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Abstract: *Water is essential in rice farming and managing it requires understanding water balance. This study estimated the water balance for rice (NSIC Rc160) at various growth stages using the FAO CROPWAT 8.0 model. It also determined crop water needs, developed irrigation schedules, and compared model results with farmer practices in Butuan City. Results showed the reproductive stage required the most water, while the initial stage needed little to no water due to rainfall and residual soil moisture available. A Kendall's tau of 0.5556 indicated a moderate correlation between CROPWAT 8.0 estimates and farmer practices; however, the p-value (0.1932) indicated it was not statistically significant. Discrepancies were attributed to traditional methods, diverse soil types, and real-time irrigation decisions based on current weather. While CROPWAT 8.0 provides valuable guidance, its fixed assumptions may not reflect field realities.*

Keywords: Water Balance; Irrigation; CROPWAT 8.0; and Oryza Sativa NSIC Rc160

1. INTRODUCTION

Water balance is a critical component in rice production, influencing both crop yield and the sustainability of agricultural practices [1]. Rice (*Oryza sativa*), known for its high-water demand, requires effective water resource management to optimize growth and maximize yield [2]. This becomes even more important in regions experiencing water stress, where efficient water use can boost productivity while conserving limited water supplies [3].

As a staple for nearly half of the global population, rice plays a vital role in food security and the economy, especially in Southeast Asia. In the Philippines, rice farming is not only a key livelihood but also an integral part of the nation's culture and economy [4]. However, climate variability and declining water availability have become pressing challenges. Drought severely affects rainfed areas and significantly reduces yield [5, 6]. To address this, increasing rice production using less water is essential [7].

Each stage of rice growth, seedling, vegetative, reproductive, and ripening, requires varying amounts of water. Understanding water balance during these stages is vital for planning irrigation and conserving water [8,9]. Traditional field-based methods, such as measuring evapotranspiration and soil moisture, are labor-intensive and prone to inaccuracies [10]. As a result, crop simulation models have become valuable tools, as they integrate climate, soil, and crop data for more accurate estimations [11].

FAO CROPWAT 8.0 is one such tool that estimates evapotranspiration, effective rainfall, crop water requirements, and irrigation schedules under specific agroclimatic conditions [12-14]. This study used CROPWAT 8.0, developed by the Food and Agriculture Organization of the United Nations, to estimate the water balance of NSIC Rc160 rice in Butuan City and support sustainable irrigation practices in the region.

2. METHODOLOGY

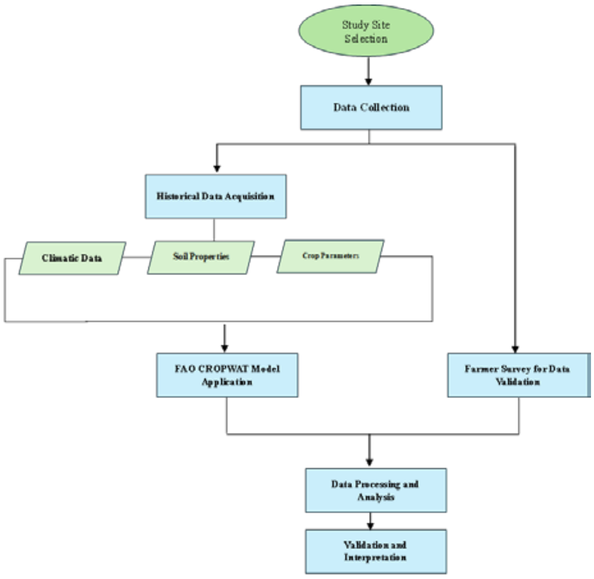


Fig. 1. General process flow of the study.

The general process flow is shown in Fig.1, which includes: (1) Study site selection; (2) Data Collections; (3) Data Processing and Analysis; (4) Validation through farmer survey; and (5) Interpretation of results. The historical data was climate, soil properties, and crop parameters, which were used to simulate the FAO CROPWAT 8.0 model. The simulation results of the data using the FAO CROPWAT 8.0 model are validated using the data gathered from the survey. These results are analyzed using correlation statistics as a statistical tool in the Statistical Tool for Agricultural Research (STAR) to compare the model's computations with actual farmer practices. The conceptual framework of the model application is presented in Fig. 2.

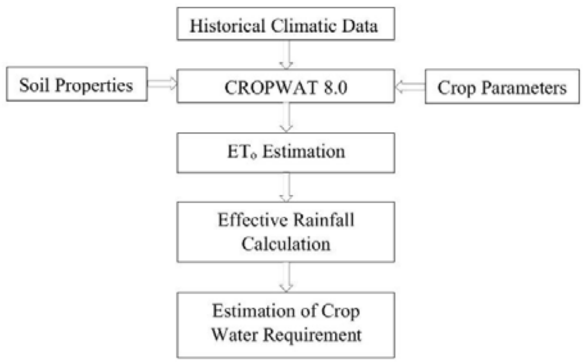


Fig. 2. Conceptual framework of the model application.

2.1 Site and Crop Selection

This study was conducted in Butuan City, located in the Caraga Region, Philippines. Geographically, the site is positioned at a latitude of 8° 56′ 57″ N and a longitude of 125° 32′ 36″ E. According to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Caraga falls under the Type II climate classification, which is characterized by the absence of a distinct dry season and a pronounced maximum rainfall from November to January. This tropical climatic condition plays a significant role in water balance, particularly in evaluating irrigation needs and effective rainfall throughout the rice crop's growth stages. The variability and distribution of rainfall directly influence the scheduling and amount of irrigation required, impacting overall crop productivity [15].

Based on data from the Butuan City Agriculture Office (BCAO), forty-four (44) barangays have been identified as rice farming areas within the city, as mentioned in the study of [16]. Due to time constraints and the rice harvesting calendar, some of these barangays had already completed harvesting during the study period. Fortunately, eight (8) barangays had not yet harvested their rice, and these became the primary respondents of this study. These barangays were Ampayon, Antongalon, Bancasi, Bonbon, Lemon, Libertad, Mahay, and Pinamanculan are also among the top rice producers in the city.

The rice variety used in this study is *NSIC Rc160*, also known as Tubigan 14. The selection of this variety is based on its popularity among local farmers, and its adaptability to the climatic and soil conditions of Butuan City. This variety is known for its high yield potential up to 8.2 tons per hectare under ideal conditions [17]. Moreover, it is suited for both wet and dry seasons, with farmers reporting higher yields during the wet season reaching up to 125 cavans per hectare [18]. It also demonstrates intermediate resistance to major rice diseases such as blast and bacterial leaf blight, making it a reliable choice for farming environments [19].

2.2 Historical Climatic Data Acquisition

This study utilized the past 10 years of climatic data specifically from 2015 to 2024, which are also used in the paper of [20, 21]. The data includes minimum and maximum temperature, humidity, wind speed, and rainfall obtained from the meteorological agency, PAGASA-Butuan Station. Due to the unavailability of sunshine duration data from the station, the historical sun hour data was accessed from TuTiempo.net, a global provider of climate and weather data. The platform offers reliable meteorological parameters and has been used in several studies, including those by [22-25].

The required soil data were sourced from FAO Manual 56, following the studies of [20, 25]. Clay soil was used as the representative type for simulation. Similarly, the crop coefficient values (Kc) were also taken FAO Manual 56. Kc values for the initial, mid, and late growth stages of rice were adopted from the study of [20, 21].

2.3 Data Validation through Survey

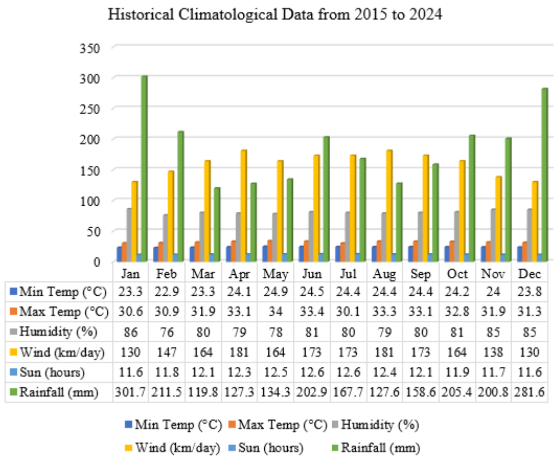
To verify the water needs estimated by the FAO CROPWAT 8.0 model, the study used a survey through face-to-face interviews with 16 rice farmers in Butuan City growing the NSIC Rc160 variety. Farmers were chosen through purposive sampling from 8 barangays. The sample size follows the suggestion of these studies [26-28], 10-16 participants are enough for focused studies.

3. RESULTS AND DISCUSSION

The findings include the rice water requirements per stage, the model's suggested irrigation schedule, and comparison with the actual irrigation practices of local farmers in Butuan City.

3.1 Water Balance Estimation using FAO CROPWAT 8.0

The 10-year average climate data from 2015 to 2014 from PAGASA Butuan as shown in Fig. 3, were used as input in the FAO CROPWAT 8.0 model. This data helps estimate effective rainfall, evapotranspiration, crop water use, and irrigation needs. As noted by [28], climate factors like rainfall, temperature, humidity, sunshine, and wind significantly influence crop water requirements.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min Temp (°C)	23.3	22.9	23.3	24.1	24.9	24.5	24.4	24.4	24.4	24.2	24	23.8
Max Temp (°C)	30.6	30.9	31.9	33.1	34	33.4	30.1	33.3	33.1	32.8	31.9	31.3
Humidity (%)	86	76	80	79	78	81	80	79	80	81	85	85
Wind (km/day)	130	147	164	181	164	173	173	181	173	164	138	130
Sun (hours)	11.6	11.8	12.1	12.3	12.5	12.6	12.6	12.4	12.1	11.9	11.7	11.6
Rainfall (mm)	301.7	211.5	119.8	127.3	134.3	202.9	167.7	127.6	158.6	205.4	200.8	281.6

Fig. 3. Average 10 years historical climatological data (2015 - 2024).

Based on the data, May was the hottest month, with temperatures reaching 34°C. Rainfall was highest in January (301.7 mm) and December (281.6 mm), and lowest in March (119.8 mm). Relative humidity stayed high year-round, between 76% and 86%. Wind speeds peaked in April and August (181 km/day), while sunshine hours were highest in May (12.5) and slightly higher in June and July (12.6), increasing evapotranspiration during these months.

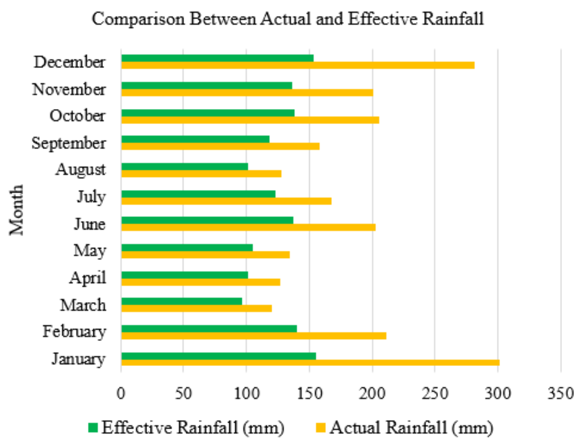


Fig. 4. Monthly distribution of actual and effective rainfall in Butuan City.

As shown in Fig. 4, January and December had the highest actual and effective rainfall, while March had the lowest. Total rainfall during the study was 2,239.2 mm, but only 1,505.7 mm (about 67%) was the effective rainfall, meaning usable by crops. The remaining 733.5 mm was lost through runoff, deep percolation, or evaporation.
Effective rainfall generally ranges from 50% to 70% of total rainfall, aligning with [30, 31], who noted that in tropical areas, only 50-80% of rainfall is effective depending on soil, slope, and rooting depth. Allen et al. (1998) also emphasized that factors like runoff, infiltration, and rainfall intensity affect water availability to crops.
Moderate rainfall in months like March and April may have been better distributed, improving soil absorption [1]. In contrast, heavy rains in January and December likely exceeded soil capacity, causing losses and reducing effective rainfall.

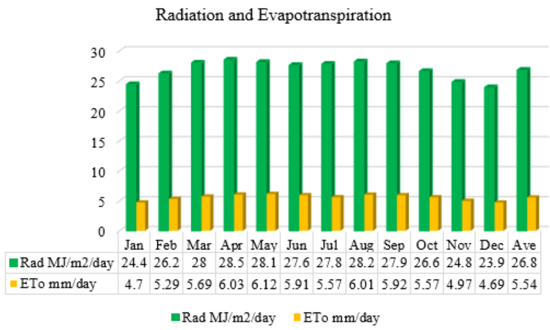


Fig. 5. Monthly solar radiation and evapotranspiration (ETo).

Based on the climatological inputs in the CROPWAT model, solar radiation (MJ/m²/day) and evapotranspiration (mm/day) were calculated, and the results are shown in Fig. 5. It shows that higher solar radiation leads to higher evapotranspiration. The month of December has the lowest solar radiation, implying the lowest evapotranspiration, while April, May, and August have the highest values for both.
Solar radiation strongly influences evapotranspiration. Study of [32] noted that the FAO-Penman-Monteith equation is highly sensitive to surface incoming solar radiation, confirming this study's finding that increased solar input results in higher evapotranspiration. Also, [33] explained that solar radiation is affected by sunshine duration, or sun hours. It was also observed that longer sun hours increase solar radiation, aligning with the trends in this study [34].
High evapotranspiration means more water must be applied to maintain crop needs. This follows the water balance principle; water lost must be replenished. For lowland rice, this balance is essential, as the crop depends heavily on sufficient root water intake for growth [35].

Table 1. FAO CROPWAT Model Estimation for Rice Water Requirements

Month	De-cade	Stage	Kc coef.	ETc mm/day	Eff rain mm/dec	Irr. Req. mm/dec
Jan	1	Init.	1.10	5.17	52.0	0.0
Jan	2	Init.	1.10	5.17	52.5	0.0
Jan	3	Dev't	1.11	5.44	50.6	9.3
Feb	1	Dev't	1.13	5.74	49.2	8.2
Feb	2	Mid	1.14	6.05	47.9	12.6
Feb	3	Mid	1.15	6.24	42.7	7.2
Mar	1	Mid	1.15	6.39	35.6	28.3
Mar	2	Mid	1.15	6.54	30.0	35.4
Mar	3	Mid	1.15	6.68	31.3	42.2
Apr	1	Late	1.12	6.66	33.3	33.3
Apr	2	Late	1.08	6.51	33.8	31.3
Apr	3	Late	1.03	6.26	34.2	28.3
				Total	**493.1**	**236.1**

This study analyzed the water balance for rice at different growth stages, such as seedling, vegetative, reproductive, and ripening, using the FAO CROPWAT 8.0 model, which refers to these as initial, development, mid, and late stages. As shown in Table 1, the seedling stage needs no irrigation due to soil saturation from land preparation. The reproductive stage has the highest water demand as presented in Table 1, followed by the ripening stage. Irrigation usually stops 2-3 weeks before harvest to allow soil drainage and ease of harvesting [36]. Irrigation depends on effective rainfall, higher rainfall reduces the water required. Study of [37] showed that considering effective rainfall in scheduling can minimize irrigation needs by 33.84%. Crop coefficient (Kc), which varies by growth stage, is key in estimating evapotranspiration (ETC) and irrigation. The reproductive stage has the highest Kc (1.15), with water needs reaching 42.2 mm/day [38].
The FAO CROPWAT model results show that rice irrigation requirements vary by growth stage, peaking during the mid-stage and requiring none during the initial stage. Studies by [39-41] confirm that water needs differ significantly across stages.
During the initial stage, rainfall and residual soil moisture typically meet water needs [42]. Clay soils with good land leveling retain moisture longer, reducing the need for irrigation [43]. As the crop enters the development stage, water demand rises for root and shoot growth, requiring careful water management to avoid seed rot or stunted growth [2, 44]. In the mid-stage, irrigation demand is highest and most prolonged. Water stress here can severely impact flowering, grain size, and yield [45-47]. Proper irrigation is essential to avoid drought stress and ensure productivity. In the late stage, water needs to decrease but remains important for grain filling. Insufficient water may reduce grain weight, while excess water can cause lodging [48, 49]. Thus, balanced irrigation is key for optimal yield.

3.2 Validation of FAO CROPWAT Results with Actual Farmer Practices

During the farmer interviews, the current growth stage of the rice crops was documented to help assess the actual field conditions during data collection. Regardless of the growth stage observed, farmers were asked to estimate the amount of water they typically apply at each growth stage. Drawing from their extensive experience in rice farming, they provided reliable insights into their usual irrigation practices. These estimates were essential for comparing and validating the water depth values generated by the FAO CROPWAT 8.0 model.

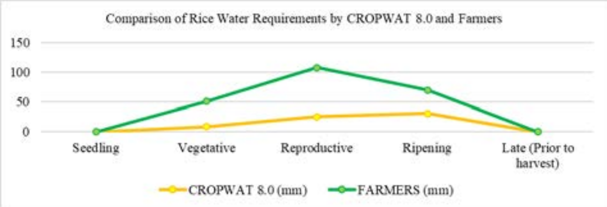


Fig. 6. Comparison of rice water requirements between the FAO CROPWAT model and Actual Farmers' Survey

Fig. 6 compares the rice water requirements estimated by the FAO CROPWAT 8.0 model and actual farmer practices across growth stages. Based on the results, both agreed that no irrigation is needed during the seedling and late stages. Farmers rely on residual soil moisture early on and drain fields before harvest to avoid muddy conditions for harvest operation, as supported by [2]. During the vegetative stage, farmers applied 42.07 mm of water, far more than the model's 8.5 mm estimate. This reflects their reliance on experience and the belief that more water supports stronger plant growth. A similar pattern appears in the reproductive stage, where farmers used 82.55 mm and the model's 25.14 mm, citing its importance for flowering and grain development, as well as pest management. In the ripening stage, both sources showed closer estimates with 30.97 mm in the model and 38.89 mm with farmers accounting for pests like the brown planthopper [49]. These findings suggest that farmers typically apply more water than the model recommends, especially during critical stages, due to field experience and the need to address environmental challenges, while the model relies on and utilizes fixed historical climatic values.

Table 2. Descriptive Statistics of Parameters

Variable	N_NonMissObs	Min	Max	Mean	StdDev
CROPWAT	5	0.00	30.97	12.92	14.39
FARMERS	5	0.00	82.55	32.60	34.44

Note: *N_NonMissObs* refers to Number of Non-Missing Observations, *Min* means minimum, *Max* means maximum, *StdDev* denotes the Standard Deviation.

Table 2 presents descriptive statistics using STAR to compare rice crop water requirements between FAO CROPWAT 8.0 estimates and farmers' actual irrigation practices across different growth stages. Both sources reported a minimum of 0.00 mm during the seedling stage. However, the maximum irrigation values differ significantly, 82.55 mm for farmers and 30.97 mm for the CROPWAT 8.0 model, indicating higher water use by farmers.

The mean irrigation for farmers was 32.60 mm, more than double the model's 12.92 mm, suggesting consistent over-irrigation. Likewise, the standard deviation was higher for farmers, indicating that the data points are far from the mean [50] and showing greater variability in their practices. According to [51], such differences are influenced by climate, crop stages, and soil conditions. This supports the observation that farmers tend to apply more water, particularly during the vegetative and reproductive stages.

Table 3 displays the correlation analysis computed using Kendall's rank correlation tau (τ) between the variables CROPWAT 8.0 model and farmers' responses. Kendall's rank correlation was used because it's suitable and efficient for small samples [52]. The computed Kendall's tau coefficient is 0.5556, indicating a moderate positive correlation between the two variables as stated by Rafael and Coelho (2021), a Kendall's tau coefficient of 1 is perfect, 0.7000-0.9999 is strong, 0.4000-0.6999 is moderate, and 0.1000-0.3999 is weak.

The p-value of 0.0.1932 for both variables thus exceed the statistical significance of the correlation at 5% level of significance ($p<0.05$), meaning it is not statistically significant [53]. The n=5 represents the different rice crop growth stages which are seedling, vegetative, reproductive, ripening, and late before harvest. Even though five (5) samples are small, Kendall's tau is known to work well even with limited data. According to [54], Kendall's tau is more stable than Pearson's correlation when sample sizes are small, making it a good choice for this study as supported by [55].

Table 3. Kendall's rank correlation analysis result

		CROPWAT	FARMERS
CROPWAT	coef	1.0000	0.5556
	p-value		0.1932
	n	5	5
FARMERS	coef	0.5556	1.0000
	p-value	0.1932	
	n	5	5

Note: coeff means coefficient, p-value is the statistical significance, and n denotes sample size.

This result indicates a significant difference in irrigation practices. Farmers often irrigate more than what CROPWAT 8.0 recommends due to several practical and environmental factors. Farmers have limited access to technical guidance and sometimes do not attend seminars and instead rely on traditional knowledge or visual observation, which often leads to over-irrigation, as noted by [56]. A common belief among farmers is that more water ensures better yields, especially during critical growth stages, prompting them to irrigate beyond actual crop needs, as reported by [57].

Additionally, farmers cultivate rice on different soil types, each with varying water retention capacities. CROPWAT 8.0, however, used general or fixed soil data, such as clay soil, in which actual rice fields that are not clay soil which affects irrigation and contributes to irrigation levels that do not match actual field needs [58, 59].

Climatic data is another important factor. CROPWAT uses historical climate data, while farmers respond to the actual conditions in real time. When the weather is hot or dry, they tend to irrigate more, as found in the study of [60]. Many farmers also use traditional irrigation methods like flood irrigation, which requires more water

to keep crops healthy, leading to big losses of water according to [61]. The assumptions used in CROPWAT do not always match the real conditions in the field, which shows the need for further validation [62].
In terms of irrigation scheduling, the FAO CROPWAT model recommends a fixed irrigation interval of every 10 days, or one application per decadal period. This model operates based on historical climate data and provides a general guideline for determining crop water requirements and irrigation timing. While it may not always reflect current field conditions, it remains a valuable tool for planning and managing irrigation.

Table 4. Summary of the responses of the famers

Category	Common Responses/Patterns
Irrigation Timing	Mostly *as needed* (13 farmers), some *weekly or bi-weekly.*
Decision Factors	Visual inspection, weather, crop growth stage (all farmers).
Monitoring Frequency	Daily (majority), 2 farmers reported *weekly/as needed.*
Water Source	NIA Canal (11 farmers), Rainwater and Canal Drainage (3), River (1).

Note: NIA means National Irrigation Administration

Table 4 presents a summary of the farmers' irrigation schedules, decision-making factors, frequency of field monitoring, and water sources. Most of the respondents reported checking their rice fields daily, with particular attention to water levels. Visual inspection, observation of weather patterns, and assessment of the crop's growth stage are the most common methods used in determining when to irrigate. This highlights the importance of real-time data in supporting timely and efficient irrigation decisions.
Although most farmers prefer flexible scheduling, the results also reveal that some of them follow a more structured routine, irrigating either weekly or bi-weekly. This shows that while the majority rely on dynamic field conditions, there are still variations in practice based on farmer preference, available resources, and access to water.
Hence, the study confirmed that solar radiation significantly influenced evapotranspiration (ETo), with higher radiation levels leading to increased water loss due to ETo. Among the total rainfall, the effective rainfall accounts for 67.24%, resulting in 32.76% rainwater loss. Overall, the results indicated that water balance was maintained throughout the crop growth stages, as water inputs from irrigation and rainfall were sufficient to meet or exceed losses from evapotranspiration, percolation, and depletion.

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