM) | P (ppm) | K (meq/100g) | pH (1:1$H_2O$) | EC (mS/cm) |
| Baao | Sta. Eulalia | 4.06 | 14.06 | 0.14 | 5.61 | 0.199 |
| | SF | - | - | - | - | - |
| Canaman | Mangayawan | 3.84 | 6.94 | 0.16 | 5.36 | 2.56 |
| | SF | 4.13 | 15.86 | 0.10 | 5.97 | 0.08 |
| Minalabac | DCDR | 3.90 | 24.72 | 0.12 | 5.55 | 0.19 |
| | Taban | 4.06 | 14.06 | 0.14 | 5.61 | 0.19 |

SF-San Francisco, DCDR-Del Carmen Del Rosario than the usual grain varieties (Singh and Singh, 2017). With this, there is a challenge to maximize the yields of crops cultured in degraded soil. Efforts required to mitigate such soil types is unsustainable on the global scale (Moe et al., 2019). Added impediment in the optimal rice yield are water irrigation systems with high concentrations of salt intrusion which can be facilitated by arrays of multifactor such as but not limited to human activities and climate change.

The most critical factor in the management of salt-affected soils is the irrigation quality of water being used (Tak et al., 2012). This is observed to positively influence crop yield and physical conditions. Therefore, well-strategized establishment of irrigation water quality is instrumental to understand management changes that can be employed for long term productivity. To date, salt content in irrigation waters is easily tested. Values are estimated in terms of EC and is the basic parameter in assessing the quality and suitability of irrigation waters.

Generally, all irrigation waters from sampling sites recorded an EC within the ranges of 0.403-0.557 mS/cm (Table 2). These are considered suitable to cropping except in some frequent conditions in very sensitive crops and highly clayey soils of poor permeability. According to Visconti and Paz (2016), EC of less than 0.75 mS/cm are ideal for cropping activities. Unexpectedly, high concentrations of salt are not detected in irrigation waters of Mangayawan, currently reported to be salt intruded area. This discordance may be explained with the large absorptions by the soil in the farming sites. According to the works of Tak and colleagues (2012), pH levels from 6.5 to 8.4 are normal for irrigation water. The above data suggests that all water systems are suitable for rice farming.

$NO_3$-N is also quantified in the study. It can be observed that DCDR showed an elevated concentration of nitrogen at 4.33 ppm and least levels were seen at equal amount of 1.44 ppm in Sta. Eulalia, SF, Canaman and Taban (Table 2). Nitrate-nitrogen ($NO_3$-N) is an important N source because it is abundant in wastewaters and irrigation waters across the globe. It is well understood that nitrogen is an essential crop nutrient that enables plant growth. Usually, the source of N is the natural soil and its supplementation in fertilizers. Nonetheless, the N found in the farm water sources has the same outcome to that of the applied fertilizer. Thus, N levels within these sources should also be considered because excessive nitrogen could cause issues like plant growth overstimulation, delayed maturity or poor quality. To address

**Table 2.** Physicochemical characteristics of irrigation waters analyzed.

| Location Site | | pH | EC (mS/cm) | $PO_4$-P (ppm) | $NO_3$-N (ppm) |
|---|---|---|---|---|---|
| Baao | Sta. Eulalia | 6.75 | 0.403 | 1.21 | 1.44 |
| | SF | - | - | - | - |
| Canaman | Mangayawan | 6.69 | 0.545 | 27.36 | 2.16 |
| | SF | 6.51 | 0.557 | 32.26 | 1.44 |
| Minalabac | DCDR | 6.34 | 0.198 | 12.65 | 4.33 |
| | Taban | 6.88 | 0.215 | 36.34 | 1.44 |

SF-San Francisco, DCDR-Del Carmen Del Rosario such concerns, ideal fertilizer and effective irrigation management are key players. Also, it is noteworthy that the need of crops differs in every maturation stage. According to a report, high nitrogen levels can provide positive effects during initial growth stages but may cause detrimental outcomes when overexposed during the later flowering and fruiting stages (Tak et al., 2010). This would mean that farm water with elevated N level can be used early in the cropping season but this should be controlled as the nitrogen needs deescalates as it matures. Also, in whichever rice variety, nitrate should be credited toward the fertilizer rate especially when the concentration exceeds 10 ppm $NO_3$-N or 45 ppm $NO_3^-$. It can be deduced that all farming sites have optimal source of $NO_3$-N levels and conform with the required standard concentrations.

Integrated rice-duck farming (IRDF) is a potential farming technology that can be adapted for a sustainable agriculture. Aside from beneficial effects in the amelioration of crop yields, Xu and associates (2017) highlighted that the organic farming methodology significantly decreased the $CH_4$ emission and increased the $N_2O$ emission. However, IRDF suitability to vulnerable communities along BRB is a challenge to be won by the farmers. Attention must be extended to the ducks such as herding them into rice paddies in the daytime and keeping them back before night time. Elaborated work confirm that regular feeds and the fencing instalment take an initial additional capital (Suh, 2014). Also, in salt intruded paddy fields, ducks must be monitored in their time of exposure because this condition may affect the duck health and behavior.

## CONCLUSIONS

IRDF is a prospective farming methodology in tropical countries like the Philippines, with promising effect not just in the sustainable production of rice yields but also in mitigating the threats of biocides' long-term adverse health effects and more so, global warming. In this study, IRDF was investigated to improve various rice yield characteristics such as number of grains, number of tillers, number of panicles and the weight of grains in grams, supporting the notion that it can be employed in rural farmlands with close proximity to BRB. This study suggests that IRDF can be economically profitable even in flood-persistent areas because practical poultry products from ducks are favored by consumers, and thus can be an alternative source of livelihood in such areas. Taken together, more researches must be carried out to characterize other physicochemical parameters that can display pivotal effect on farming development. Future studies on the economic viability of IRDF is also warranted.

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