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Field-based Evaluation of Rice Suitability Classification as Influenced by Cultural Management Interventions

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ABSTRACT

Background: Rice production is constrained by declining soil fertility, imbalanced fertilizer use, climate variability and cultivation in areas with biophysical limitations. Land suitability assessments provide guidance for sustainable production but often lack field validation. This study validates rice land suitability by evaluating agronomic performance, yield and aims to identify site-specific fertilizer responses and recommend interventions to improve productivity across marginal, moderate and highly suitable areas.

Methods: Field experiment were conducted in three selected rice farms such as Cahumpan, Calbayog, Samar, Philippines: highly suitable classification, Guinbaoyan Sur, Calbayog, Samar, Philippines: moderately suitable and Rizal, Calbayog, Samar, Philippines: marginally suitable from December 2022 to December 2023 to validate the different level of rice suitability and its specific fertilizer recommended rates. Treatments are: T_1- Farmers' practice (FP): Traditional red rice transplanted without fertilizer; pre-emergence herbicide applied 10 days before transplanting; no post-transplant weeding. T_2- Good agricultural practice 1 (GAP1): Red rice (local variety) transplanted with basal fertilization (general recommended rates) at 200 kg ha^{-1} complete fertilizer (14-14-14) and 50 kg ha^{-1} urea (45-0-0). T_3- Good agricultural practice 2 (GAP2): Traditional red rice transplanted with site-specific fertilization based on soil analysis: 100-40-30 kg N-P_2O_5-K_2O ha^{-1} for marginal areas, 120-60-100 for moderately suitable areas and 100-20-30 for highly suitable areas. T_4- Good agricultural practice 3 (GAP3): Certified NSIC Rc 216 transplanted with basal fertilization (general recommended rates) at 200 kg ha^{-1} complete fertilizer and 50 kg ha^{-1} urea. T_5- Good agricultural practice 4 (GAP 4): Certified NSIC Rc 216 transplanted with soil analysis-based fertilization: 100-40-30 kg N-P_2O_5-K_2O ha^{-1} (marginal), 120-60-100 (moderate) and 100-20-30 (high).

Result: Rice agronomic and yield performance varied across suitability classifications and GAPs. While the local red rice exhibited taller plant height, NSIC Rc 216 consistently produced superior yield components, particularly in marginally and moderately suitable areas under soil-based fertilizer recommendations (GAP 4). In highly suitable areas, GAP 3 and GAP 4 resulted in comparable performance. Fertilizer application based on soil analysis improved red rice yield, whereas farmers' practice produced the lowest results. Overall, the adoption of certified inbred varieties, site-specific nutrient management, proper timing of fertilizer application and integration of organic and inorganic fertilizers are recommended to enhance productivity, reduce costs and improve soil health.

Key words: AHP, GIS, Multicriteria evaluation, Rice suitability.

INTRODUCTION

Rice (*Oryza sativa* L.) remains the primary staple food for more than half of the global population and plays a critical role in food security, poverty reduction and rural development, particularly in Asia FAO (2023). In the Philippines, rice is central to both household consumption and agricultural livelihoods. However, domestic rice production continues to face constraints such as declining soil fertility, imbalanced fertilizer use, climate variability and the cultivation of rice in areas with inherent biophysical limitations.

Land suitability evaluation has been widely used as a scientific approach to determine the potential of specific areas for sustainable crop production. The land evaluation framework developed by the FAO (1976) classifies land into categories such as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) based on soil characteristics, topography, drainage and climatic conditions. This framework has been applied globally to guide land-use planning, optimize resource allocation and improve site-specific crop management. Suitability assessments are commonly supported by soil surveys, geographic information systems (GIS) and agro-climatic datasets. Kihoro *et al*. (2013) and Adrian *et al*. (2022) both declared that rice suitability mapping is a systematic evaluation of land characteristics such as soil, climate, topography and water availability to determine areas most appropriate for rice cultivation. It integrates multiple biophysical variables including soil texture, slope, rainfall and temperature using geographic information systems (GIS) and multi-criteria evaluation (MCE)

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techniques to support agricultural planning and decision-making. Moreover, land suitability data can serve as a fundamental basis for decision-makers and farmers in designing and implementing effective pulse crop management systems aimed at enhancing land productivity (Souza and Patil, 2024).

Despite their usefulness, many land suitability studies remain largely predictive and descriptive. Several assessments rely heavily on spatial modeling and secondary data without validating the predicted suitability classes under actual field conditions. As emphasized by FAO (1976), land evaluation results must be verified through performance monitoring to ensure that classifications reflect actual productivity. Without empirical field validation, it remains uncertain whether areas classified as highly suitable consistently produce superior yields compared with moderately or marginally suitable lands.

In Eastern Visayas, particularly in Calbayog, Samar, Philippines, rice-growing areas exhibit variability in soil fertility status, drainage conditions and topographic characteristics. Farmers often apply generalized fertilizer recommendations, which may not adequately address site-specific soil limitations. The absence of field-based validation of suitability classifications limits the reliability of agronomic recommendations and may contribute to suboptimal yield performance.

Field validation through agronomic trials is therefore essential to bridge the gap between theoretical land evaluation and actual crop productivity. By evaluating rice growth parameters, yield components and economic returns across predicted suitability categories, researchers can assess the accuracy of classification results and refine management recommendations. Integrating land suitability assessment with field experimentation strengthens evidence-based decision-making, supports site-specific nutrient management and enhances the sustainability of rice production systems. Hence, the objectives were the following:

1. To evaluate the growth and yield performance of rice across predicted land suitability categories under field conditions.
2. To assess the response of rice to fertilizer recommendations based on soil analysis and suitability classification.
3. To recommend appropriate agronomic interventions to improve rice productivity in moderately and marginally suitable areas.

MATERIALS AND METHODS

In the 1st phase of the experiment, three suitability levels were identified with the following fertilizer recommended rates: 100-40-30 kg N-P_2O_5-K_2O ha^{-1} for marginal areas (30 hectares), 120-60-100 for moderately suitable areas (212 hectares) and 100-20-30 for highly suitable areas (107 hectares). This suitability classification was coming from the raw 30-year temperature and rainfall data obtained from Catbalogan, Samar PAGASA, Philippines. The raster datasets were generated using Inverse Distance Weighted (IDW) spatial interpolation tool in QGIS platforms. Rice barangays were georeferenced using hand-held Geographical Positioning System (GPS) to map the elevation and soil types within the study domain. The soil samples taken from 0-30 cm soil depth were collected in a zigzag manner, such that all points in the area. The collected soil samples were air-dried, crushed with mortar and pestle, mixed well and passed through a 2-mm sieve for soil physical and chemical properties, such as: soil pH, organic C (OC) content and available N and P. Standard methods were used, namely: Potentiometric method for soil pH, Kjeldahl method for total N, Spectrophotometric method for per cent P and Modified Walkley and Black method for C. All laboratory analysis were done at the Soils Laboratory of the Central Mindanao University, Bukidnon, Philippines.

The actual and secondary data parameters were reclassified based on the suitability criteria (Table 1) into different suitability levels in QGIS version 2.14. The suitability

Table 1: Criteria used, data range and suitability class of rice.

Parameters	Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Not suitable (N)
Mean monthly temperature (°C)	24-28	22-24	18-22	<18
		28-30	30-35	>35
Monthly rainfall (mm)	180-500	125-175	100-125	<100
Soil texture	c, cl,	l	sl	S
Soil reaction (pH)	5.5-6.0	5.0-5.5	4.0-5.0	>8.0
		6.0-7.0	7.0-8.0	<4.0
Organic C (%)	2.0-5.0	1.0-2.0	0.5-1.0	<0.5
				>5.0
Available P mg/kg)	>40	20-40	10-20	<10
n/N growing cycle	>0.75	0.75-0.65	0.65-0.45	<0.45
Slope angle (%)	<1	1-2	2-4	>4
Free from flooding (duration) (Months)	<4	3-4	2-3	>4

Source: FAO. (1976); Yoshida (1981); Sys *et al.* (1993).

levels for each factor were ranked as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (NS), based on the structure of FAO land suitability classification. S1 classified areas have yield potential above 80% of the maximum attainable harvest. This value drops to 60% and 40% for S2 and S3 classes, respectively (Table 2).

Maps from each criterion were given importance or weight based on the weights from the literature, local experts and actual experience of the researcher. The rating was based on the fundamental scale of Saaty (1980) shown in Table 3. In determining the relative importance/ weight of criteria, the pairwise comparison matrix (PWCM) was followed (Table 4). Finally, priorities of the alternatives and each criterion weight was integrated in QGIS to produce a suitability map (Fig 1).

Field experiments were conducted in three selected rice farms such as Cahumpan, Calbayog, Samar, Philippines: Highly suitable classification, Guinbaoyan Sur, Calbayog, Samar, Philippines: Moderately suitable and Rizal, Calbayog, Samar, Philippines: Marginally suitable from December 2022 to December 2023. The experiment was laid out in randomized complete block design (RCBD) with three replications in each suitability classification. Replication and treatment plots were separated by 2 m and 1 m alleyways, respectively, to facilitate farm operations, management and data gathering. Plot size was 5 m × 4 m. Experimental treatments were as follows:

T_1- **Farmers' practice 1 (FP):** Traditional red rice transplanted without fertilizer; pre-emergence herbicide applied 10 days before transplanting; no post-transplant weeding.

T_2- **Good agricultural practice 1 (GAP1):** Traditional red rice transplanted with basal fertilization at 200 kg ha^{-1} complete fertilizer (14-14-14) and 50 kg ha^{-1} urea (45-0-0).

T_3- **Good agricultural practice 2 (GAP2):** Traditional red rice transplanted with site-specific fertilization based on soil analysis: 100-40-30 kg N-P_2O_5-K_2O ha^{-1} for marginal areas, 120-60-100 for moderately suitable areas and 100-20-30 for highly suitable areas.

T_4- **Good agricultural practice 3 (GAP3):** Certified NSIC Rc 216 transplanted with basal fertilization at 200 kg ha^{-1} complete fertilizer plus 1 bag ha^{-1} urea.

T_5- **Good agricultural practice 3 (GAP 4):** Certified NSIC Rc 216 transplanted with soil analysis-based fertilization: 100-40-30 kg N-P_2O_5-K_2O ha^{-1} (marginal areas), 120-60-100 (moderately suitable areas) and 100-20-30 (highly suitable areas).

Seeds were sown in seedbeds elevated about 5 cm above ground level, with drainage ditches constructed around them. Seeds were soaked in water for 24 hours and incubated for 36 hours. Pre-germinated seeds were broadcast in the late afternoon to reduce heat stress. Seedlings were transplanted according to the experimental design and treatments. They were carefully uprooted with attached soil and immediately transplanted in the field. Missing hills were replanted at 7 days after transplanting (DAT).

During the vegetative stage, golden snails were observed and controlled through manual picking and opening of dikes. At booting, rat damage was managed by cleaning surrounding dikes. No pest damage occurred at flowering and milking stages. During the dough stage until harvest, birds were controlled by assigning a watchman to scare them away.

Harvesting was done when about 90% of the grains were straw-colored. Samples were taken from the harvestable area, excluding border rows and end hills. Panicles were cut, threshed, dried to about 14% moisture content and winnowed before yield data collection.

Agronomic and yield data were collected from randomly selected ten plants per plot. Analysis of variance (ANOVA) was conducted using Statistical Tool for Agricultural Research (STAR) v2.0.1 by International Rice Research

Table 2: Land suitability classification for rainfed agriculture.

Suitability class	Description
S1: Highly suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not require cost or inputs above an acceptable level.
S2: Moderately suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.
S3: Marginally suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that any expenditure will be only marginally justified
NS: Not suitable	Land having limitations which appear as severe as to preclude any possibilities of successful sustained use of the land in the given manner. In other words, not Suitable as the range of inputs required is unjustifiable.

Source: FAO (1976).

Institute and treatment means were compared using Tukey's HSD at P≤0.05.

RESULTS AND DISCUSSION

Agronomic performance

Plant height varied across areas with different levels of suitability under different good agricultural practices. Red rice in a highly suitable area was taller. NSIC Rc 216, regardless of good agricultural practices (GAP) imposed, was consistently short in terms of plant height compared

Table 3: Fundamental scale used in pairwise comparison.

Intensity of importance	Description
1	Equal importance
3	Moderate importance
5	Strong or essential importance
7	Very strong or demonstrated importance
9	Extreme importance
2,4,6,8	Intermediate values

Source: Saaty (1980).

Table 4: An example of pair-wise comparison matrix of criteria in AHP.

Criteria	Soil	Rainfall	Temperature	Slope	Oxygen
Soil	1	1/9			
Rainfall	9	1			
Temperature			1		
Slope				1	
Oxygen					1

AHP: Analytic hierarchy process.

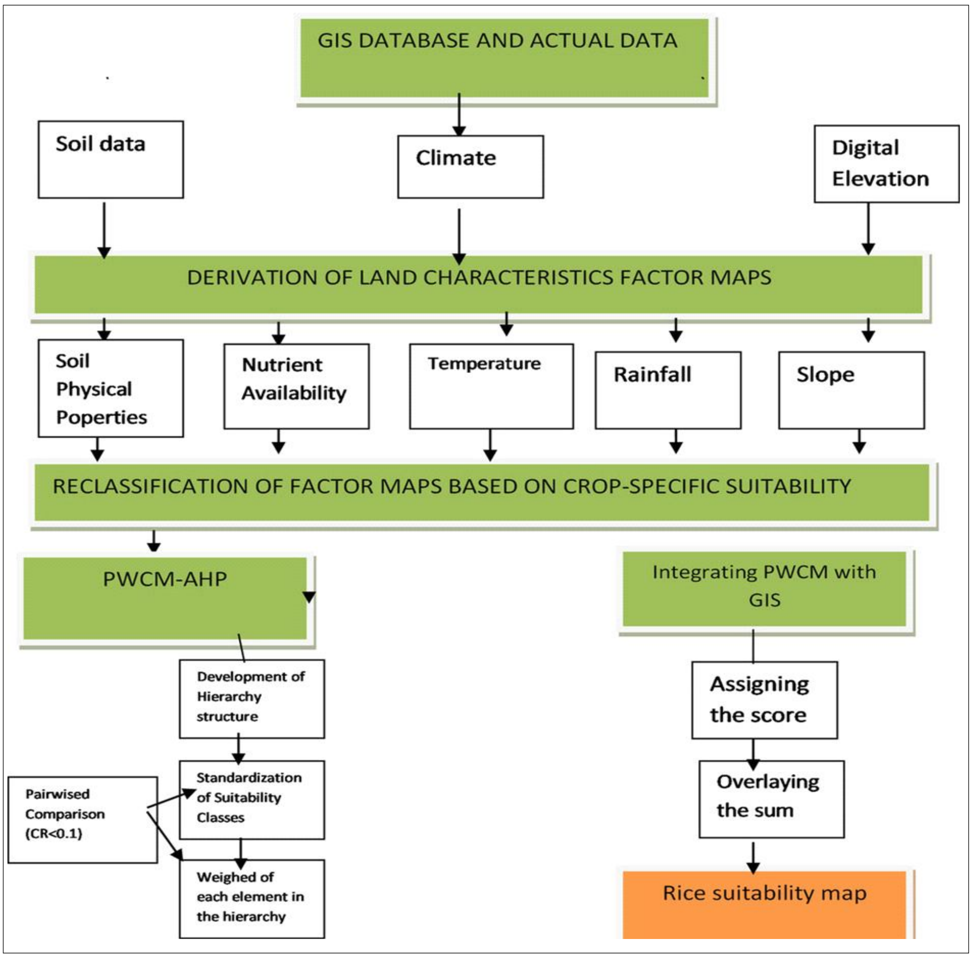


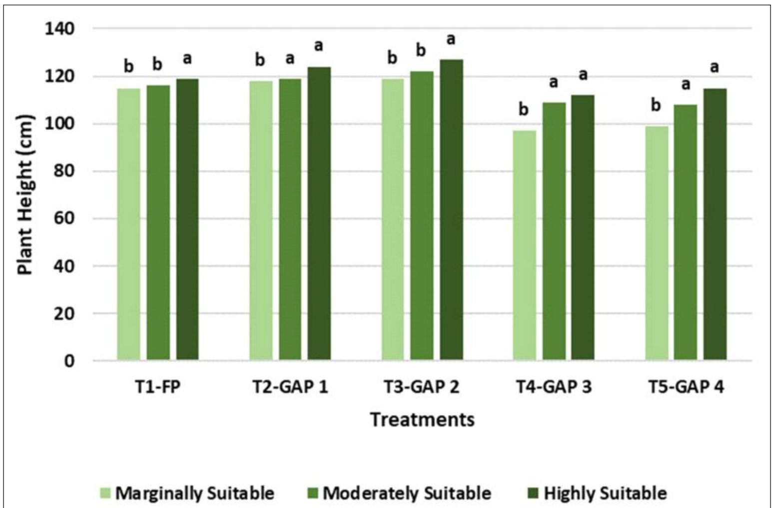
Fig 1: Processes of generating rice suitability map.

with red rice. Lutao, Jr. and Baòoc (2020) reported earlier that red rice remarkably grows to a height of 102.11 cm regardless of crop establishment. NSIC Rc 216 planted in moderately suitable areas had similar plant height with those planted in highly suitable areas when applied with fertilizers, whether fertilizer rates are based on soil analysis or general fertilizer rates (Fig 2). On the other hand, harvest index, dry matter and number of productive tillers per hill and has no significant differences (Fig 3). This idea was contested, arguing that different rice cultivars have a significant effect on rice straw yield production (Pardeep and Balwinder, 2023). The number of filled spikelets per panicle of red rice did not vary across rice suitability levels as affected by the GAP treatments (Fig 4). However, NSIC Rc 216 had the highest number of filled spikelets per panicle in highly-suitable areas under GAP 4 (soil-based fertilizer rates) treatment. An inadequate fertilizer applied through improper application technique was one of the factors responsible for low yield of rice. This finding is consistent with Ahmed *et al.* (2016) that efficient and balanced fertilizer recommendation under environment-friendly conditions is crucial to increase rice production worldwide.

The percentage of filled spikelets per panicle of red rice in marginally and moderately- suitable areas did not vary when general recommended fertilizer rates or soil-based fertilizer rates were applied following the GAP 1 and GAP 2 treatments, respectively (Fig 5). Highest percentage of grain was observed in highly-suitable rice areas. Karthika *et al*. (2024) supported that the climatic characteristics of the area were highly favorable for rice cultivation, which justifies its classification under the highly suitable category. The prevailing temperature, rainfall distribution and relative humidity during the growing season closely matched the optimum requirements for rice growth and development, thereby promoting improved vegetative performance and yield potential. Such favorable climatic conditions likely enhanced physiological processes including tillering, panicle initiation and grain filling, ultimately contributing to its designation as highly suitable for sustainable rice production. Meanwhile, lands categorized as marginally and moderately suitable may still achieve improved productivity through appropriate management strategies. On the other hand, planting NSIC Rc 216 in moderately-suitable had similar field spikelets per panicle in highly-suitable classification whether under GAP 3 or GAP 4 regime.

Yield and yield components

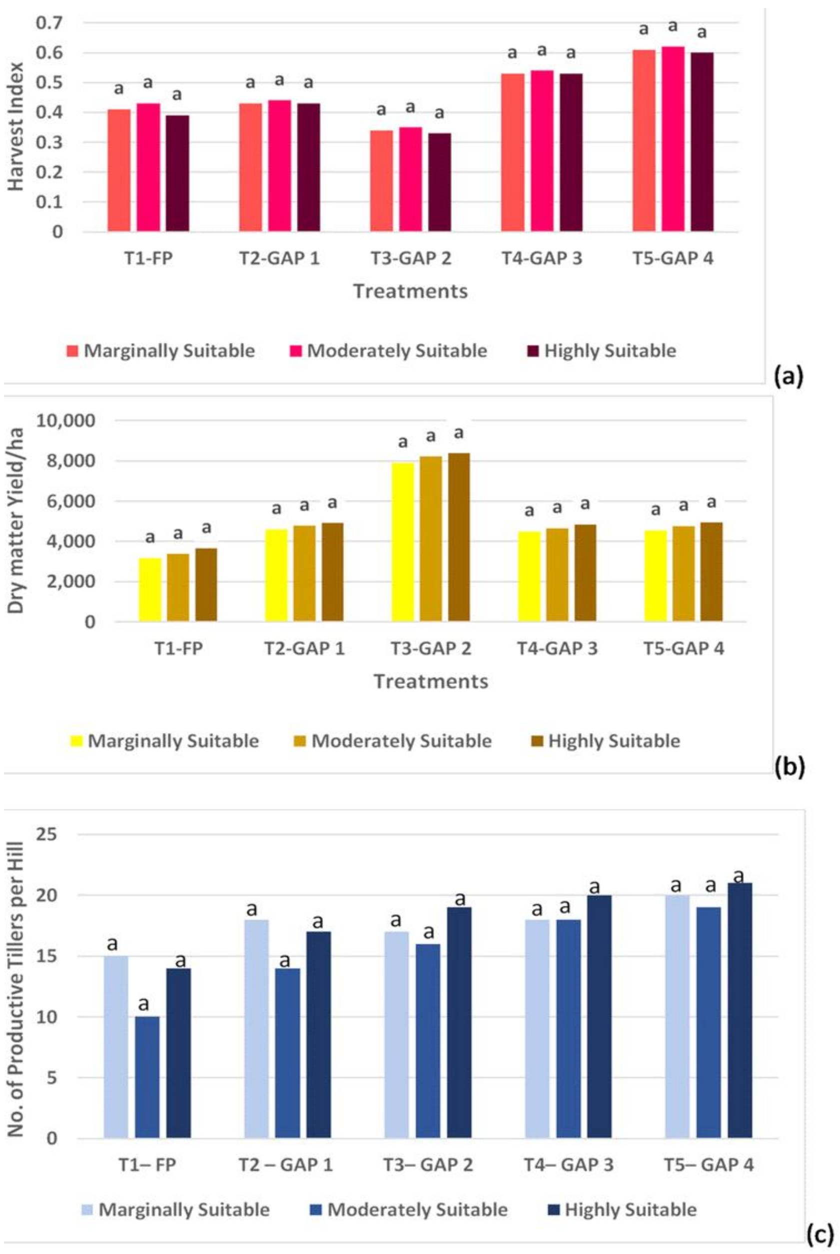
Weight of grain per panicle in identified highly-suitable classification had the heaviest among rice weight grain among three levels of suitability classification across all treatments (Fig 6). Grain weights obtained between marginally and moderately-suitable areas did not vary and both relatively lower compared with that of highly-suitable areas. Generally, treatments for GAP 2, GAP 3 and GAP 4 produce heavier grains compared with GAP 1 (unfertilized farms) classification and had a comparable weight of grains per panicle across all treatments except in the FP. The results suggest that nutrient management during the grain filling stage has to be reviewed and modified to improve grain weights in marginally- and moderately-suitable areas.



Means within rows followed by the same letter are not significantly different at HSD 5% level of significance.
Mean 109.51.
C.V. 4.55.

Fig 2: Plant height of rainfed lowland rice grown in areas with different rice suitability classification as affected by varying cultural management combinations in Calbayog, Samar.

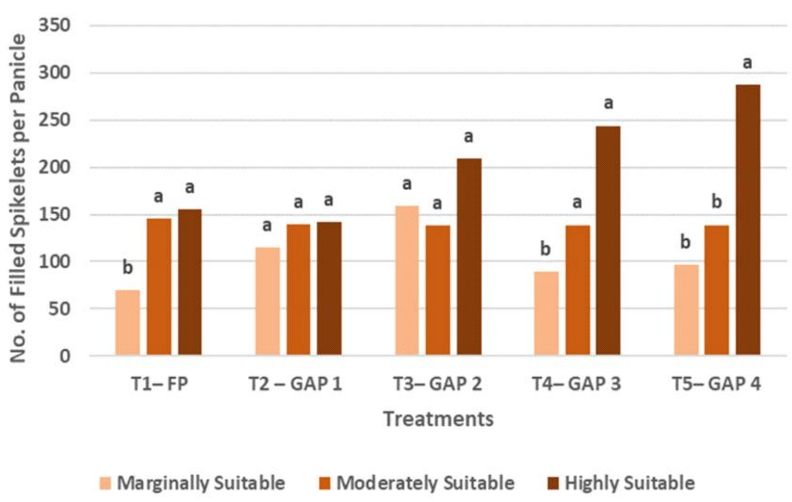
Thousand grain weight across all GAP treatments and rice suitability levels are shown in Fig 7. It is apparent that regardless of variety (NSIC vs red rice), highly-suitable areas produced the heaviest grains, relative to marginally- and moderately-suitable areas regardless of variety and GAP treatments. Hence, the need to improve nutrient management at post-flowering stage or grain-filling stage in marginal and moderately-suitable rice growing areas was noticed. These observations further supported by Sonia *et al*. (2023) that the highly suitable category was observed to favor pearl millet production with minimal constraints. Conversely, the moderately suitable category necessitates enhanced farm management practices to attain optimum yield and performance. In the marginally suitable category, more careful management is required, especially in ensuring the adequate application of essential agricultural inputs such as fertilizers.



Treatment means with same letter designations are not significantly different at HSD 5% level of significance.

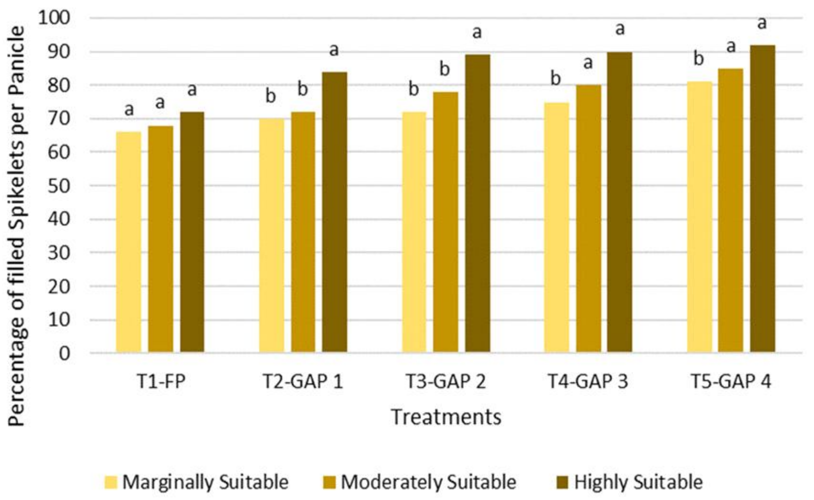
Fig 3: Harvest index (a) and dry matter (b) and number of productive tillers per hill (c) of rainfed lowland rice grown in in areas with different suitability levels as affected by varying cultural management combinations. Calbayog, Samar.

Grain yield of rainfed lowland rice grown under different rice suitability classified areas and good agricultural practice treatments are shown in Fig 8. Red rice when unfertilized (FP) had low yields and this was not improved with fertilizer application GAP 1 (general recommended rate). However, when GAP 2 (soil-based recommended rate) was adopted, Red rice yields in highly-suitable areas increased from 3,066 kg ha^{-1} to 6,933 kg ha^{-1}. Similar response was observed in NSIC Rc 216, wherein soil-based recommended rate produced higher yields compared with blanket recommended rate applied with fertilizer recommended rates (GAP 3). Sharada and Sujathamm (2018)



Means within columns followed by the same letter are not significantly different at HSD 5% level of significance.
Mean 151.
C.V. 32.98.

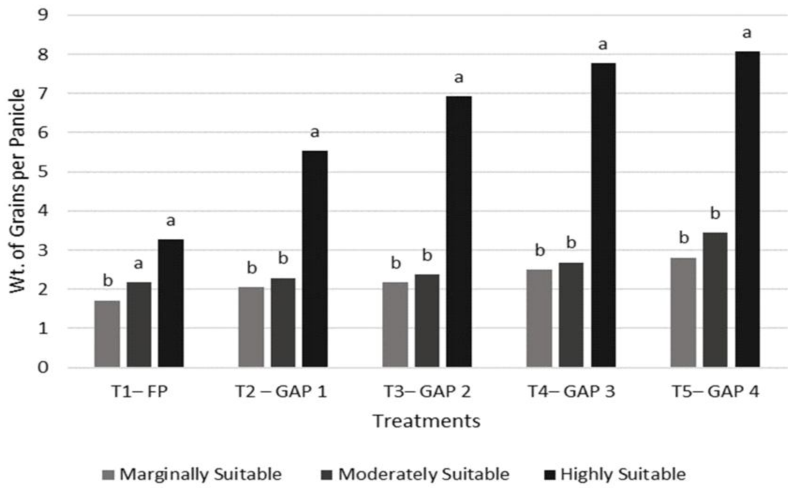
Fig 4: Number of filled spikelets per panicle from varying rice suitability classified areas as affected by different good agricultural practices. Calbayog, Samar.



Means within rows followed by the same letter are not significantly different at HSD 5% level of significance.
Mean 78.11.
C.V. 4.16.

Fig 5: Per cent filled spikelets per panicle from varying rice suitability classified areas as affected by different cultural practices. Calbayog, Samar.

and Daquiado (2019) reported earlier that appropriate fertilizer application is an important management practice to improve soil fertility and production of rice. Availability of plant nutrients, particularly N at various plant growth stages is of crucial importance in rice production. On the other hand, NSIC Rc 216 performed better (5,394 kg ha^{-1}) in moderately-suitable areas when fertilizer recommended rates were based on soil analysis (GAP 4), *i.e*. with generally higher N, P and K applications. This result corroborates the findings of Mohanty *et al*. (2023) that balanced fertilization with recommended doses of nitrogen, phosphorus and potassium to both rice and groundnut is important.

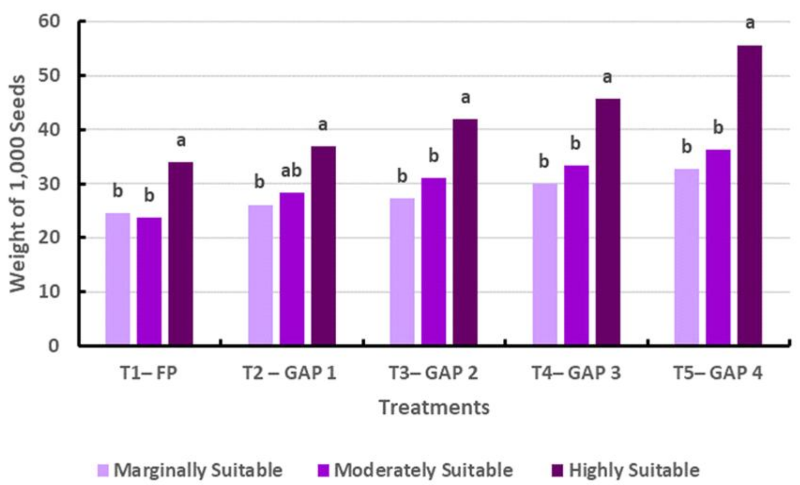


Means within columns followed by the same letter are not significantly different at HSD 5% level of significance.

Mean 3.72.

C.V. 13.1.

Fig 6: Grain weight per panicle from varying rice suitability classified areas as affected by different suitability levels and different cultural practices. Calbayog, Samar.

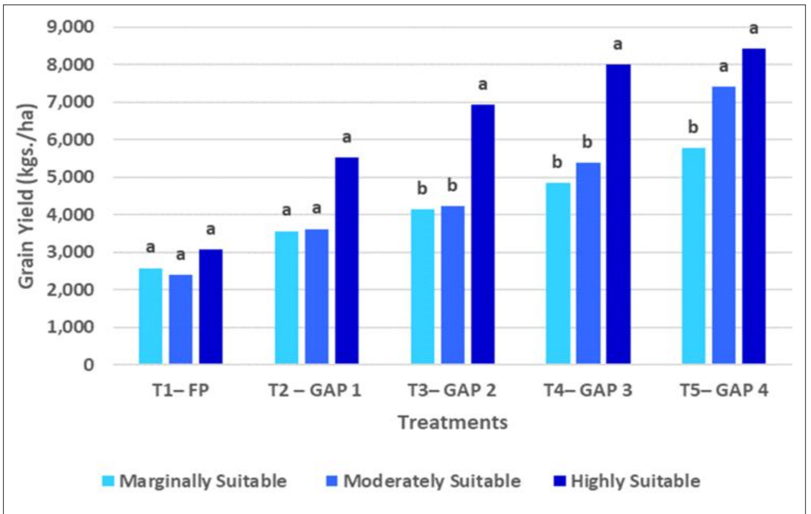


Means within columns followed by the same letter are not significantly different at HSD 5% level of significance.

Mean 33.82.

C.V. 8.32.

Fig 7: Thousand grain weight from varying rice suitability classified areas as affected by different cultural practices. Calbayog, Samar.



Means within columns followed by the same letter are not significantly different at LSD 5% level of significance.

Fig 8: Grain yield per hectare from varying rice suitability classified areas as affected by different cultural practices. Calbayog, Samar.

CONCLUSION

Across the suitability rice classification and GAPs, local variety (red rice) had the tallest plant height compared with NSIC 216 variety but the latter had the highest yield-determining parameters. In marginally and moderately suitable classification, NSIC Rc 216 showed the highest agronomic and yield parameters by following the GAP 4 (soil-based fertilizers). In highly suitable areas, GAP 3 and GAP 4 shown a similar agronomic and yield parameters due to the huge amount of fertilizer applied in moderately suitable. Red rice improved the yield when applied with fertilizer (soil analysis) while Farmers' practice shown the least. To improve the rice yield in Calbayog, it is recommended to increase utilization of certified inbred rice seeds. Likewise, the physiological response and stresses experienced by the rice plants that might affect the yield should be studied, the study of the timing of fertilizer application especially from rice establishments and reproductive stage must be conducted. The use of organic fertilizers, or inorganic-organic combination to help the soil to be rich in organic matter.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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