DLSU RESEARCH CONGRESS 2023
MANILA, PHILIPPINES
JULY 5-7, 2023

Fostering a Humane and Green Future:
Pathways to Inclusive Societies and Sustainable Development

Visualizing Data to Communicate Agro-Climate Effects on Rice Production in Cotabato Province

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Abstract This study develops an analytics dashboard with visualization to assess rice production in Cotabato, Philippines. Its objectives are to identify relevant data, apply data mining techniques, and evaluate the usability of the dashboard. The research utilizes a scoping review, data from the Office of Provincial Agriculturist, and agro-climate data from NASA POWER. Through multivariate linear regression analysis, significant agro-climates affecting irrigated and rainfed rice production are identified. The design and development of the dashboard employ unified modeling techniques and benchmark tasks for user interface design. The prototype undergoes usability testing, receiving an 88% approval rating. Feedback indicates the system's usefulness in agro-climate and rice production surveillance, supporting data reporting. The study provides insights into Cotabato's rice production and serves as a reference for future research on rice production and climate data analysis. It recommends conducting predictive analytics research at the municipal level and distributing rice varieties based on agro-climates.

Key Words: Multivariate Linear Regression; Descriptive-Exploratory Analysis; Data Visualization; Rice Production; Cotabato Province

1. INTRODUCTION

Rice production plays a vital role in ensuring food security, particularly in the Philippines, where it is a staple food. A decrease in rice production can have significant repercussions for the entire country, affecting every province, including Cotabato. Cotabato has experienced a series of droughts and La Nina events, leading to a notable decline in rice production. Annual rice production reports submitted to the Department of Agriculture from 2007 to 2021 provide evidence of substantial decreases, particularly in 2008, 2014, and 2016, coinciding with the presence of droughts and La Nina. These declines have resulted in food insufficiency and even conflicts among the people of Cotabato.

Rice production is influenced by climatic factors in both irrigated and rainfed systems. Fluctuations in these factors can have a significant impact on rice production. This study aimed to assess the current state of rice production in Cotabato by developing analytics with visualization techniques. It utilized seasonal climate data and historical rice production data to achieve this goal.

The primary objectives of this study were as follows: firstly, to identify and understand the data required for analytics, including seasonal climate data, historical rice production data, and potentially other relevant datasets; secondly, to employ data mining techniques to generate analytics; and lastly, to implement and evaluate the usability of the analytical dashboard. In pursuit of these objectives, the study collected and analyzed the necessary data sources, applied data mining algorithms to extract valuable insights, and developed an analytical dashboard for visualization. The usability of the dashboard was assessed through testing and evaluation, considering user feedback and recommendations for improvement.

2. METHODOLOGY

The present study focuses on answering the research question of how analytics can assist in assessing rice production in Cotabato. The study proposes a conceptual framework (Figure 1) consisting of five phases: data source, data preparation, data analytics, visualization, and evaluation. The first objective involves utilizing data sources such as The NASA POWER dataset and OPAg rice production data to assess rice production in Cotabato. Factors such as temperature, precipitation, humidity, soil moisture, and radiation are identified as crucial agro-climate factors affecting rice production. The second objective involves data preparation using ETL techniques, followed by data analysis using descriptive analytics techniques like correlation and regression to identify patterns and trends in the data. Data visualization techniques such as Power BI and interactive visualization are suggested to effectively communicate the insights gained. The third objective includes data visualization and evaluation, where dashboard designing, and interactive visualization techniques are employed to present the data in a clear and concise manner. The effectiveness of the analytical dashboard will be evaluated using usability evaluation checklists and benchmark statements. The study aims to draw scenarios, develop an analytical dashboard, and provide insights to improve rice production in Cotabato through data-driven decision-making.

2.1 Data Understanding

In the data understanding phase, a scoping review was conducted using the PRISMA methodology (O'Dea et al., 2021). This review aimed to gather relevant literature that provided insights into the granularity of data, methods, and techniques used in previous studies related to climate impacts on rice production. By conducting a thorough literature review, the study ensured that it had a comprehensive understanding of the data requirements, methodologies, and analytical approaches that would be suitable for analyzing and visualizing climate impacts on rice production in Cotabato.

2.2 Data Preparation

Data Collection

To visualize the rice production of Cotabato, the study collected data from two primary sources. First, data on rice production was obtained from the Office of Provincial Agriculturist in Cotabato. This dataset covered the period from 2007 to 2021 and included information on annual, irrigated, and rainfed rice production, as well as the cropping area. Second, agro-climate data was retrieved from the NASA POWER online dataset. This dataset contained information on various agro-climatic variables such as rainfall, soil moisture, radiation, humidity, and temperature for the same time. By gathering data

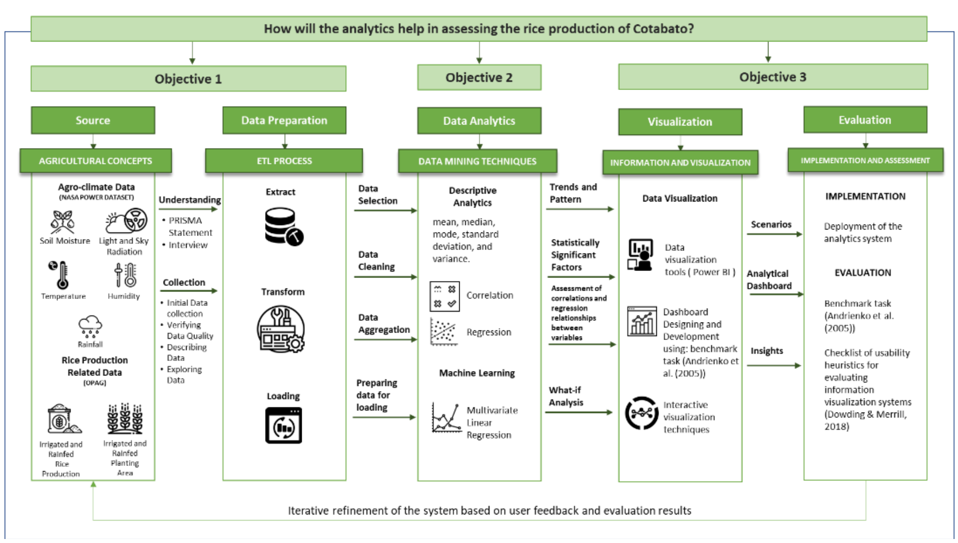

Fig. 1. Agro-climate and Rice production Analytical dashboard Implementation

from both the agricultural and climatic perspectives, the study aimed to examine the relationship between these factors and rice production.

Data Processing

Following data collection, the data underwent processing and preparation for analysis. This encompassed various stages, including data extraction, transformation, and loading. Data extraction involved retrieving pertinent information from the collected sources. The extracted data was subsequently transformed, which involved tasks like data cleaning, resolving inconsistencies, handling missing values, and standardizing the data format. Once transformed, the data was loaded into POWER BI, an influential tool for data analysis and visualization.

2.3 Data Analytics

Multivariate linear regression (Bevans, 2022) was employed to examine the correlation between various factors and rice production in North Cotabato, focusing on both irrigated and rainfed farms. This regression analysis enabled the identification of significant influences of temperature, humidity, soil moisture, rainfall, radiation, and crop area on different types of rice crops. Variables with a significance level lower than 0.05 were deemed meaningful. The outcomes of the exploratory analysis guided the determination of agro-climate data that required visualization.

2.4 Visualization and Implementation

The benchmark tasks based on Andrienko et al. (2005) provided a standardized framework for designing the user interface of the agro-climate and rice production analytical dashboard. Within the elementary search level, tasks like Task 1 and Task 7 followed the (Given what? & When? Find where?) and (Given where? Find what? & When?) structure to identify specific information based on given criteria. Similarly, Tasks 2, 3, 8, and 9 focused on finding information related to what, when, and where. In the general search level, tasks such as Task 4, Task 5, Task 10, Task 11, and Task 12 required users to perform similar actions with a higher level of difficulty, following the (Given what? & Where? Find when?) and (Given what? & When? Find where?) structure. These tasks expanded the scope of analysis and exploration, allowing users to derive meaningful insights from the dashboard.

Due to limited space, the benchmark questions were not included in this paper. However, these benchmark tasks formed a solid foundation for designing the user interface of the agro-climate and rice production analytical dashboard. They ensured that users could easily locate, filter, and analyze relevant data based on different criteria, such as what, when, and where. By providing a structured approach to data exploration, the tasks facilitated a user-friendly experience and enabled users to derive meaningful insights from the dashboard.

Moreover, Power BI, a robust data visualization tool, was employed to visualize the agro-climate and rice production data for Cotabato. The components of Power BI, namely Power Query, Power Pivot, and Power View, were utilized to extract, transform, and load the data for further processing. These tools facilitated data preparation and integration, enabling the creation of various visualizations for exploratory analysis. Spatial analysis, timeline analysis, and multivariate regression analysis were performed to uncover insights and patterns, which were then incorporated into the agro-climate and rice production analytical dashboard.

2.4 Evaluation of the Analytical Dashboard

Usability testing was conducted to evaluate the effectiveness and user-friendliness of the developed prototype of the analytical dashboard. The evaluation involved using a benchmark of (Andrienko et al., 2005) and a checklist (Dowding and Merrill, 2018) of usability heuristics designed for information visualization systems. The Dowding and Merrill checklist encompasses several principles that were considered during the evaluation. These principles include perceptual and cognitive principles *(p1)*, navigation and interaction principles *(p2)*, clarity and legibility principles *(p3)*, consistency and standardization principles *(p4)*, error prevention and recovery principles *(p5)*, data accuracy and integrity principles *(p6)*, responsiveness and performance principles *(p7)*, flexibility and customization principles *(p8)*, aesthetics and visual appeal principles *(p9)*, and user guidance and assistance principles *(p10)*.

The evaluation results guided improvements to meet usability requirements, ensuring the dashboard effectively supports decision-making and data exploration. By incorporating user feedback, the dashboard can be optimized for a seamless and user-friendly experience.

3. RESULTS AND DISCUSSION

The search query "rice production and climate for data analysis" yielded 66 articles from the Directory of Open Access Journals (DOAJ), covering the years 2012 to 2022. Among these articles, only 17 were considered eligible after the PRISMA process. These eligible studies examined various factors, including temperature, humidity, soil moisture, rainfall, radiation, and crop area, in relation to specific crops such as rice, maize, wheat, millet, sorghum, yam, soybeans, cotton, and sugarcane, under both rainfed and irrigated conditions.

The collected data focused on aspects such as crop yield, production, harvested area, heavy rainfall, temperature (minimum, maximum, average), precipitation, solar radiation, soil condition, and land area. These findings contribute to our understanding of the impact of climate change on agricultural production and inform adaptation practices in different regions. Moreover, the data that was collected for this study is available in (Delena & Tangkeko, 2023).

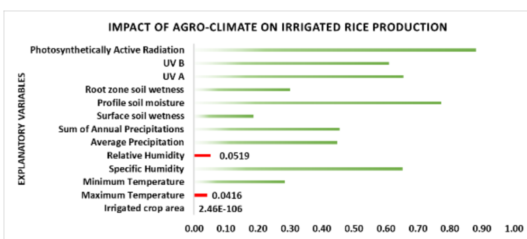

Fig. 2. Statistically significant agro-climate factors in irrigated rice production

Table 1. Regression statistics for the effect of climate on irrigated rice production.

Regression Statistics	
Multiple R	0.9385
R^2	0.8809
Adjusted R^2	0.8744
Standard Error	7278.1406

In irrigated farmlands, maximum temperature, relative humidity, and irrigated crop areas were found to be significant factors in explaining changes in rice production due to climate change (Figure 2). However, radiation, soil moisture, minimum temperature, specific humidity, and rainfall did not show significant effects on rice production in Cotabato. The regression model revealed that the explanatory variables accounted for approximately 88% of the changes in irrigated rice production, indicating a strong relationship. The regression analysis demonstrated a good fit of approximately 94% between the explanatory and response variables as shown in table 1.

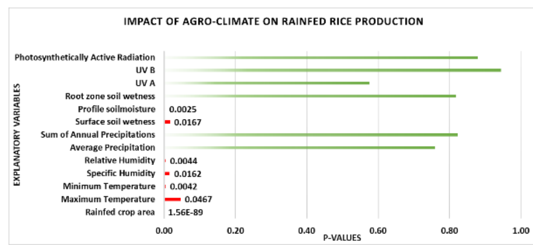

Fig. 3. Statistically significant agro-climate factors in rainfed rice production

Table 2. Regression statistics for the effect of climate on rainfed rice production.

Regression Statistics	
Multiple R	0.8972
R^2	0.8050
Adjusted R^2	0.7943
Standard Error	3344.2232

An analysis of rainfed rice production showed the significance in various agro-climate factors. Figure 3 illustrates that rainfed crop area, maximum and minimum temperatures, specific and relative humidity, surface soil wetness, and profile soil moisture had a statistically significant impact on changes in rainfed rice production. Additionally, rainfall, radiation, and root zone soil wetness were found to be significant in explaining the effect of climate change on rainfed rice production in Cotabato.

The result from the regression model was presented and shows (Table 2) that the explanatory variable for irrigated rice production jointly accounts for approximately 80% of changes in irrigated rice production. Also, the regression analysis (figure 3) is approximately 89% fit to prove the relationships between the explanatory and response variables.

The result from the regression analysis was used to develop an analytical dashboard platform (Figure 4) to visualize the rice production data of Cotabato with the help of the explanatory variables. The presence of the explanatory variables that affect the production of Cotabato was highlighted to understand why there were decreases or increases in the production. The agro-climate and rice production analytical dashboard in Cotabato offers valuable insights for decision-makers. It helps identify patterns and trends in rice production, optimize resource allocation, and make informed decisions. The dashboard compares the performance of different municipal rice production under various agro-climatic conditions, informing future production plans. Additionally, it identifies risks and vulnerabilities, enabling the development of contingency plans. Ultimately, the dashboard supports planning,

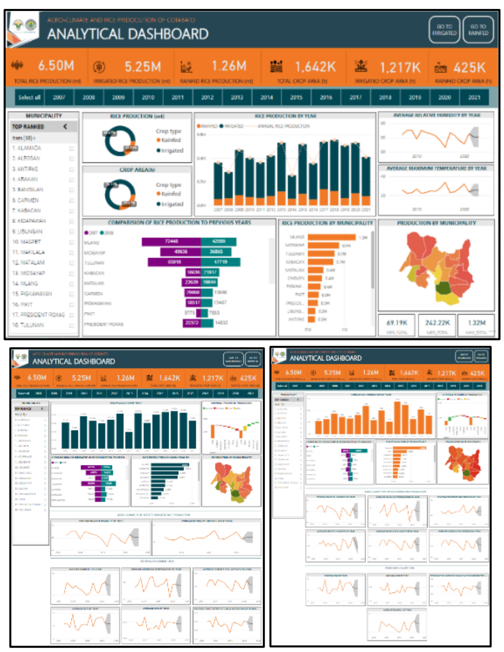

Fig. 4. Screenshots of the overall agro-climate and rice production analytical dashboard and irrigated and rainfed rice production.

investment, and risk management strategies to ensure the sustainability and profitability of the rice industry in Cotabato. Additional details about the dashboard can be found in the repository by Ampuan Azimah (n.d.).

The benchmark task assessed the usability of the analytical dashboard and guided users in navigating the system. The results show that all guide questions were successfully addressed, highlighting the effectiveness of the dashboard and data visualization in facilitating the identification and interpretation of relevant information.

The evaluation questionnaire by Dowding and Merrill (2018) was used to assess the acceptability of the analytical dashboard. The heuristic evaluation, conducted by a team of OPAg experts, resulted in an 88% rating (Table 5), indicating the dashboard's usefulness in understanding historical production data in relation to agro-climate factors. This evaluation provided valuable insights and demonstrated that the dashboard effectively captures the relationship between agro-climate conditions and rice production, enhancing data understanding.

Table 3. Result of the heuristic evaluation rating of the analytical dashboard

Usability principle	Maximum score	Mean score	Result (%)
P1	6	5.7	95%
P2	5	4	80%
P3	5	4	80%
P4	6	5.3	88%
P5	4	3.5	88%
P6	7	6.5	93%
P7	7	6	86%
P8	3	2.67	89%
P9	2	2	100%
P10	4	3.33	83%
Total	49	43	88%

Table 3 provides the results of the heuristic evaluation rating of the analytical dashboard. The evaluation considered various usability principles, such as perceptual and cognitive, navigation and interaction, clarity and legibility, consistency and standardization, error prevention and recovery, data accuracy and integrity, responsiveness and performance, flexibility and customization, aesthetics and visual appeal, and user guidance and assistance.

The highest-rated principle in the evaluation was P9 (aesthetics and visual appeal) with a mean score of 6.5, indicating a strong performance. On the other hand, the lowest-rated principle was P2 (navigation and interaction) and P3 (clarity and legibility) with mean scores of 4, highlighting areas that may require improvement.

The overall result of the evaluation is 88%, which represents the average score achieved across all the usability principles. This indicates that the analytical dashboard demonstrates a good level of usability, with room for further enhancement in certain areas to optimize the user experience.

The overall comment from the key informant demonstrates that the system was useful and helpful for agro-climate and rice production surveillance, since the dashboard provides visualizations and insights into what happened with the rice production provided with the presence of the effect of the agro-climates. It was also expressed that the system can efficiently support data reporting as it saves time compared to their current process (manual).

4. CONCLUSIONS

In conclusion, the importance of rice as a major dietary staple for over half of the global population, particularly in the Philippines, cannot be overstated. However, the production of rice is threatened by climate change due to its dependence on agro-climate factors. To overcome this insufficiency in production, researchers have shown great interest in understanding the relationship between rice production and agro-climate factors. The scoping review revealed that several agro-climate factors, such as rainfall, soil moisture, radiation, humidity, and temperature, significantly affect changes in rice production. These statistically significant explanatory variables were used to complete the components of the analytical dashboard, which was assessed for its usability and effectiveness in visualizing the relationships between agro-climate and rice production data. The results showed that the dashboard was useful in decision-making and could be used to develop farmer-friendly Decision support systems (DSS) for a given crop and climatic environment. Further research is recommended to develop predictive values of rice production at a more detailed level, such as the municipal level, and to distribute different varieties of rice that can withstand the effects of climate change.

5. ACKNOWLEDGMENTS

The authors express their deepest thanks to the people behind the Office of the Provincial Agriculturist of Cotabato and the Provincial Governor for authorizing us to use the data needed for the success of this study.

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